Foresight Study

Evaluation of sector opportunities for AI in NI

2021 report

matrix.

**Northern Ireland
Science Industry Panel**

Foresight Study - Evaluation of sector opportunities for AI in NI

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foreword

Foreword

Since the publication of the "AI Research in Northern Ireland" report in 2019, we have continued to observe accelerated growth of AI enabled technologies and data driven system innovation across prominent sectors such as Advanced Manufacturing and Financial Services.

The recent pandemic has had an undoubted global impact and the long term effects will be felt by society and industry for many years. However, it is evident that technology and AI in particular will play an integral role in post Covid-19 economic recovery and cross sector innovation. In short the need for accessible AI excellence has been fast tracked.

However, there are many application challenges to be overcome if we are to realise the full social and economic benefits of this key enabling technology. Adoption of AI is not consistent across various sectors due to a number of factors including the availability of digital skills and infrastructure, absorption capability of industry and the maturity of localised research and innovation ecosystems.

We in Northern Ireland find ourselves with a once in a lifetime opportunity with considerable public sector investments on the horizon. The Belfast City and Derry City and Strabane region and growth deals propose projects which will start to address some of the technology adoption challenges while developing further clusters of excellence across the region.

It is exciting to see the prospects that these investments will make to Advanced Manufacturing, Creative Industries and Health / Life Sciences economic growth. However, it is clear and as stated in the 2019 AI report, that the development of a Northern Ireland AI cluster can further enhance these investments providing support for the widespread adoption of AI.

It has been a privilege for Digital Catapult NI to lead on a key recommendation of the 2019 AI report focusing on the action plan for the establishment of an AI collaboration centre for Northern Ireland. It is clear that any AI cluster should be industry focused to eradicate the adoption challenges currently limiting productivity growth in many businesses and organisations.

However, we must also take this opportunity to evaluate the medium and long term sector growth for the NI economy associated with the adoption of AI technology. With the correct alignment of the City and Growth deals, the AI collaboration centre and the focus on UK government "Levelling Up" proposals, Northern Ireland can accelerate its innovation capability.

With that in mind, I was pleased to chair this foresight study to evaluate opportunities arising from AI adoption for existing Northern Ireland sectors. It is key that we identify how sectors will benefit from the adoption of AI and the impact this will have on employment and future growth.

In addition, we must understand the long term benefits for the NI economy through the development of new AI based businesses utilising industry and academic strengths. This has been evaluated within the report and I welcome the recommendations and economic insights from the Firetail team across 14 key sectors. These include traditional and high growth sectors for NI ranging from Human Health and Social Care, Biomedical and Pharmaceutical manufacturing to Energy systems and Agriculture.

I particularly welcome the report highlighting that the development of a flexible and responsive AI cluster in Northern Ireland positons the region perfectly to avail of both all-island and UK wide AI collaborations in emerging areas of sectoral strength.

Previous MATRIX reports have demonstrated that Northern Ireland has the component parts to successfully scale and grow its AI capabilities. We must now act to ensure that these public investments in AI are met with focused Industry adoption, the support to commercialise innovation and the ambition to reach the regions AI potential.

Dr Adrian Johnston MBE

executive summary

Executive summary

This report brings together the findings of a sectoral foresight study of current and future opportunities of Artificial Intelligence (AI) in Northern Ireland (NI). It was commissioned by Matrix to inform the AI Competence Centre (AICC) business case.

The Department for the Economy is currently finalising the business case for this Centre, which will be a hub for industry, academia and government. To inform decisions about the AICC's approach to key sectors of Northern Ireland's economy, Matrix commissioned this study with the aim to "*help support the development of NI's AI Sector and maximise future research and commercialisation opportunities*".

This findings report builds on a high-level briefing that was submitted to the Department for the Economy and the industry-led expert panel Matrix on September 17, 2020. The briefing provided an overview of the foresight exercise, an initial assessment of key sectors, and the framework against which the relative sector opportunities have been evaluated in the second project phase.

Relevance and objectives of this study

In setting up the AICC, the Department for the Economy explored a sectoral focus as one potential route to support the impact of the centre's small team and to differentiate the AICC from similar institutions in other parts of the UK.

The objectives of this foresight study are to provide an evidence base with regards to opportunities and challenges for AI across key sectors of NI's economy, and to develop recommendations with regards to the sectoral approach of the AICC.

The study assesses the relative attractiveness of key sectors of the economy of Northern Ireland through a three-step evaluation framework that examines:

- the state of the current research base for AI in Northern Ireland,
- key sectors' roles in the Northern Ireland economy and
- the opportunities for AI to have a distinct impact across these.

Context

The development of the AICC comes at a time where AI technologies are developing rapidly. With the potential to deliver almost £10tn to the global economy by 2030[1], around 70% of companies globally are set to adopt some type of AI technology over the next decade.[2] As such, AI will affect a significant share of jobs, in terms of the nature and volume of jobs across different sectors and the skill requirement for these.

AI in Northern Ireland is an emerging field. The region lags behind the UK average in terms of attainable economic impact of AI[3] and has a high and increasing proportion of tech vacancies in comparison to other regions in the UK.[4] Interviewees highlight that AI research in Northern Ireland is present, but is less tightly focused or differentiated than in some other UK clusters. Current venture capital investment in NI in emerging tech and AI specifically is also lower than in other regions.[5]

Nevertheless, stakeholders interviewed for this research point to the significant potential for AI to develop in NI to foster sustained economic growth. Current research capabilities as well as the Belfast Region City Deal[6] and the Derry / Londonderry City Deal[7] aim to leverage the existing research and industry base to drive further adoption of AI and unlock AI funding.

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[1] McKinsey Global Institute, 2018, Notes from the AI frontier: Modelling the impact of AI on the world economy. Retrieved from: https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy#part1

[2] McKinsey Global Institute, 2018, Artificial intelligence: The next digital frontier? Retrieved from:
https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx

[3] PricewaterhouseCoopers, 2017, £2.6bn Artificial Intelligence boost for Northern Ireland's GDP by 2030. Retrieved from: https://www.pwc.co.uk/who-we-are/regional-sites/northern-ireland/press-releases/responsible-AI-report.html

[4] The Royal Society, 2019, Dynamics of data science skills – How can all sectors benefit from data science talent? Retrieved from https://royalsociety.org/-/media/policy/projects/dynamics-of-data-science/dynamics-of-data-science-skills-report.pdf & Carly Minsky (TechNation), 2020, UK tech jobs bounce back after lockdown. Retrieved from: https://technation.io/news/uk-tech-jobs-growth-data/

[5] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020/#northern-ireland

[6] Belfast Region City Deal - Innovation and Digital, 2020, About the Belfast Region City Deal. Retrieved from: https://www.brcd-innovation.co.uk/about

[7] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from:

Throughout this study, interviewees highlighted considerable growth and excellence across the NI software sector as a significant strength for the region. This Northern Ireland asset, highlighted in the 2016 Matrix Digital ICT report, provides a strong foundation on which NI AI capabilities and skills can be built upon. The symbiotic relationship of AI as a platform technology and the software sector will be required to drive AI excellence, adoption and support skills development in sectors such as advanced manufacturing, financial services, creative industries and the public sector.

This is already paying dividends with leading companies such as Kainos and Allstate utilising its expertise in software engineering to support developments in AI. It should be noted that while the software industry is not evaluated as a standalone sector within this study it is viewed as a critical component which any NI AI Strategy must support to be successful.

Methodology

The in-depth evaluation of the relative attractiveness of sectors of NI's economy focused on key areas of NI's economy that were identified in the first project phase. These areas included traditional sectors, aligned to the UK's SIC 2007 sector structure, as well as cross-cutting themes with a strong AI component. A full list of all 2-digital SIC categories that the traditional sectors map to can be found in Appendix II of this report.

The evaluation was guided by a three-step evaluation framework, focusing on the following areas:

1. **State of the research base:** What research assets does NI currently have to guide sector focus?

2. **Economic state of sector in NI**: What sectors are most important to NI?

3. **Opportunity for AI:** Where will AI have the biggest impact?

For each category, a number of evaluation questions and indicators guided the analysis of the traditional sectors and cross-cutting perspectives. For the traditional sectors, the assessment was further supplemented by an illustrative economic modelling exercise.

Based on this assessment, each sector received a red / amber / green attractiveness rating for each sub-category of the evaluation framework. From this, an overarching rating for each of the three evaluation categories was derived per sector. In this context, it is important to note that the red / amber / green rating is a

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https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

relative rating of the sectors, rather than an *absolute* rating on how well placed a sector is in itself or in the international context.

The detailed methodology that has guided this foresight study can be found in Chapter 2.

Sectoral analysis: Key findings

The in-depth sector analysis is outlined in Chapter 3 and provides insights into the strengths and challenges of AI-specific developments per sector. Given their performance across most categories of the evaluation framework, five sectors were identified as relatively attractive in comparison to other sectors subject to this study: Advanced manufacturing, materials and engineering, biomedical R&D and pharmaceutical manufacturing, cryptocurrency and cyber security, finance incl. FinTech, and human health and social work. While no sector received the highest rating across all categories, these five stood out due to their relatively strong performance across most indicators of the evaluation framework. This is in addition to the 'ICT and Telco' sector, which also received a relatively positive rating which however was driven by the fact that AI technologies are inherent to the sector.

Opportunities and challenges with regards to the adoption of AI across those five sectors are briefly summarised below.

- **AMME**: The sector is one of the significant drivers of NI's economy. AI offers significant potential to reshape the sector in areas such as robotics and 3D printing. Relative to other sectors, interviewees saw a potential for the sector to have a distinct impact, as it is one of NI's key export sectors with some large companies already active in the space. This is further exemplified in the range of complementary initiatives supporting innovation in the sector, including the Belfast Region and Derry / Londonderry City Deals. To leverage its transformative potential, it will be key for sector leaders to embrace AI solutions and to focus on the sub-sectors where NI's expertise is highly specialised and exportable, such as in the area of machinery and transport equipment.

- **Biomedical R&D and pharmaceutical manufacturing**: In comparison to other sectors, a positive assessment across many evaluation categories highlights the potential for the adoption of AI in the life sciences. While a small sector in NI's economy, there are already a range of complementary initiatives in NI, and the UK more broadly, to expand the impact of AI in the sector. There is opportunity to build on existing local strengths, e.g. around diagnostics. However, given the multitude of existing initiatives, it would be challenging for new initiatives to have a distinct impact at a national and international level.

- **Cryptocurrency and cyber security:** NI has a well-established cyber security cluster that combines academic excellence with cyber security innovation in large and smaller, specialised companies. Stakeholders made the connection

between the academic cyber cluster and the emergence of the FinTech cluster. However, it is currently too small in terms of investment capital and the number of companies to compete distinctively nationally and regionally.

- **Finance, incl FinTech:** In comparison to other sectors, this sector is characterised by high AI maturity, both globally and in NI specifically. Given its strength in NI, there is some opportunity for distinct impact. This is also recognised by several interviewees who also point to the well-established cyber cluster as an area from which this sector will benefit. To build on its opportunity for distinct impact, it will be crucial that NI leverages the sector's largest players and start-ups, and builds on its expertise in building software.

- **Human health and social work**: Relative to other sectors subject to this study, this sector offers a wide range of opportunities for the adoption of AI. It is one of the largest sectors of NI's economy, with many cross-cutting initiatives and companies active in the field. There is some distinct value within NI's centralised healthcare data. However, a key challenge for impact is the current lack of industry readiness in healthcare settings.

An overview of the relative attractiveness rating and the detailed assessment of all sectors can be found in Chapter 3 of this study.

Sectoral analysis: Challenges of sector focus

The five sectors that emerge from the analysis are the most attractive sectors for focus in relative terms, considering the current state of the NI economy, its research and the likely impact of AI. However, the foresight exercise and many of the stakeholders consulted reveal that in absolute terms, these sectors may not provide a sufficiently robust or distinct platform for the AICC to deliver impact at scale for Northern Ireland.

This becomes apparent when looking at the general state of the research base in NI, the economic context and the current ability of these sectors to leverage the transformative potential of AI to have a distinct impact:

- **Research:** Across the high performing sectors, research activities are being undertaken, and the City Deals have recognised this research activities as well as the opportunities for improving collaboration across research clusters in these areas. However, the amount of sector-specific research is limited and AI research clusters are still of comparatively small scale. Research is generally less differentiated than in some other AI research clusters across the UK and the question of distinctiveness in AI was raised as a *"hugely difficult question for NI"*[8].

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[8] Stakeholder interview

Successful translational partnerships to date have been cross-sectoral, with sector skills and competences provided by commercial partners.

- **Economy:** The largest sectors of the NI economy by GVA are labour intensive with limited potential for AI. For the health and social care sector this holds true when looking at the industry readiness at the end of the supply chain in healthcare settings. Northern Ireland is an SME driven economy, which is challenging for the adoption of AI. Together, these factors mean that *"the absorptive capacity of the local economy is low"*[9] when it comes to AI according to some interviewees. In each of the high performing sectors, whilst there are one or two large and recognised players with in-house AI capacity, there may not be enough scale to sustain a sector-led approach.

- **AI transformation:** The five sectors identified as relatively attractive are characterised by generally high AI maturity on a global scale. Yet globally, *"for almost every industry, there are well established precedents of machine learning"* [10] and a sectoral approach risks *"targeting an already saturated marketplace"*.[11] These high performing sectors in NI face strong global competition which will make it difficult for them to achieve impact at scale. Beyond this, these sectors are already being supported in NI through a variety of initiatives and partnerships, most notably the Belfast Region[12] and Derry/Londonderry City Deals[13], which aim to deliver sustainable growth to the region. There is an opportunity for the AICC to support and enhance existing initiatives across these sectors. The case for a distinct, AICC-owned sector focus is less clear.

Sectoral analysis: Implications for the AICC's approach

The objective of this study was to conduct a foresight exercise designed to provide an evidence base about the future to inform policy-makers' decision-making around the AICC's approach to key sectors of NI's economy.

There are different approaches that the AICC could take towards sectors of NI's economy:

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[9] Stakeholder interview

[10] Stakeholder interview

[11] Stakeholder interview

[12] Belfast Region City Deal - Innovation and Digital, 2020, *About the Belfast Region City Deal.* Retrieved from: https://www.brcd-innovation.co.uk/about

[13] Derry City & Strabane District Council, 2018, *Delivering inclusive growth: city deal for the Derry-Londonderry city region.* Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

- **Proactive:** The AICC would select 2-3 of the high performing sectors and proactively focus its activities from the onset on developing specific sector-expertise. This would have the advantage that the AICC could develop strong ties with a few key players in the selected sectors through focusing the majority of its engagement on these stakeholders. However, this would come at the cost of limited engagement with actors from other sectors. The AICC would be less able to facilitate the transfer of cross-sectoral technologies and skills beyond the 2-3 selected sectors. Another disadvantage of this sectoral approach is that the AICC would be less able to foster co-production and learning beyond the limited set of actors engaged in the selected sectors.

- **Responsive**: The AICC would launch without a specific sector focus. Rather, it would initially focus its activities on building an AI focused cluster that is open to all sectors. Using foresighting, it would assess emerging opportunities as they arise. If promising niche opportunities come up that offer potential for NI to have impact at scale, the AICC could adapt its activities to actively support AI growth in this area. This approach has the advantage that the AICC would not have to narrow its focus in its early stages, given that AI is still emerging across sectors in NI. The AICC would not focus its activities on developing strong ties with specific key players in 2-3 sectors. Instead, the AICC could facilitate the transfer of knowledge and skills across a wider range of sectors, thus effectively fostering cross-sectoral collaboration and mutual learning. This could for instance take the form of supporting several seed projects that foster transferable skills. The responsive approach would build on one of the key strengths of NI which is the interconnectedness of its communities. The AICC could support activities that ensure effective community building in areas where there is opportunity to further strengthen community ties, for instance across universities. This sector approach has the additional advantage that the AICC could enhance activities of already existing initiatives, such as the Belfast Region and Derry/Londonderry City Deals. It would also allow the AICC to remain responsive to supporting the priorities for a post-COVID-19 economic recovery of NI.

- **Neutral**: The AICC would not launch with a specific sector focus and would not foresee adapting its open approach to sectors in the future, rather aiming to remain a hub that brings stakeholders from all sectors with an interest in AI together. Initially, this approach has the same practical advantages as the responsive approach, namely that the AICC would not restrict its activities to a few selected actors, but could instead support cross-sectoral exchange and learning, as well as the transfer of skills and technologies. However, a neutral approach could come at the cost of missing out on emerging opportunities as they develop. If the AICC would pursue this approach, it would not adapt its activities based on new developments, thus making it less responsive to new technological developments that may warrant focused support in the future. It would also make it less responsive to supporting the priorities for a post-COVID-19 recovery as these priorities emerge.

The in-depth assessment identifies five sectors that are relatively attractive in comparison to other sectors. However, stakeholders consulted and the analysis lead us to conclude that it is not advisable at the onset of the AICC to adopt a proactive sector approach.

It was the view of a number of stakeholders, especially those closest to the research base and global cutting-edge practice that a more desirable model would be to focus on areas of global underinvestment in AI research and practice. This led these stakeholders to a variety of ideas, including a focus on sustainability, smart agriculture, regtech and autonomy verification/validation.

These were narrower conceptions of a "sector focus" that drew less on local research, skills and experience and more on claiming the remaining "white space" in the AI landscape. In this analysis, the local context is less relevant. Success with this approach would require partnerships with global firms, academic leadership and regulatory sandboxing. Whilst this approach may be more attractive, it is also seen as higher risk. The AICC may be better served by establishing itself before pursuing a global niche like this.

If the AICC were to take on a proactive sector approach, this study suggests that the added advantage for the development of AI in NI would be limited. Given the currently emerging research base and the economic context of being a small SME economy with the larger sectors not being the ones with the highest AI potential, taking a focused sectoral approach would make it very difficult for the AICC to drive impact at scale.

This is particularly relevant as one of the key strengths identified in this study is the interconnectedness of NI's communities across sectors. In addition, most AI skills are largely sector-agnostic and transferable. A responsive sector approach thus offers the opportunity to strengthen skills that can be applied in a wide range of sectors. This could for instance be achieved by supporting several seed projects that focus on the development of transferable skills that can then be applied across sectors. Similarly, many AI technologies can be applied across sectors. These reflections further align with the findings of research conducted by the Department for the Economy to inform the development of the business case for the AICC.

Instead of restricting its activities to a number of sectors at this point, a responsive approach has the advantage of allowing the AICC to focus its activities on building a strong AI focused cluster that supports actors in the local economy, strengthens the skills base and enhances collaboration. Through this, a wider set of sectors will be able to learn from one another and benefit from the development of transferable skills. This approach also aligns with the suggested pillars of the AICC, as outlined in its business case, including the pillar focused on feeding and improving the current and future workforce capabilities and the pillar on building a world class AI community through collaboration. It further allows the AICC to be responsive to priorities of economic recovery in the aftermath of COVID-19.

As AI growth will happen organically across sectors, the decision to prioritise particular sectors is best taken once there is established momentum behind niches that provide NI with an opportunity for impact at scale. Considering that key programmes that will provide investment in innovation, such as the Belfast and Derry / Londonderry City Deals, have only recently been announced, this approach also offers the opportunity to respond to developments resulting from the City Deals and to link the AICC's activities to opportunities that emerge from these initiatives.

Recommendations

- **Build an AI focused cluster with a responsive approach to sectors**: Build an AI cluster focused on strengthening the AI community as a whole, accelerating growth and facilitating technological developments. By building this cluster on an open-call basis, the AICC will be able to focus its activities on promoting sector cohesion, co-production and learning across all sectors. As AI is an enabling technology, this open and responsive approach will support the development of an AI-enabled environment in NI where specific focus areas and leadership can emerge over time. This approach further recognises the interconnectedness of NI's communities as a key strength with untapped potential. This will allow the AICC to support the development of transferable skills and technologies that have the potential to spur innovation across a wide set of sectors, for instance through supporting seed projects that foster the development of transferable skills. By pursuing this approach, the AICC will also be responsive to the priorities of the post-COVID-19 economic recovery and it will be able to align its activities to the City Deals, while keeping the AICC open to sector-specific opportunities should these emerge over time.

- **Strengthen collaboration across actors, sectors and borders**: Given the diversity of existing initiatives and partnerships, the AICC should enhance AI collaboration across academia and industry, in NI and across the island of Ireland. Through this, the AICC could support activities that aim to foster effective community building in areas where this is currently limited. By strengthening collaboration across sectors and actors, different sectors will be able to learn from one another and skills will be easier transferrable. A responsive sector approach will ensure that the AICC will be aligned to and able to support developments under the City Deals. Several interviewees highlight particular opportunities in strengthening ties with AI players in the Republic of Ireland (RoI), given the similar geographical and economic context, the opportunities and appetite for partnerships and the fact that many global companies in attractive sectors have a presence in the RoI.

- **Build on the 'levelling up' agenda:** While specific priorities for this agenda have not yet been established, there is opportunity to strengthen NI's voice in the UK wide AI conversation. Focusing on this will also allow the AICC to respond more flexibly to funding opportunities arising through the 'levelling up' agenda and to align its activities with the economic priorities of the post-COVID-19 recovery.

- **Align activities to national strategies and the AI Council:** The UK's AI Council, an independent expert committee, provides advice to Government and high-level leadership of the AI ecosystem. Its members include the Alan Turning Institute Chief Executive, Professor Adrian Smith, as well as Professor Máire O'Neill from Queen's University Belfast in Northern Ireland. Building on this, aligning the AICC's activities to the AI Council and national strategies will ensure that the AICC can effectively take part in wider conversations around the strategic direction of AI developments. It will also be better able to respond to funding opportunities that emerge from these strategies.

introduction

1 Introduction

This report brings together the findings of a sectoral foresight study of current and future opportunities of Artificial Intelligence (AI) in Northern Ireland. It was commissioned by Matrix to "*help support the development of Northern Ireland's AI Sector and to maximise future research and commercialisation opportunities*".[14]

This research explores the opportunities and challenges with regards to developing a sector specialisation for the AI Competence Centre (AICC). This hub for AI in Northern Ireland is currently being set up and will bring together industry, academia and government. Towards this end, the report assesses **the relative attractiveness of different key sectors of the economy of Northern Ireland to serve as potential focus areas of the AI Competence Centre**. Based on a comparative analysis of current and future opportunities of AI across these sectors and of AI opportunities in Northern Ireland more broadly, it identifies implications to be considered when considering the AI Competence Centre's approach to supporting different sectors.

This second report builds on a high-level briefing, which was submitted to the Department for the Economy and Matrix, the Northern Ireland Science and Industry Panel, on September 17, 2020. This initial briefing provided a high-level overview of the context of the foresight exercise and an initial assessment of key sectors. It further outlined a framework against which the different sectors and opportunities were evaluated in the second project phase.

Incorporating feedback from the Matrix panel on the high-level briefing note, the second project phase encompassed a deep dive analysis of the relative attractiveness of the selected sectors. This second report outlines the opportunities and drawbacks of a sector focus for the AICC, drawing on perspectives and insights from other regions and from the AI opportunity for Northern Ireland more broadly and the perspective of other regions. It was informed by a combination of desk research and conversations with key stakeholders from Northern Ireland's industry, AI experts and other relevant stakeholders. The detailed methodology is outlined in Chapter 2.

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[14] Matrix, the Northern Ireland Science and Industry Panel,
2020, Technical specification: DfE – Northern Ireland AI Sector Foresight Study, p. 1

1.1 Definition of AI

There is no single generally accepted definition of Artificial Intelligence (AI). Corresponding with the 2019 Turing Institute Report[15], this report also uses the definition by the Engineering and Physical Science Research Council:

"Artificial Intelligence technologies aim to reproduce or surpass abilities (in computational systems) that would require 'intelligence' if humans were to perform them. These include: learning and adaptation; sensory understanding and interaction; reasoning and planning; optimisation of procedures and parameters; autonomy; creativity; and extracting knowledge and predictions from large, diverse digital data."

1.2 Structure of the report

The introduction to this report is followed by a section outlining the context for this research, including the state of AI in Northern Ireland, in comparison to the UK and more broadly, and information on the purpose of the AI Competence Centre. The report thereafter provides an overview of the research methodology, including the analysis framework and economic modelling. The report's main section brings together the findings of the analysis of the relative attractiveness of the selected sectors and the economic modelling exercise. It thereafter draws out implications of these findings and from this, the report concludes by providing recommendations with regards to the sectoral approach of the AICC.

1.3 Context for this research

1.3.1 Global and UK wide AI opportunity

Across the world, AI technologies are already reshaping many industries. With the potential to deliver almost £10tn to the global economy by 2030[16], the wider rollout of AI is expected to change the way society works.[17] A simulation by McKinsey found that about 70% of companies are likely to adopt some type of AI technology

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[15] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[16] McKinsey Global Institute, 2018, Notes from the AI frontier: Modelling the impact of AI on the world economy. Retrieved from: https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy#part1

[17] House of Lords: Select Committee on Artificial Intelligence, 2018, AI in the UK: ready, willing and able?. Retrieved from: https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/100.pdf

by 2030.[18] While a significant part of jobs will be affected by AI, impact on the nature, skill requirement and volume of jobs is uncertain.[19]

In its 2017 report on the AI sector in the UK, the government estimated that by 2035, AI could add £630bn to the UK economy, equivalent to a 30% uplift.[20] Other estimates are slightly lower, with PWC forecasting a 10.3% uplift in 2030 vis-a-vis 2017[21] and McKinsey expecting a 22% uplift vis-a-vis 2019 by that year.[22]

The UK features in the top of many global rankings on AI potential. For example, McKinsey ranks the UK as a leader within Europe when it comes to AI readiness, especially with regards to where it stands in terms of innovation, digital readiness and the AI startup climate.[23] The Government AI Readiness Index places the UK second only after the US, citing the high market value of its technology companies, its government commitment to support AI development, and the strong data strategy and infrastructure at its disposal. AI research in the UK is particularly strong, although there have been some questions on how well this research is being translated into commercial opportunities.[24] While the UK overall is well positioned in terms of AI Readiness, this is not the case for all regions to a similar extent, with lower

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[18] McKinsey Global Institute, 2018, Artificial intelligence: The next digital frontier? Retrieved from:
https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx

[19] E.g. Frontier Economics, 2018, The impact of Artificial Intelligence on work: An evidence review prepared for the Royal Society and the British Academy. Retrieved from:
https://royalsociety.org/-/media/policy/projects/ai-and-work/frontier-review-the-impact-of-AI-on-work.pdf; and PricewaterhouseCoopers, 2017, How will automation impact jobs? Retrieved from: https://www.pwc.co.uk/services/economics/insights/the-impact-of-automation-on-jobs.html

[20] UK Government: BEIS & DCMS, 2017, Growing the artificial intelligence industry in the UK. Retrieved from: https://www.gov.uk/government/publications/growing-the-artificial-intelligence-industry-in-the-uk/executive-summary

[21] PricewaterhouseCoopers, 2017, The economic impact of artificial intelligence on the UK economy. Retrieved from: https://www.pwc.co.uk/economic-services/assets/ai-uk-report-v2.pdf

[22] McKinsey Global Institute, 2019, Artificial intelligence in the United Kingdom: Prospects and challenges. Retrieved from:
https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Artificial%20intelligence%20in%20the%20United%20Kingdom%20Prospects%20and%20challenges/Artificial-intelligence-in-the-United-Kingdom-VF2.ashx

[23] McKinsey Global Institute, 2019, Tackling Europe's gap in digital and AI. Retrieved from: https://www.mckinsey.com/featured-insights/artificial-intelligence/tackling-europes-gap-in-digital-and-ai

[24] Oxford Insights, 2020, Government AI Readiness Index 2020. Retrieved via:
https://static1.squarespace.com/static/58b2e92c1e5b6c828058484e/t/5f7747f29ca3c20ecb598f7c/1601653137399/AI+Readiness+Report.pdf

levels of AI capacities in regions including Northern Ireland. While specific priorities for the UK's "levelling up" agenda have not yet been established, it also provides an opportunity to strengthen NI's role in the UK wide AI conversation.

The UK government's ambition is to maintain this position as a leader in AI in research and industry and has committed to this through its Industrial Strategy.[25] The UK's AI Sector Deals constitute a commitment of up to £960m from the UK government to realise the potential of AI and big data. It is underpinned by a vision to make the UK a global centre for AI, support existing sectors with AI, be a world leader in safe and ethical use of data and developing appropriate skills for the future of work.[26] In addition, through its R&D Roadmap, the UK Government is committed to levelling up R&D across the UK including in regions with lower concentration of current R&D activity.[27]

In this context, there is opportunity for regions to strengthen collaboration both within the UK and across borders to make the most of existing synergies in AI. In the specific case of Northern Ireland, interviewees particularly point to opportunities around collaborating with the Republic of Ireland, given its close geographic proximity, emerging shared research opportunities, and the strong basis of global tech (and particularly pharma) companies in the Republic of Ireland.[28]

Disruptions to the UK's economy, such as Brexit and the COVID-19 pandemic have the potential to accelerate innovation and increase the adoption of AI technologies in specific niche areas. Interviewees highlight that COVID-19 has driven companies to focus their efforts in the areas of digital transformation, automation and robotics.[29] Exemplary for this, one interviewee suggested that there could be an opportunity for NI to become a test bed for medical devices that manufactures would like to use in Europe, while the focus on this specific area shifts away in the rest of the UK. Another suggested that a "regulatory sandbox" could be created to consider questions of logistics around post-Brexit border issues that could lead to the development of exportable technology.[30] However, in the short term, the aggregate effect of these disruptions on the economy and R&D budgets is generally agreed to be negative.

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[25] House of Lords: Select Committee on Artificial Intelligence, 2018, AI in the UK: ready, willing and able?. Retrieved from:
https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/100.pdf

[26] UK Government: BEIS & DCMS, 2019, AI Sector Deal. Retrieved from:
https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal#executive-summary

[27] UK Government, 2020, UK Research and Development Roadmap. Retrieved from:
https://www.gov.uk/government/publications/uk-research-and-development-roadmap

[28] Stakeholder interviews

[29] Stakeholder interviews

[30] Stakeholder interviews

1.3.2 Skills base

Over the next ten years, a significant share of jobs will be affected by AI, both in terms of the nature of jobs, the skill requirement, the volume of jobs available, and the jobs required across different sectors.

The 2016 Matrix Digital ICT report points to the strong local skills base in software engineering as supporting the development of more specialised skills in areas such as cyber security, advanced networking and sensors development and data analytics. This continues to be evidenced by recent investments from the BT group and international software Development Company Bitwise in establishing software and innovation centres of excellence in Belfast. BT in particular will focus on the intersection of AI, IoT, communications and system development.

There is widespread agreement that it will be important to access a comprehensive base of AI skills.

In order to leverage the opportunity of AI, Northern Ireland will also need to create and access a pool of high-skilled talent. This talent pool will recognise that successful AI requires an "ecosystem of roles"[31] and is not a purely technical exercise.

However, it is noted that of the 20 million software engineers globally, more than half are employed outside of technical industries. This will continue to grow and bring further challenges but also opportunities with the accelerated adoption across many economic sectors.

Companies across the NI economy will require particularly strong digital, software engineering and development capability to overcome AI deployment challenges across their business operations. AI roles will also need to draw from social and behavioural science, economics, safety and ethical issues, but are all likely to be higher-skill levels.

In addition, interviewees agree with the desk research that many of these high-level skills needed to support the adoption of AI technologies in the future are not sector specific but transferable across sectors.[32]

The prospect of employment opportunities that draw on Further Education skills was more mixed. Areas like robotics, business intelligence (BI) development, NLP and computer vision were all thought to be areas where there could be opportunities for roles that required FE level skills, especially in the deployment and management of systems. As with the higher-level skills, these were less sector-oriented.

The agreed long-term perspective is that AI will eliminate many lower-skilled roles. It is less clear to see how AI will create new roles in lower and semi-skilled areas. As

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[31] Stakeholder interviews

[32] Stakeholder interviews

automation and mechanisation ultimately reduce employment in agriculture and manufacturing, it is likely that AI will reduce total employment levels in services and semi-skilled areas of the economy. New roles will emerge, but these may be unrelated to AI. For example, other trends drive employment in the caring professions.

Looking to Northern Ireland specifically, interviewees reported challenges relating to the skills base that included the absence of a strong digital start-up community, the tendency of high skilled AI professionals to seek (and stay in) jobs at well-established large companies such as Kainos, Seagate and Allstate, as opposed to seeking out roles in startups, and the lack of a sufficiently big talent pool.[33]

One interviewee reported that many of the larger companies that were investing in local AI capability were historically based in NI in order to access a lower-cost employment pool and had built a higher-skilled workforce from that base. These employers recognised the skills that were available in NI and based thereon, were demanding more of the "right" graduates, with a focus on data analytics and data science. The interest of these employers when it came to skills was more about access to talent, co-production and cross-sector learning than it was about skills that would support the creation of a cluster of sector specialists.

1.3.3 The state of Northern Ireland's economy and ICT

In 2018, the Northern Ireland economy had a GVA of £42.2bn, which constituted 2.2% of the UK's total GVA[34] with its economic activities centred in small and medium enterprises. The main sectors in NI in terms of employment are the public sector (education, health and public administration), manufacturing, trade, agriculture and construction.[35]

In late 2018, NI's ICT sector (SIC J61-63) accounted for 2.2% of all (full-time and part-time) employment[36] and over £1,277m of GVA (3% of total GVA). NI's ICT sector is

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[33] Stakeholder interviews

[34] Office for National Statistics, 2019, Regional gross value added (balanced) by industry: all NUTS level regions. Retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry

[35] European Commission, 2019, Northern Ireland: Economy. Retrieved from: https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/northern-ireland

[36] Northern Ireland Statistics and Research Agency, 2020, Quarterly Employment Survey Historical Tables March 2020: Table 5.10. Retrieved from: https://www.nisra.gov.uk/publications/quarterly-employment-survey-historical-tables-march-2020

smaller than the UK average of 5.28% ICT sector share of total GVA.[37] At the same time, an analysis of the current open vacancies shows that there are more vacancies in tech in NI (relative to the total vacancies) than in the rest of the UK.[38] Across the UK, job postings for Data Scientists and Advanced Analyst positions also grew the most in NI (563%).[39]

While the ICT sector in NI is relatively small compared to the UK more broadly, the Matrix Digital ICT Report 2016 report identifies that within Northern Ireland, the core ICT strengths include software engineering, application development, cyber security, data analytics and advanced networks & sensors. The report further identifies five key sectors that benefit from these ICT capabilities and clusters: FinTech, Manufacturing, Public Services, Agriculture and Life & Health Sciences.[40]

Investment into innovation and ICT in NI over the next years will likely come from a number of sources. The most significant investment into ICT and innovation that has already been announced will be the City Deals for the Belfast and Derry / Londonderry region, in which many national and regional public and private parties are participating. The Belfast Region City Deal totals almost £1bn, unlocking £350m investment from the UK government, which is matched by a further £350m from the NI Executive, as well as co-investments of upwards of £150m from City Deal partners such as private sector, councils and universities.[41] The Derry / Londonderry City Deal will receive £50m from the UK government, supplemented by £55m for the new Inclusive Future Fund.[42] This seems somewhat similar to other regions: the Cardiff capital region City Deal will receive £500m from the UK government (total value is £1.2bn), the Swansea bay city region unlocks £115.6m UK government funding and

[37] Office for National Statistics, 2020, Regional gross value added (balanced) by industry: all NUTS level regions (2018 data). Retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry

[38] Carly Minsky (TechNation), 2020, UK tech jobs bounce back after lockdown. Retrieved from: https://technation.io/news/uk-tech-jobs-growth-data/

[39] The Royal Society, 2019, Dynamics of data science skills – How can all sectors benefit from data science talent? Retrieved from https://royalsociety.org/-/media/policy/projects/dynamics-of-data-science/dynamics-of-data-science-skills-report.pdf

[40] Matrix, 2016, Matrix Digital ICT Report 2016. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

[41] Belfast Region City Deal - Innovation and Digital, 2020, About the Belfast Region City Deal. Retrieved from: https://www.brcd-innovation.co.uk/about

[42] UK government press release, 2019, £105 million economic package for the North West. Retrieved from: https://www.gov.uk/government/news/105-million-economic-package-for-the-north-west#:~:text=The%20Derry%2DLondonderry%20region%20will,the%20UK%20Government%20announced%20today.&text=The%20Derry%20City%20and%20Strabane,and%20unlock%20local%20partner%20funding.

the Edinburgh and South East Scotland Deal includes a joint investment of the UK and Scottish government of £600m.[43] In addition, many interviewees also anticipate that the "levelling up agenda"[44] will be a potential source of future new funding, though amounts and priorities are not yet established.

The Belfast Region City Deal has four strands, of which one focuses specifically on Innovation and Digital. Artificial intelligence and machine learning is specifically identified in this City Deal. It further identifies five sectors as areas that have the potential to be transformed by innovation and data analytics: Life and Health Sciences; Agri-food; Advanced Manufacturing, Materials, and Engineering; Digital and Creative Technologies; and Financial, Business, and Professional Services.[45] Those sectors align more or less to those identified in the 2016 Matrix Digital ICT report.[46] The Derry-Londonderry City Deal has four investment areas, of which both innovation and digital infrastructure include a focus on AI. Main sectoral focuses of innovation and digital are Health and Life Sciences and Advanced Manufacturing.[47]

1.3.4 AI in Northern Ireland

AI in Northern Ireland is still an emerging field with few well-established players. The 2016 Matrix report illustrates the benefits of Northern Ireland increasing its focus on AI.[48]

Interviewees agree that there is potential for AI to develop in NI, and point to current research capabilities as well as the City Deals which aim to leverage research for real-life applicability and unlock significant funding. They also see an increasing number of startups working in the field, although this is in early development.

For those interviewees outside NI, cyber at QUB was the area in which there was a clear academic centre of excellence and many believed that the long-term

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[43] UK Parliament research briefings, 2020, City Deals. Retrieved from: http://researchbriefings.files.parliament.uk/documents/SN07158/SN07158.pdf

[44] UK Government, 2020, Speech: Levelling up research and innovation right across the United Kingdom. Retrieved from: https://www.gov.uk/government/speeches/levelling-up-research-and-innovation-right-across-the-united-kingdom

[45] Belfast Region City Deal - Innovation and Digital, 2020, Vision: digital technologies and data assets. Retrieved from: https://www.brcd-innovation.co.uk/vision

[46] Matrix, 2016, Matrix Digital ICT Report 2016. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

[47] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

[48] Matrix, 2016, Matrix Digital ICT Report 2016. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

investment in cyber had supported the growth of economic activity, especially in FinTech.

Many interviewees from NI, in comparison, struggled to indicate particular areas of research excellence in AI capabilities that sets NI apart compared to other areas in the UK. In general, the question of distinctiveness in AI was raised as a *"hugely difficult question for NI"*.[49]

According to one interviewee, research *"excellence is distributed"*[50] such that the only way to build competitive scale was to prioritise collaboration and shared research agendas – which echoes the recommendations of the Turing Institute report.[51] For many interviewees, this was true of much research across NI and the Republic of Ireland, leading to calls for shared research agendas.

Interviewees point to the development of CARL as an important step to bring a *"unifying theme"*[52] to AI research at Ulster University combining the *"theoretical expertise of the Jordanstown campus"*[53] with the *"more engineering and computational expertise of the Magee campus"*.[54] Since CARL had brought these two together, it has grown the total number of academic posts and improved their REF impact.

Others areas of strength, such as health (interviewees cited cardiology and dementia), were starting to apply AI techniques in their research.

The 2019 Turing Institute report finds that UU and QUB together would rank 6th in terms of AI publications[55]. Interviewees felt that collaboration across these areas between the two universities was improving, stimulated by the regional initiatives and personal relationships.[56]

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[49] Stakeholder interview

[50] Stakeholder interview

[51] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[52] Stakeholder interview

[53] Stakeholder interview

[54] Stakeholder interview

[55] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[56] Stakeholder interview

Lastly, the economic structure of Northern Ireland - as an SME driven, relatively lower global trade economy - can be challenging to the adoption of AI.[57] Economic priorities over the next couple of years will be to create jobs with current skill profiles and economic recovery for major sectors in the aftermath of COVID-19 and Brexit, which could conflict with areas of AI opportunity.

Given those barriers, there is still plenty of opportunity for Northern Ireland to develop its AI capabilities. The UK's current AI readiness is world-class and the UK government's commitment to accelerate AI is also likely to benefit Northern Ireland. Drawing on these opportunities, the 2019 report by the Turing Institute identified the space to establish an AI Competence Centre in Northern Ireland.[58]

1.4 State of the research base

AI research in Northern Ireland is present, but is less tightly focussed or differentiated than in some other UK clusters.

Within Northern Ireland, Ulster University (UU) and Queen's University Belfast (QUB) are important hubs for AI research, with some involvement from the regional colleges. UU ranks 14th and 16th in two rankings on the number of AI publications in the UK, and ranks 48th out of 89 UK universities on "Computer Science and Informatics". QUB's number of AI publications rank 31st and 35th in two rankings, and QUB ranks 38th in the "Computer Science and Informatics" ranking. Interviewees point to the specific strengths in cyber security, brain-computer interfaces and cardiology, and to the university-industry connections at UU. However, as current collaborations between the universities happen mainly through initiatives or networks such as the City Deals, some interviewees question to what extent the two universities can be treated as a cluster.[59] Within the UK, overall AI capacity of the universities is picked up to a lesser extent, mainly because it has not been part of Turing Institute's partners or collaborators.[60]

[57] PriceWaterhouseCoopers, 2017, £2.6bn Artificial Intelligence boost for Northern Ireland's GDP by 2030. Retrieved from: https://www.pwc.co.uk/who-we-are/regional-sites/northern-ireland/press-releases/responsible-AI-report.html

[58] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[59] Stakeholder interviews

[60] The Alan Turing Institute, 2020, Current partnerships and collaborations. Retrieved from: https://www.turing.ac.uk/collaborate-turing/current-partnerships-and-collaborations

While UU and QUB together employ 150 staff involved in AI research from all levels, none involved in AI have been listed as EPSRC fellows[61], nor as one of the over 400 researchers collaborating at the Turing Institute.[62] Main research clusters in UU and QUB involve cyber security hardware, Internet of Things, medicine, robotics, multimedia analytics and economics; additional research clusters are engineering, ethics, humanities & social science and government[63]. Main research centres that focus on core AI and machine learning are QUB's Centre for Data Science and Scalable Computing[64] as well as some research on machine learning and AI in the Mathematical Sciences Research Centre.[65] The UU's main research centre for core AI is the Artificial Intelligence and Applications research group, which is part of the computer science and informatics research topic.[66] Other AI research capabilities are spread throughout the universities and are elaborated upon per sector in Chapter 3.

QUB is renowned for its ability to spin out companies from the university[67]. Both QUB and UU have produced spin-outs with a focus on AI, and have worked together with companies small and large on AI through collaboration and knowledge transfer partnerships.[68] Interviewees felt that the current portfolio of AI focussed startups tended to focus on applications, such as monitoring networks, energy management and healthcare applications rather than clustering around a particular sector. Partnerships were taking place across sectors (interviewees cited organisations as

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[61] EPSRC, 2020, People. Retrieved from:
https://epsrc.ukri.org/about/people/?selectedCategories=University%252EQueen%2527s%2520University%2520Belfast&pageNumber=1&resultsPerPage=25&filterSortBy=personLastName&filterSortOrder=asc&displayList=default

[62] The Alan Turing Institute, 2020, Researchers. Retrieved from:
https://www.turing.ac.uk/people/researchers

[63] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from:
https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[64] Queen's University Belfast, 2020, DSSC. Retrieved from: https://www.qub.ac.uk/ecit/DSSC/.

[65] Queen's Unversity Belfast, 2020, MSRC: Research. Retrieved from:
https://web.am.qub.ac.uk/wp/msrc/msrc-home-page/research/

[66] Ulster University, 2020, About Artificial Intelligence and Applications. Retrieved from:
https://www.ulster.ac.uk/research/topic/computer-science/artificial-intelligence/about

[67] Octopus Ventures, 2019, Research to Riches: Entrepreneurial impact ranking 2019. Retrieved from: https://www.praxisauril.org.uk/sites/praxisunico.org.uk/files/Octopus-Ventures-Entrepreneurial-Impact-Ranking.pdf

[68] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from:
https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

diverse as the BBC, NASA and the Samaritans as partners in AI-related work). However, several interviewees question how much of the research taking place in universities is being applied commercially, and how broad this application is.[69]

More applied research and development is also taking place outside of universities in companies small and large, such as at the British Telecom Innovation Centre, which focuses on the Internet of Things (IoT), AI and Data analytics.[70] There is an appetite to further deepen interaction between industry and AI research and there is the expectation that the City Deals will provide a significant boost to this.

1.5 Economic opportunity and employment

Assessing the economic opportunity for Northern Ireland shows that while it boosts a high proportion of tech vacancies, the region is lagging behind the UK average in terms of attainable economic impact of AI.

If NI were to experience the UK government's predicted uplift from AI proportionally to GDP, this would add up to a £14.4bn uplift by 2035.[71] However, PwC indicated that the expected added value of AI for Northern Ireland will be £2.6bn by 2030, which is a 5.4% uplift compared to 2017, about half of their estimate for the UK as a whole. PwC attributes this difference mainly to the smaller global expert activity in the region. This estimate is also significantly lower than the gains for Wales and Ireland, with an expected 8-9.5%.[72] The economic model as part of this research (see section 2.2 for methodology, 4 for outputs) identifies a lower impact on GVA, being the sectoral equivalent of GDP prior to national-level adjustments and tax effects (+3.3%, in a high plausibility range of +2.5% to +4.1%). This lower estimate is driven by the negative impact of COVID-19, a focus on a subset of the overall economy, and a more conservative growth prediction than these topic-focused reports, which often have a marketing objective and can tend to take an optimistic view of the economic impact of technological advances.

Several interviewees have voiced concerns about whether Northern Ireland trains and retains enough talent to foster AI development in the region, especially with regards to highly specialised graduates and PhD candidates. There is currently one

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[69] Stakeholder interview

[70] British Telecom, 2017, BT chooses Northern Ireland for £28.6 million innovation centre and creation of 50 graduate jobs. Retrieved from: http://home.bt.com/tech-gadgets/tech-news/bt-belfast-northern-ireland-innovation-centre-11364232902959

[71] UK Government: BEIS & DCMS, 2017, Growing the artificial intelligence industry in the UK. Retrieved from: https://www.gov.uk/government/publications/growing-the-artificial-intelligence-industry-in-the-uk/executive-summary

[72] PricewaterhouseCoopers, 2017, £2.6bn Artificial Intelligence boost for Northern Ireland's GDP by 2030. Retrieved from: https://www.pwc.co.uk/who-we-are/regional-sites/northern-ireland/press-releases/responsible-AI-report.html

Artificial Intelligence MSc which is offered at UU, as well as multiple Masters in e.g. data and business analytics (both QUB), data science (UU) and cyber security (QUB)[73]. An analysis by TechNation shows that NI ranks highest in the UK of graduates with tech skills staying after they completed their studies in the region.[74] Some interviewees, however, wonder if the current pipeline is enough to fill future demand.

Currently, Northern Ireland has the UK's highest proportion of tech vacancies versus all other roles in the UK, with 23% of vacancies being in digital tech. It is unclear whether this is due to a high demand for or low supply of tech skills[75] With an average salary of £40,000, digital tech salaries in Belfast are relatively high compared to places such as Cardiff (£37,500), Newcastle (£35,000) and Oxford (£38,000), although similar or lower than in places such as Edinburgh (£44,938), Cambridge (£40,000), Bristol (£40,000) and London (£55,000).[76]

As Belfast is ranked 2nd in terms of tech salaries versus the cost of living[77], interviewees are questioning whether the skilled workforce will take on a "startup" or product approach towards AI, instead preferring the stability and payment in larger companies and the government. There are also questions on what a transition to AI will mean for lower- and semi-skilled work and the balance between those, and to what extent the work in big deep tech companies can be paired with lower- and semi-skilled work.

1.6 Industry engagement

There are a range of NI companies engaging or solely focusing on AI. However, Northern Ireland has a scattered range of initiatives to support AI in business, attracts less AI venture capital (VC) than other regions, and does not always connect well to the UK-wide AI agenda. This is endorsed by interviewees, who mentioned Allstate and Kainos as some of the places that have significant private sector local capacity in AI.

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[73] Postgraduate Search, 2020, MSc Computer Science and Information Technology in Northern Ireland. Retrieved from: https://www.postgraduatesearch.com/pgs/search/?course=computer-science-it&qualification=msc&location=northern-ireland

[74] TechNation, 2020, Part 2: Tech skills: Key Findings. Retrieved from: https://technation.io/talent/key-findings/

[75] Carly Minsky (TechNation), 2020, UK tech jobs bounce back after lockdown. Retrieved from: https://technation.io/news/uk-tech-jobs-growth-data/

[76] TechNation, 2020, Jobs and skills report. Retrieved from: https://technation.io/jobs-and-skills-report/#tech-salaries

[77] Carly Minsky (TechNation), 2020, UK tech jobs bounce back after lockdown. Retrieved from: https://technation.io/news/uk-tech-jobs-growth-data/

There is a wide range of initiatives to connect academia with industry engagement. Main research centres in the universities, of which some also engage with industry, are CARL at UU and several initiatives under the school of electronics, electrical engineering and computer science at QUB.[78] The universities also connect to different initiatives under the City Deals, which aim to bring together research and industry partners. Notable initiatives are the Global Innovation Institute on data security, connectivity and analytics as part of the Belfast Region City Deal[79], as well as an investment priority in CARL as part of the Derry / Londonderry City Deal.[80] In addition, initiatives such as Catalyst (formerly Northern Ireland Science Park) with the Belfast Digital Innovation partnership and Digital Catapult Northern Ireland also stimulate business to innovate in tech and AI.[81]

The 2019 Turing Institute report estimated that there are 80-90 NI companies of various sizes involved in AI developments, including Kainos, Allstate, Seagate Technology, Citi, BT and PWC.[82] While there are examples of spin-outs as highlighted in the "state of the research base"-section, the UK in general struggles to turn its academic foundations in AI into business and commercial success.[83] Anecdotal evidence from the interviews suggests that Northern Ireland also struggles to translate its research, which is often low in Technology Readiness Level (TRL), into commercial opportunities.

Current VC investment levels in Northern Ireland in emerging tech and AI specifically are lower than in other regions with £18m and £3m investment between 2015 and

[78] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[79] Belfast Region City Deal: Innovation and Digital, 2020, Global Innovation Institute. Retrieved from: https://www.brcd-innovation.co.uk/projects/gii

[80] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

[81] Catalyst, 2002, Who we are: about us. Retrieved from: https://wearecatalyst.org/who-we-are/about-us/ and Digital Catapult, 2020, Digital Catapult Northern Ireland. Retrieved from: https://www.digicatapult.org.uk/regional-centres/northern-ireland

[82] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[83] McKinsey Global Institute, 2019, Artificial intelligence in the United Kingdom: Prospects and challenges. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Artificial%20intelligence%20in%20the%20United%20Kingdom%20Prospects%20and%20challenges/Artificial-intelligence-in-the-United-Kingdom-VF2.ashx

2019 respectively. Scotland attracts £93m investment in emerging tech and £25m in AI, Wales £36m and £32m.[84] The £3m investment is concentrated in a handful of companies, and public R&D spend per company is among the lowest in the UK.[85] Interviewees also suggest that NI in general is struggling to attract R&D funding.[86] The regional distribution of UKRI funding supports this assessment, as NI, together with the North West and Wales, receives the least Innovate UK funding across the UK regions.[87]

In addition, there is some mixed evidence on whether VC in NI is increasing or not.[88] Some interviewees also suggest that Northern Ireland's companies could further benefit from leveraging themselves on a UK wide scale.

1.6.1 AI Competence Centre

The Department for the Economy is currently working to establish an AI Competence Centre (AICC) in Northern Ireland. Work on this began following the publication of the 2019 Turing Institute report "*Artificial Intelligence Research in Northern Ireland and the Potential for a Regional Centre of Excellence*". One of the report's recommendations was to establish a regional centre of excellence (RCE) on AI.

The Department for the Economy is currently developing the business case for the AICC, which will be a hub for industry, academia and government

1.7 Organisational set-up

The purpose of the AI Competence Centre to bring together industry, academia and government to make Northern Ireland a world leader in AI. It will help Northern Ireland execute world class AI research, develop the unrealised AI talent pipeline, support world class AI businesses and product commercialisation and pioneer the use of open data for breakthrough AI R&D.

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[84] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020/#northern-ireland

[85] Conversation with Michael McClelland, 19 August 2020

[86] Stakeholder interview and Nesta, 2020, The Missing £4 Billion: Making R&D work for the whole UK. Retrieved from: https://media.nesta.org.uk/documents/The_Missing_4_Billion_Making_RD_work_for_the_whole_UK_v4.pdf

[87] UKRI, 2020, Regional distribution of funding, Retrieved from: https://www.ukri.org/about-us/what-we-do/funding-data/regional-distribution-of-funding/

[88] P. O'Brien, 2020, TechIreland - H1 2020 startup funding review. Retrieved from: https://irishtechnews.ie/techireland-h1-2020-startup-funding/ and Belfast Telegaraph, 2019, Growing venture capital scene offers new funding avenues for NI startups. Retrieved from: https://www.belfasttelegraph.co.uk/business/northern-ireland/growing-venture-capital-scene-offers-new-funding-avenues-for-ni-start-ups-37733429.html

The Centre focuses on four pillars:

- Research & Innovation Services
- Talent Pipeline & Future workforce
- Data Accessibility, Governance & Ethics
- Community and Collaboration

The Centre is looking to employ permanent staff including policy advisors, coordinators and principal data scientists, and fixed term staff including data and industry analysts and academic researchers.[89]

While details for the AICC are still being finalised, funding will be a small percentage of other regional AI investments. However, its specific focus on AI will help to develop more targeted interventions. In comparison, the Data Lab in Scotland receives £13.5m from Scottish public bodies[90] for the next five years, Insight SFI Research Centre for Data Analytics in the Republic of Ireland is driven by €150m in funding[91] and the Turing Institute has almost £40m of restricted and unrestricted funding available on a yearly basis.[92]

1.8 Rationale for sectoral focus

In setting up the AICC, the Turing Institute report outlined that a sectoral focus should be explored, as a potential route in order to maximise the impact of a small team, and to differentiate the AICC from similar institutions in other parts of the UK. In addition, it was suggested that a sectoral focus could attract funding from e.g. the government and UKRI/EPSRC, which will help secure the long-term sustainability of the AICC.

However, our research highlights that similar initiatives are often sector-agnostic, instead focusing on AI and tech capabilities more broadly which can be applied across a range of sectors. Insight, Science Foundation Ireland's Research Centre for Data Analytics, delivers its work under four focus areas: health and human performance, smart communications and Internet of Things, Enterprises and services,

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[89] Conversation with Michael McClelland, 19 August 2020

[90] The Data Lab, 2018, The Data Lab secures £13.5m Scottish Government Funding. Retrieved from: https://www.thedatalab.com/news/the-data-lab-secures-13-5m-scottish-government-funding/

[91] Science Foundation Ireland, year unknown, Insight: SFI Research Centre for Data Analytics. Retrieved from: https://www.sfi.ie/sfi-research-centres/insight/

[92] The Alan Turing Institute, 2020, Annual report 2018-2019. Retrieved from: https://www.turing.ac.uk/sites/default/files/2019-08/turing_annualreport_20190801_0.pdf

and sustainability and operations. Under this, it is able to work with a large range of companies, ranging from biomedical to transport and from agriculture to retail.[93]

The Data Lab is Scotland's innovation centre for data and AI and runs several funding and support projects for business as well as public sector and academics, alongside work in building skills and in running events. Funding is open for any sector or industry. Funding and support is agnostic of sector and companies from any size and industry are encouraged to apply.[94]

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[93] Insight, 2020, About. Retrieved from: https://www.insight-centre.org/about-us/ and interview with Pat Dempsey.

[94] The Data Lab, 2020, Support to innovate. Retrieved from: https://www.thedatalab.com/support-to-innovate/

methodology

2 Methodology

The in-depth analysis of the relative sector attractiveness for the AI Competence Centre was guided by an analysis framework. For the traditional sectors that align to the SIC structure, this was complemented by an economic modelling exercise.

2.1 The analysis framework

The analysis framework assesses each sector / cross-cutting perspective against three research categories: the state of the research base, the economic state and the opportunity for AI. Within each category, the analysis was guided by specific questions and indicators, summarised in Table 2 below.

Data collection for each indicator was based on a distinct approach that included quantitative and qualitative desk research and a stakeholder engagement programme. As part of the stakeholder engagement, we conducted 18 semi-structured 1:1 interviews with stakeholders from different backgrounds and areas of expertise, including from academia, industry, government and other similar AICCs. The full list of interviewees can be found in Annex I of this report. The framework below sets out the data source(s) for each question.

Based on the research findings, each sector / cross-cutting perspective received a red / amber / green rating per sub-question and based thereon, a similar rating per overarching research category.

Given that the cross-cutting perspectives do not align with specific SIC categories, the assessment of these perspectives across the second research category ("Economic state of the sector") was more explorative in nature with stronger emphasis placed on a qualitative assessment of the areas' share and potential impact on economic growth.

Table 1: Analysis framework

Category	Overall assessment	Questions / subcategories	Selected indicators	Data collection / methodology include	Assessment
State of NI research base for sector	Red / amber / green	Q1.1: What is the volume of sector-specific research available in NI?	Qualitative insights	Turing Institute background data	Red / amber / green
		Q1.2: What is the applicability of the sector-specific research?	Qualitative insights	Interviews, desk research, interviews	Red / amber / green
		Q1.3: Is there specific research capability/community in that area?	Quality and quantity of research groups	Turing Institute report, interviews, desk research, interviews	Red / amber / green
Economic state of sector in NI	Red / amber / green	Q2.1: What is the share of the sector in the NI economy by GVA?	GVA	NISRA and ONS data	Red / amber / green
		Q2.2: What is the share of the sector in the NI economy by employment levels?	Employment levels	NISRA and ONS data	Red / amber / green
		Q2.3: What is the forecasted long-term economic growth path of the sector?	Forecasts	OBR forecasts, historical NISRA/ONS trend data, desk research, economic modelling	Red / amber / green
Opportunity for AI for sector	Red / amber / green	Q3.1: What is the current and expected role of AI in the sector globally?	Qualitative insights, forecasts on AI penetration and transformative potential	Interviews, desk research, input subject matter expert	Red / amber / green
		Q3.2: What initiatives in NI are complementary to the sector?	City Deals, Industry strategy, AI Sector Deal, partnership opportunities, etc.	Interviews, desk research	Red / amber / green
		Q3.3: What is the opportunity for distinct impact NI can have on a global level?	Other AICCs, NI distinctiveness for situation (e.g. border), existing excellence, potential of AICC to fulfil sector's potential	Interviews, desk research	Red / amber / green
		Q3.4: What is the sector's ability to attract venture capital / investment?	Alignment to major public and private funders' strategies and City Deals	Interviews, desk research	Red / amber / green
		Q3.5: What is the industry-readiness for AI?	Number of companies in sector already working on AI, type of jobs in sector, company awareness/willingness to adopt AI	Interviews, reports, desk research	Red / amber / green

> *Key methodological considerations:*
>
> The red / amber / green rating resulting from the framework is a *relative* rating of sectors in Northern Ireland, rather than an *absolute* rating on how well placed the sector is in itself or in the international context.
>
> The 'state of the research base' categories mainly assess the capabilities of leading universities, such as UU and QUB, rather than research conducted by companies or other initiatives more broadly. These wider initiatives are a stronger focus of the "complementary initiatives" section.
>
> The sector assessment draws on current knowledge as well as any indication for future development to the furthest extent possible. However, it does not claim to have identified all initiatives that are still in development for the sector, nor to capture the impact of unexpected disruptions or future shocks.
>
> The sector assessment provides insights into current strengths and challenges of AI-specific developments per sector, but it is not prescriptive of policies that can enhance sector performance.

2.2 Sector economic forecast

2.2.1 Purpose

An economic model was developed to estimate the impact of AI in NI on GVA and employment in each traditional sector (those that map to the SIC categories), based on a series of scenario-based assumptions that can be adjusted and sensitivity-tested in the Excel model that accompanies this report. The model's output shows the absolute and relative impact on GVA and employment meaningfully affected by AI per sector. It reflects current sector share, economic trends, forecasted impact of AI globally in developed countries and adjustments for the likely impact of AI specifically within NI.

2.2.2 Approach to modelling

Central estimates of AI growth are already implicit in the productivity growth assumptions that drive macroeconomic forecasting. In this model, we draw on the pre-COVID macroeconomic forecasts from the UK Office for Budget Responsibility (OBR), as an authoritative source for macroeconomic forecasting. The OBR's macroeconomic forecasts do not analyse individual sectors, nor do they explicitly identify the contribution of AI to its growth. The purpose of the modelling exercise was to draw out likely sectoral evolution over time and the role of AI. The model

projects the GVA in each sector that can be accounted for by developments in AI from the baseline data (2018) to the estimated 2030 value.

The model sets out a number of **long-term economic assumptions** including the annual GVA and employment growth, adjustments for COVID-19, the bandwidth for the low and high scenarios and subsequent GDP and employment growth for the periods 2018-2025 and 2018-2030.

The model then incorporates the 2018 **baseline data** for GVA and employment as the sector's share of the total, using statistical data from Northern Ireland, and extrapolates from recent trends to identify the likely sectoral evolution of GVA share and employment share through to 2030. Combining the long-term economic assumptions with the projected evolution in sectoral share results in a projected scale for each sector in 2025 and 2030, in terms of GVA (constant 2016 pounds) and employment (number of part-time and full-time employees).

The **AI impact for each sector** is then calculated on a marginal basis: it is the incremental additional impact of AI from today's baseline through to the forecast horizon (the contribution AI has already made to 2018 GVA is not addressed). The marginal AI impact is calculated in two steps. A benchmark for impact in developed countries is synthesised from a number of global reports outlining economic estimates on AI's GDP boost[95] as well as the share of jobs that will be affected by AI[96] in Western Europe and North America. These global benchmarks are then adjusted to reflect the potential of AI for NI. Based on the assessment of Q3.2-3.5 from the analysis framework as set out in Table 2, sectors are adjusted up- or downwards by a maximum 20% (+2.5% for each green rating, 0% for each amber rating, -2.5% for each red rating). As interviewees have argued that Northern Ireland has slightly less AI uptake compared to other developed regions and countries on average (such as Germany, the USA and the rest of the UK) as indicated in the global reports, estimated AI sector impacts are adjusted downward by 10%.

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[95] Primarily McKinsey Global Institute, 2018, Notes from the AI Frontier: Modelling the impact of AI on the world economy. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Notes%20from%20the%20frontier%20Modeling%20the%20impact%20of%20AI%20on%20the%20world%20economy/MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx and PricewaterhouseCoopers, 2018, The macroeconomic impact of artificial The macroeconomic impact of artificial intelligence. Retrieved from: https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf

[96] Primarily McKinsey Global Institute, 2017, A future that works: automation, employment and productivity. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works_Full-report.pdf and PricewaterhouseCoopers, 2018, The macroeconomic impact of artificial intelligence.

The outcomes of the model should be treated as indicative and provide a sense of relative and overall scale, rather than precise estimates given the level of uncertainty involved. The findings of the model are shared in a separate file and are further elaborated upon in Chapter 4 of this report. Stakeholders are invited to use the model as a decision-making tool to support scenario assessment, adjusting parameters and assumptions to explore the impacts on sectors.

findings

3 Findings

The heatmap in Table 3 gives an overview of the ratings per sector for the research base, economic state of the sector in NI and opportunity for AI. The section below provides the rationale for this rating and an in-depth assessment for each of these categories, and the respective sub-categories per sector.

Table 2: Summary ranking of sectors by evaluation category

Sectors	Research base	Economic state of sector in NI	Opportunity for AI
Advanced manufacturing, materials and engineering	Amber	Green	Green
Agriculture and food production	Red	Amber	Green
Biomedical R&D and pharmaceutical manufacturing	Green	Amber	Green
Construction	Red	Green	Red
Creative industries incl. gaming	Red	Amber	Amber
Employment and business support activities	Red	Amber	Red
Energy	Red	Red	Red
Finance incl FinTech	Green	Amber	Green
Human health and social work	Amber	Green	Green
ICT and Telco	Amber	Green	Green
Professional and research services excl. biomedical	Red	Green	Red

Sectors	Research base	Economic state of sector in NI	Opportunity for AI
Public administration, education and defence	🔴	🟡	🟡
Trade (wholesale and retail)	🔴	🟢	🟡
Transportation and storage	🔴	🟡	🟡
Augmented / virtual reality (AR/VR)	🟡	🟡	🟡
Cryptography and cybersecurity	🟢	🟡	🟢
Internet of Things / sensors	🟡	🟡	🟡

3.1 Traditional sectors

A list of key sub-sectors for the foresight exercise was compiled in the first phase of the research through a high-level review of all industries in NI's economy. The "traditional" sectors align to the UK's SIC 2007 sector structure. The following section provides the findings of the in-depth assessment of these sectors.

3.1.1 Advanced manufacturing, materials and engineering

AMME constitutes a significant sector of NI's economy with some research and industry activities already taking place in the area of AI. In light thereof, several interviewees identify the sector as having some potential as a sectoral focus for the AICC. Nevertheless, for AI to live up to its transformative potential, significant capital investment and commitment by sector leaders is required. While the AMME sector globally is set to experience significant growth, for the sector in NI to make the most of the opportunities provided by AI, it will have to focus on those sub-sectors where it has highly specialised and exportable expertise, as in the area of machinery and transport equipment.

Overall assessment:

- State of the research base

- Economic state of the sector in NI

- Opportunity for AI

The advanced manufacturing, materials and engineering sector has a long tradition in Northern Ireland with particular expertise in areas such as plastics and polymers, composites design and manufacturing, precision manufacturing, design and stress modelling, and aircraft seating and interiors.[97]

State of the research base

- **Volume:** Engineering is assessed as "low" on the scale of AI publication activity (UU: N/A, QUB: low) and robotics, which can have applications in the AMME sector is assessed as high (UU: medium, QUB: medium).[98] Several research groups in UU and

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[97]visitBelfast, 2020, Advanced Manufacturing. Retrieved from: https://meetbelfast.com/belfast-ambassadors/city-of-talent/advanced-manufacturing/?doing_wp_cron=1603104199.4997420310974121093750

[98] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

QUB as well as the Belfast Region City Deal (see below) could help increase the volume of AI engineering research.

◉ **Applicability**: While the quantity of outputs is low, the quality of AI engineering research outputs is assessed as medium (UU: N/A, QUB: medium), and of robotics as high (UU: high, QUB: high).[99] Several initiatives by the universities have connections to industry, for example via the City Deals, which makes the research more applicable than the other sectors.

◉ **Capability and community**

There is some AI research activity in both universities:

- The Advanced Manufacturing Innovation Centre (AMIC) is part of the Belfast Region City Deal and will focus on developing the "Factory of the Future", drawing on the expertise of both UU and QUB (for more information, see "Complementary initiatives").[100]

- QUB's Centre for Intelligent Autonomous Manufacturing Systems (i-AMS) is an interdisciplinary team with researchers from engineering, computer science, mathematics, statistics and psychology working on innovative technologies and solutions to "address the challenges of Industry 4.0", to help shape the manufacturing plant of tomorrow's world. It works across a spectrum of topics including robotics and autonomous systems, VR and AR, and AI and machine learning. It works in partnership with the Northern Ireland Technology Centre which has been included in the Belfast Region City Deal.[101]

- UU's Cognitive Analytics Research Lab (CARL) brings in industry and government to work on intelligent data analytics. Advanced Manufacturing is one of the key sectors, although there has not been a significant cluster of research in this, as of yet.[102]

Economic state of the sector in NI

◉◉ **GVA & employment:** AMME is the fourth largest sector of NI's economy by GVA and employment. Its share of the NI economy amounts to 7.3% by GVA and 5.9% by employment. Manufacturing has a long tradition in Northern Ireland with a strong

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[99] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[100] Belfast region city deal: innovation and digital, 2020, Advanced Manufacturing Innovation Centre. Retrieved from: https://www.brcd-innovation.co.uk/projects/amic

[101] Queen's University Belfast, 2020, i-AMS Vision. Retrieved from: https://www.qub.ac.uk/sites/iams/Vision/

[102] Ulster University, 2020, Cognitive Analytics Research Lab: Research. Retrieved from: https://www.ulster.ac.uk/cognitive-analytics-research/research

cohort of AMME companies. Highly developed AMME sectoral clusters can be found in areas such as aerospace, polymers and materials handling.[103] Brexit poses a significant challenge for the sector given that manufacturing goods account for c. 70% of goods sold to the EU.[104]

- **Long-term growth path**: Based on this study's growth forecast, the sector's GVA can be expected to grow by c. 15% from 2018 to 2030. Its relative share in NI's economy by GVA is set to increase slightly to 7.6%, while its share by employment is forecasted to remain the same.[105]

Opportunity for AI

- **Global role for AI**: AI is already reshaping the AMME sector across areas such as robotics, 3D printing and sustainable manufacturing. The current value of AI in the global sector amounts to around US$1.1bn. Compared to other sectors subject to analysis, this is mid-range. However, in comparison to other sectors analysed, AI in this sector has one of the highest growth rates, with the value of AI projected to grow by 57.2% CAGR over the next years.[106]

- **Complementary initiatives**: AMME is part of both City Deals, reflecting its important role in NI's economy. The Belfast Region City Deals aims to strengthen the sector through investment in an Advanced Manufacturing Innovation Centre (AMIC). AMIC focuses on disruptive technologies across areas such as aerospace, maritime, materials handling, construction, agri-food & engineering sectors through a Factory of the Future and the NI Technology Centre. The indicative treasury contribution to the Centre is £65m, with additional funding from university- and partner sources, with a total budget of up to £96m. The Centre aims to create 4,000 AMME jobs by 2030 and contribute £8.7m of GVA. The Belfast Region City Deal will further create a Global Innovation Institute, a cross-sectoral digital innovation hub that will also support innovation in Advanced Manufacturing.[107] The Derry / Londonderry City Deal aims to support the sector among others through investment in the Centre for

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[103] visitBelfast, 2020, Advanced Manufacturing. Retrieved from: https://meetbelfast.com/belfast-ambassadors/city-of-talent/advanced-manufacturing/?doing_wp_cron=1603104199.4997420310974121093750

[104] TradeNI, 2019, Vision 2030. Retrieved from: http://www.manufacturingni.org/media/uploads/2205%20-%20Trade%20NI%20Vision%202030%20document%20web%20version.pdf

[105] Economic forecast of this study

[106] Markets and markets: Artificial Intelligence in Manufacturing Market. Retrieved from https://www.marketsandmarkets.com/Market-Reports/artificial-intelligence-manufacturing-market-72679105.html

[107] EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from: http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

Industry Digitalisation, Robotics and Automation (CIDRA), the Virtual and Augmented Reality Centre at North West Regional College (NWRC), and the Innovation Station, a partnership between NWRC and Ulster University. [108]

● **Opportunity for distinct impact:** The AMME sector in NI has a long tradition. It is one of NI's key export sectors, with machinery and transport equipment being its biggest export to the EU and the rest of the world.[109] It outperforms the NI industry average in terms of innovation activity. Individual companies classified within AMME as 'Highly Specialised Individuals' together account for over 30% of top AMME performers.[110] This provides some opportunity to build a foundation for distinct impact if these companies embrace AI technologies. Interviewees highlight the region's heritage in shipbuilding and aerospace, with firms like Spirit AeroSystems (previously Bombardier) holding knowledge and supply chains. Interviewees point to the strengths of pharmaceutical manufacturing in the Republic of Ireland, with 9 out of 10 of top pharma manufacturers having plants there[111] and with the sector being served by the I-Form Advanced Manufacturing Research Centre. NI could strengthen its collaboration with these manufacturers. They further pointed to interest from local manufacturers in computer vision from production lines.[112]

● **Investment opportunities:** Adopting AI in this sector will require high levels of capital investment from the beginning as AI in AMME is often closely integrated with high value machine tools and similar equipment. Generally, in NI, R&D investment by manufacturing companies is higher than the average R&D investment across all sectors.[113] There is some investment coming into the sector in NI through the Belfast Region City Deal (e.g. £96m for the AMIC) and the Derry / Londonderry City Deal (including through the Centre for Industry Digitalisation, Robotics and Automation (CIDRA) and the Virtual and Augmented Reality Centre (VARC)).

● **Industry readiness:** There are some large companies already active in the space such as Spirit AeroSystems. Beyond these, the number of early stage startups in the

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[108]Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

[109] Diane Dodds, 2020, Advanced manufacturers powering ahead in Northern Ireland. Retrieved from: https://www.belfasttelegraph.co.uk/opinion/comment/advanced-manufacturers-powering-ahead-in-northern-ireland-39383205.html

[110] Matrix, 2016, Advanced manufacturing, materials & engineering. Retrieved from: https://matrixni.org/wp-content/uploads/2016/11/AMME-Report.pdf

[111] Stakeholder interview

[112] Stakeholder interview

[113] Matrix, 2016, Advanced manufacturing, materials & engineering. Retrieved from: https://matrixni.org/wp-content/uploads/2016/11/AMME-Report.pdf

sector is more limited. In NI, an example of a manufacturing company using AI is IPEC, an engineering firm that provides control systems solutions with built-in AI algorithms[114].

A key challenge for the future application of AI is the ability and willingness of current sector leaders to embrace AI solutions and acknowledge their potential to transform the sectors. Additionally, some interviewees doubt whether the sector can effectively transition from traditional to advanced manufacturing.[115]

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[114] LoveBelfast, 2020, Lisburn based control systems developer utilises AI technology in assisting businesses restore operations. Retrieved from: https://lovebelfast.co.uk/ai-technology-the-unicorn-group/

[115] Stakeholder interview

3.1.2 Agriculture and food production

> Agriculture and food production is a key sector in NI's economy but its contribution to GVA is expected to experience a significant decline over the next ten years. Given that the majority of farms in NI are small, it would be challenging to have a distinct impact on a global scale through the adoption of AI in the sector. To increase the impact of AI - which would also offer an opportunity to counter the decline in sector growth - it would be crucial to strengthen collaboration with countries with similar livestock, crops and conditions.
>
> **Overall assessment:**
>
> ● State of the research base
>
> ● Economic state of the sector in NI
>
> ● Opportunity for AI

Agriculture is one of Northern Ireland's largest sectors, but technological innovation is still limited.

State of the research base

● **Volume:** Agriculture was not explicitly mentioned in the Turing Institute report as a category. There is no evidence of a significant body of AI research specifically focused on agriculture. However, this does not mean that research underway might not have any applicability in the agricultural sector.

● **Applicability:** See above.

● **Capability and community:** Currently, there is limited evidence for specific capabilities for AI academic research in agriculture in NI. Nevertheless, several institutes could touch upon Agri-Tech and AI themes in the future, such as the Institute for Global Food Security[116] at Queen's University Belfast and the Agri-Food and Bioscience Institute (AFBI)[117]. However, the emphasis on AI in the new Innovation Strategy of the NI's Department of Agriculture, Environment and Rural

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[116] The Institute For Global Food Security, 2020. Retrieved from: https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/

[117] The Agri-Food & Biosciences Institute, 2020. Retrieved from: https://www.afbini.gov.uk/

Affairs[118] as well as the new cross-border AgTech Fund (see "Opportunity for AI") could improve AI research capabilities.[119]

Economic state of the sector in NI

◉◉ **GVA & employment:** Agriculture and food production is the sixth largest sector in NI's economy by GVA and employment. It currently accounts for 5.6% of GVA and 4.5% of employment. Gross output of NI agriculture in 2019 consisted primarily of milk (31%), cattle (20%) and poultry (14%) - indicating that the majority of sector activity by GVA is in livestock as opposed to crops.[120] The poultry meat producer *Moy Park* is NI's largest private sector business and one of the UK's largest food companies.[121]

◉ **Long-term growth path**: The GVA of the sector is expected to shrink by 20% in absolute terms over the next ten years. Assuming a continuation of the current trajectory, our forecast suggests the sector's share in NI's economy will decline to 4% by GVA, while the share by employment remains stable at 4.6%.[122]

Opportunity for AI

◉ **Global role for AI**: On a global scale, AI offers significant transformative potential for the agricultural and food production sector. Key opportunities for AI centre around predictive analytics, crop and soil monitoring, robots for agricultural tasks and food sorting, real time data analysis, and precision agriculture which has the potential to improve yield quality and accuracy. Interviewees point to an opportunity for AI to drive sustainability and "greener" agriculture. There are also significant opportunities for AI in livestock farming. This area is of higher relevance for NI given its heavy reliance on milk, cattle and poultry. The potential for AI in this context centers around animal tech, such as livestock video monitoring.

However, in both areas, AI hardware typically require investments which may be beyond smallholder farmers' resources or skills. Moreover, these technologies are most impactful when used on a large scale with single crop farms or large animal populations, and not on smaller farms.

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[118] Department of Agriculture, Environment and Rural Affairs, 2020, DAERA Innovation Strategy 2020-2025. Retrieved from: https://www.daera-ni.gov.uk/sites/default/files/consultations/daera/DAERA%20Innovation%20Strategy%202020-2025%20Final%2017-2-20.pdf

[119] Matrix, 2020, New all island agritech body underway. Retrieved from: https://matrixni.org/new-all-island-agritech-body-underway/

[120] Northern Ireland Statistics and Research Agency, 2019, Statistical Review of Northern Ireland Agriculture. Retrieved from: https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Stats%20Review%202019%20final.pdf

[121] Moy Park, 2002, About. Retrieved from: https://moypark.com/about

[122] Economic forecast of this study

- **Complementary initiatives**: In NI, AI in the agricultural and food production sector can benefit from some local synergies. As part of the Belfast City Region Deal, the sector will benefit from several cross-disciplinary digital innovation hubs, including the Global Innovation Institute, with total funding of £52.4m and the AMIC. Both of these recognise agri-food as one area that will benefit from innovation support.[123] Some additional support for the development of AI in the sector might come via the Department for Agriculture, Environment and Rural Affairs (DAERA)'s new Draft Innovation Strategy for 2020-2025 which aims to make NI the most successful region in the UK at exploiting opportunities in the utilisation of Big Data and AI in this area.[124] A final strategy with details on specific investment areas has not yet been published, thus the extent to which it will support the development of AI remains to be seen. NI might also benefit from cross-border synergies with the Republic of Ireland through the recently-launched Ireland AgTech Fund with €40m in funding to invest in innovative early-stage AgTech companies.[125]

- **Opportunity for distinct impact:** Some interviewees[126] see some opportunity for distinct impact in the area of precision agriculture, if NI was to succeed in increasing farm yields through machine learning, build an SME ecosystem and attract larger agritech firms. However, given that 77% of farms in NI are classified as "very small" and livestock accounts for over 80% of output, this will make it challenging for AI to have impact at scale. Several interviewees see some opportunity in claiming remaining "white space" in AI in areas such as sustainability and smart agriculture. They argue that there might be value in investing in these areas as a first-mover.

- **Investment opportunities:** The sector will benefit from some funding via the Belfast Region City Deals' Global Innovation Institute, the AMIC, and a, yet to be determined, amount of investment from the DAERA Innovation Strategy. At this stage, it is too early to say how extensive (and impactful) this funding opportunity will be. Venture Capital investment in the UK from 2014-19, shows growth of foodtech as an investment area. However, current VC funding is still lower than in areas such as healthtech, deep tech, enterprise software and fintech.[127]

[123] EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from: http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

[124] Department of Agriculture, Environment and Rural Affairs, 2020, DAERA Innovation Strategy 2020-2025. Retrieved from: https://www.daera-ni.gov.uk/sites/default/files/consultations/daera/DAERA%20Innovation%20Strategy%202020-2025%20Final%2017-2-20.pdf

[125] ThinkBusiness, 2020, €40m fund for Agtech startups. Retrieved from: https://www.thinkbusiness.ie/articles/finistere-ventures-agtech-vc-fund-kieran-furlong/

[126] Stakeholder interviews

[127] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020

• **Industry readiness:** For NI, the adoption of AI technologies in the sector remains challenging given the small farm sizes. There are however several companies active in the field in NI, such as: *Arc-Net*, a company specialised in food traceability using blockchain technology. Arc-Net was initially based in NI but its headquarters is now in Edinburgh[128]. Another company, *CattleEye*, offers an autonomous livestock monitoring platform and is one of two NI-based companies that have been selected to join Tech Nation's Applied AI 2.0 Growth programme.[129]

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[128] Arc-Net, 2020, About. Retrieved from: https://arc-net.io/about

[129] CattleEye, 2020, CattleEye selected for prestigious UK AI program. Retrieved from: http://www.cattleeye.com/news/cattleeye-selected-for-prestigious-uk-ai-program/

3.1.3 Biomedical R&D and pharmaceutical manufacturing

In comparison to most of the other sectors subject to this study, the assessment across all categories highlights the relevance and potential of the adoption of AI in the life sciences - a finding supported by many interviewees'. There is some opportunity for distinct impact if NI succeeds to tie AI into existing local strengths, such as in the area of diagnostics, with industry leader Randox. Nevertheless, it remains a small sector of NI's economy and while the strong focus of the UK more broadly on AI in the sector can be an asset, it also means more competition in the field.

Overall assessment:

- State of the research base
- Economic state of the sector in NI
- Opportunity for AI

NI has a small but active and collaborative biomedical R&D and pharmaceutical manufacturing sector with a cluster of over 250 businesses focusing on life and health science more broadly.[130]

State of the research base

- **Volume:** The scale of AI publication activity for medicine is assessed as high (UU: high, QUB: medium). Specific areas of strengths are human brain to computational device communication (which could for example be applied in assistive technology[131]) and diagnostics.[132]

- **Applicability:** The quality of publications in the medical cluster is rated as high (UU: high, QUB: medium)[133]. In addition, several research groups listed below work

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[130] Invest Northern Ireland: Life and Health Sciences. Retrieved from:
https://www.investni.com/invest-in-northern-ireland/life-and-health-sciences

[131] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[132] Stakeholder interviews

[133] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

together with public and private partners, improving the applicability of the research.

⊙ Capability and community

NI's capability in AI research on biomedical R&D is highlighted by several interviewees and shows particular strengths in cardiology and oncology, precision medicine, diagnostics and clinical trials. A range of research groups work on a variety of topics:

- UU's Intelligent Systems Research Centre (ISRC), part of CARL, focuses on cognitive neuroscience and neurotechnology by using intelligent signal and image processing to understand, restore, maintain and enhance brain dynamics and cognitive function. The commercial focus of the Centre has led to several spin-outs.[134]

- The Nanotechnology and Integrated BioEngineering Centre (NIBEC) at UU consolidates groups working on nanotechnology and bioengineering. Its Healthcare sensors systems-group uses AI and ML concepts to develop diagnostic algorithms and has paved the way for a few spin-outs[135]. The Centre for Advanced Cardiovascular Research conducts research into the field of cardiac care with an emphasis on medical instrumentation through clinical trials.[136] The Centre of Stratified Medicine is also involved in research on the intersection of cardiology and AI[137].

- The Precision Medicine Centre of Excellence at QUB is part of several initiatives to use AI to improve health outcomes. The PathLAKE consortium brings together universities across the UK as part of the Industrial Strategy Challenge Fund to work on AI and digital pathology innovation. It develops, evaluates and validates algorithms to increase the efficiency of pathology and improve molecule

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[134] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf and Ulster University, 2020, About Intelligent Systems Research Centre. Retrieved from: https://www.ulster.ac.uk/research/topic/computer-science/intelligent-systems-research-centre/about

[135] Ulster University, 2020, About NIBEC. Retrieved from: https://www.ulster.ac.uk/nibec/about

[136] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[137] R. Bond & A. Peace, 2020, Near future artificial intelligence in interventional cardiology: new opportunities and challenges to improve the care of STEMI patients. Retrieved from: https://www.escardio.org/Education/Digital-Health-and-Cardiology/Virtual-Journal/near-future-artificial-intelligence-in-interventional-cardiology-new-opportunit

diagnostics.[138] The recently instituted ACTIONED consortium works together with Roche and Sonrai Analytics on future treatments of colorectal cancer.[139]

- iREACH is part of the Belfast Region City Deal and is focused on improving healthcare in Northern Ireland. It is envisioned to apply AI, although the extent of this is not yet clear.[140]

- The Health Data Research UK Wales-Northern Ireland Substantive Site is part of the national HDR-UK institute. The QUB site is a collaboration between Swansea University and QUB using data science to develop cutting-edge approaches to address health research challenges with some focus on cancer research. It brings together researchers from across the University and has close engagement with the Institute of Electronics, Communication and Information Technology at QUB. It works on several projects leveraging AI and machine learning.[141]

- There are several spin-outs from universities demonstrating the applicability of the research[142], that then benefits the health and social care sector more broadly, including Intelesens (defibrillator and ECG manufacturer)[143], Heartsine Technologies (automated external defibrillators)[144], BrainWaveBank (EEG

[138] Queen's University Belfast, 2020, Precision Medicine Centre: PathLAKE Programme. Retrieved from: https://www.qub.ac.uk/research-centres/PMC/PathLAKEProgramme/

[139] Queen's University Belfast, 2020, Queen's part of £7 million consortium to improve outcomes for patients with early stage cancer. Retrieved via: https://www.qub.ac.uk/research-centres/PMC/News/Queenspartof7millionconsortiumtoimproveoutcomesforpatientswithearlystagecancer.html

[140] Belfast region city deal: innovation and digital, 2020, iREACH. Retrieved from: https://www.brcd-innovation.co.uk/projects/ireach

[141] Queen's University Belfast, 2020, Health data research UK. Retrieved from: https://www.qub.ac.uk/research-centres/cancer-research/OurScience/Areasoffocus/MajorResearchProgrammes/HealthDataResearchUK/

[142] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[143] Intelesens, 2020, Intelesens. Retrieved from: https://intelesens.com/

[144] HeartSine, 2020, HeartSine. Retrieved from: https://uk.heartsine.com/

recording headset)[145], PathXL (digital pathology)[146] and PulseAI (AI for cardiovascular care)[147].

Economic state of the sector in NI

◉ ◉ **GVA & employment:** The biomedical R&D and pharmaceutical manufacturing sector makes up a small share of NI's economy - accounting for only 1.1% of GVA and 0.6% of employment. The sector is nevertheless active and collaborative with a cluster of over 250 businesses that focus on life and health science.[148] With Almac Diagnostic Services and Randox, NI has two of the largest diagnostic companies in the UK. The sector is highly export-focused: in 2012, it accounted for over 10% of Northern Ireland's exports.[149]

◉ **Long-term growth path**: Looking towards 2030, the sector is set to experience significant growth in terms of GVA in comparison to other sectors subject to analysis: GVA is anticipated to grow by c. 40%. Its share in the economy remains small, growing to 1.4% by GVA and to 0.7% by employment.[150]

Opportunity for AI

◉ **Global role for AI**: AI offers significant potential in the area of biomedical research and drug discovery as it provides the opportunity to move processes that have traditionally been physical to computer simulated. The use of AI tools offers the opportunity to shortcut knowledge-related steps that used to require humans in the loop. Through this, time-to-market and costs for new drugs could be significantly reduced.[151] The sector plays an important role in the UK, with a main cluster being Cambridge and the wider "Golden Triangle" (e.g. BenevolentAI).

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[145] BrainWaveBank, 2020, BrainWaveBank. Retrieved from: https://www.brainwavebank.com/

[146] Philips, 2016, Philips expands its Digital Pathology Solutions portfolio with the acquisition of PathXL. Retrieved from: https://www.philips.co.uk/healthcare/sites/pathology/release-press/20160621-philips-expands-its-digital-pathology-solutions-portfolio-with-the-acquisition-of-pathxl

[147] PulseAI, 2020, PulseAI. Retrieved from: https://www.pulse-ai.co.uk/

[148] Invest Northern Ireland: Life and Health Sciences. Retrieved from: https://www.investni.com/invest-in-northern-ireland/life-and-health-sciences

[149] Matrix, 2015, Life and health sciences Northern Ireland. Retrieved from: https://www.investni.com/invest-in-northern-ireland/life-and-health-sciences

[150] Economic forecast of this study

[151] PWC, year unknown, No longer science fiction, AI and robotics are transforming healthcare. Retrieved from: https://www.pwc.com/gx/en/industries/healthcare/publications/ai-robotics-new-health/transforming-healthcare.html

◉ **Complementary initiatives**: There are several initiatives in NI that aim to strengthen innovation and AI in the sector. While many of these are closely linked to health and social care, a separate sector in this study, they also focus on biomedical R&D and pharmaceutical manufacturing. The Belfast City Region Deal will support an Institute for Research Excellence in Advanced Clinical Healthcare (i-REACH), an integrated clinical research centre of excellence that will link innovative clinical trials with AI investments. Funding will amount to £51-61m and it is forecast to generate an additional £43m of GVA.[152]

The Derry / Londonderry City Deal also highlights life sciences as a focus area of innovation, together with healthcare. The Deal will support the adoption of digital solutions at the Clinical Translational Research and Innovation Centre (C-TRIC), a bio-incubation space for Life and Health Science companies.[153] Another complementary initiative is the Health Innovation Research Alliance Northern Ireland (HIRANI), established to strengthen the life- and health- science ecosystem.[154]

The Nanotechnology and Integrated Bioengineering Centre (NIBEC) at Ulster University is one of the most advanced and innovative nanotechnology / bioengineering Centers in Europe today.[155] Catalyst has also established a sectoral focus on data-driven health in its Belfast Digital Innovation partnership.[156]

◉ **Opportunity for distinct impact:** AI in the sector in NI is set to grow in light of the multitude of initiatives in the field and the UK's emphasis on innovation in life sciences as part of its Industrial Strategy for Life Sciences. There is some opportunity to build on local strengths: NI-based companies Almac and Randox are already significant players on a global scale. Almac Diagnostic Services specialises in fields such as R&D, biomarker discovery and development and API manufacture, and had a global turnover of £634m in 2018-19.[157] Randox produces more clinical

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[152] EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from: http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

[153] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

[154] HIRANI, 2020, About HIRANI. Retrieved from: https://www.hira-ni.com/about

[155] Ulster University, 2020, About NIBEC. Retrieved from: https://www.ulster.ac.uk/nibec/about

[156] Steve Orr, 2020, Clusters - what and how.

[157] Almac Group, 2020, 2018-19 Figures how Almac Group's Turnover Increased by £85M to £634M. Retrieved from: https://www.almacgroup.com/news/2018-19-figures-show-almac-groups-turnover-increased-by-85m-to-634m/

diagnostic products than any other company in the world and invests c.25% of its profits into R&D. In 2019, it had a turnover of £85.4m.[158]

This provides opportunities for new AI solutions to tie into existing structures - if these companies would successfully employ AI across their activities. An additional opportunity lies within collaboration with the Republic of Ireland, where 9 of 10 globally leading pharma manufacturing companies are based.[159]

◉ **Investment opportunities:** The UK Industrial Strategy for Life Sciences underlines the potential for AI in the sector and highlights the commitment to make the UK a global leader in clinical research and life sciences. The Strategy commits increased UK spending on R&D to 2.4% of GDP by 2027, with £4bn already invested in R&D since 2017.[160] The sector in NI will to some extent benefit from investment via the Belfast and Derry / Londonderry City Deal (e.g. through c.£51-61m for the Institute for Research Excellence in Advanced Clinical Healthcare).[161]

◉ **Industry readiness:** There are several companies active in the adoption of AI in the sector in NI. In addition to Almac Diagnostic Services and Randox, these also include companies such as Auromind, and Exploristics. The sector also benefits from a number of university spinouts, as outlined above. Looking at the size of the sector by GVA in NI, the AI-adopters in the sector remain a small sub-category of active companies in total. This is also reflected by comparing the number of life science companies across different regions of the UK: NI has the fewest companies of all 12 regions.[162]

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[158] Randox. Retrieved from: https://www.randox.com

[159] Stakeholder interview

[160] UK Government, 2017, Life Sciences Industrial Strategy. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/857348/Life_sciences_industrial_strategy_update.pdf

[161] EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from: http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

[162] UK Government, 2017, Life Sciences Industrial Strategy. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/857348/Life_sciences_industrial_strategy_update.pdf

3.1.4 Construction

> While the potential for AI to transform the sector and increase efficiency is high, the large-scale application of AI-solutions in construction is still in its early stages, globally and in NI. Given the low levels of specific funding, initiatives and AI companies in the sector in NI, a sectoral focus in this area is unlikely to have a significant impact.
>
> **Overall assessment:**
>
> ◉ State of the research base
>
> ◉ Economic state of the sector in NI
>
> ◉ Opportunity for AI

Northern Ireland has an established, primarily locally-focused construction sector. On a global level, the sector relevance for this study stems from the fact that AI has strong applicability in construction.

State of the research base

◉ **Volume:** Construction was not explicitly mentioned in the Turing Institute report as a category. There is no evidence of a significant body of AI research specifically focused on construction, although some engineering research might be applicable to this sector. It does not exclude that current research being done is applicable in the construction sector.

◉ **Applicability:** See above.

◉ **Capability and community:** There are no research groups out of UU or QUB specifically focused on AI research for the construction sector.

Economic state of the sector in NI

◉◉ **GVA & employment:** Northern Ireland has a sizable and established construction sector. It is currently the 5th largest sector by GVA and employment, accounting for 6.9% of NI's economy by GVA and 4.5% by employment. NI's Draft Industrial Strategy identifies construction and material handling as one of six broad sectors of the economy where NI has world class capabilities.[163]

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[163] Department for the Economy, 2017, Economy 2030: a consultation on an Industrial Strategy for Northern Ireland. Retrieved from: https://www.economy-ni.gov.uk/sites/default/files/consultations/economy/industrial-strategy-ni-consultation-document.pdf

- **Long-term growth path**: The share of the sector's contribution to NI's GVA and employment is forecast to shrink over the next ten years. GVA in absolute terms is estimated to shrink by c.10% with its share in NI's economy expected to drop to 5.6% by 2030 and share by employment to 4%.[164]

Opportunity for AI

- **Global role for AI**: The current application of AI in the sector is relatively low. In 2017, the value of AI within the sector globally amounted to US$ c. 330 million and is expected to grow by 35% CAGR over the next years, which is at the higher end in comparison to other sectors.[165] This highlights the strong potential for AI to shape the sector in the future. The sector has a strong AI applicability, given its traditionally thin margins and possibility to increase efficiency via AI (e.g. through self-driving diggers, VR/AR for training), its application may provide a significant advantage.

The ability of AI to reduce production costs and the need for more safety measures at construction sites are expected to drive the growth of AI in the global construction market. AI can be used as an enhancement of 3D Building Information Modelling (BIM), e.g. to optimise buildings' energy efficiency from design stage.

- **Complementary initiatives**: Currently, NI-based initiatives in the sector focused on digital transformation and specifically AI, are scarce. Through the Belfast Region City Deal, the sector will benefit from the cross-disciplinary AMIC (total funding of the Centre: £82-96 million), which recognises construction as one sub-sector to benefit from innovation support in the advanced manufacturing sector. Construction has a separate Sector Deal by the UK Government which aims to support the sector's productivity through innovative technologies.[166]

- **Opportunity for distinct impact**: Desk research and interviews do not point towards a distinct opportunity for impact by NI on a global level in this sector, given the limited role that AI currently plays in construction in NI.

- **Investment opportunities:** Investment supporting AI developments in the sector in NI appears to be limited. Across the UK more broadly, the sector has been more successful in attracting funding: As an integral part of the UK Government's Construction Sector Deal, UKRI's *Transforming Construction Challenge* has invested

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[164] Economic forecast of this study

[165] Markets and markets, Artificial intelligence in construction market. Retrieved from: https://www.marketsandmarkets.com/Market-Reports/ai-in-construction-market-235710349.html

[166] UK Government, 2018, Industrial Strategy: Construction Sector Deal. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/731871/construction-sector-deal-print-single.pdf

£170m, matched by £250 million from industry into innovation in the sector. No funding appears to have been awarded to NI-based projects.[167]

◉ **Industry readiness:** Despite the wide range of opportunities for AI to be applied in the construction and its potential to drive efficiency gains, current application of AI in the sector in NI is low. Desk research did not point to specific companies within NI adopting AI solutions at scale. While construction companies made up the biggest share of the 32 companies that Tech Nation selected for its growth programme *Applied AI 2.0,* none of these companies were NI-based.[168] Key challenges with regards to industry readiness relate to adoption of AI solutions, in particular, limited availability of data, low use of technology and low margins across the sector. This is exemplified by the fact that Building Information Modelling (BIM), the virtual design tool took a long time to be adopted by players in the industry and is still not the norm. Furthermore, the application of AI in the sector is perceived to come with a very high cost of failure.

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[167] UKRI, year unknown, Transforming construction. Retrieved from: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/transforming-construction/#pagecontentid-0

[168] TechNation, 2020, Introducing: The 32 companies joining Applied AI 2.0. Retrieved from: https://technation.io/news/applied-ai-2-0-cohort/

3.1.5 Creative industries incl. gaming

In recent years, AI in the creative industries has seen some growth globally, but also more specifically in the UK and NI through a multitude of initiatives that have been launched since the creative industries were recognised as part of the UK's Industrial Strategy. Nevertheless, it remains a small sector in NI with AI developments still in its early stages, with limited opportunity for distinct impact on a global scale.

Overall assessment:

- State of the research base

- Economic state of the sector in NI

- Opportunity for AI

Northern Ireland's creative industries have recently experienced above-average growth, making it a small, but thriving, sector of the NI economy. The importance of the sector for the UK economy more broadly has been recognised with the creative industries receiving a separate Sector Deal.[169]

State of the research base

- **Volume**: Creative industries were not explicitly mentioned in the Turing Institute report as a category. However, some of the research around Virtual and Augmented Reality (VR / AR) could be applied in the creative sector, though the volume of this is small. In addition, there is a research cluster around imagine recognition, but the applicability to the sector is unclear.

- **Applicability**: A couple of recent initiatives that focus on AR / VR in creative industries, including the Creative Industries Institute and Future Screens NI (see below), link industry and research.

- **Capability and community**

- The Creative Industries Institute at Ulster University brings together research in creative disciplines, and will have a focus on developing research in VR and AR[170]

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[169] Nesta, 2020, The Art in the Artificial: AI and the creative industries. Retrieved from: https://www.pec.ac.uk/assets/publications/PEC-and-Nesta-research-report-The-art-in-the-artificial.pdf

[170] Ulster University, 2020, Creative Industries Institute. Retrieved from: https://www.ulster.ac.uk/cii

- Future Screens NI works with UU and QUB as well as a range of industrial partners to deliver technical skills, opportunity and growth to broadcast, animation, games and immersive technologies. This will include some capacities in VR and AR[171].

- The Virtual and Augmented Reality Centre (VARC) at North West Regional College focuses on creative and cultural sectors with applicability to SMEs[172].

- UU's Cognitive Analytics Research Lab (CARL) brings in industry and government to work on intelligent data analytics. Media is one of the key sectors, although there has as of yet not been a significant cluster of research in this[173].

- UU has a data science partnership with the BBC, focused on including machine learning in the media industry to foster personalisation and engagement[174].

Economic state of the sector in NI

GVA & employment: Over the last years, NI's creative industries' sector experienced above-average economic growth, primarily driven by the IT and software component of the sector, while the publishing sub-sector experienced a decline. Despite the overall growth, it is still a small part of the economy, currently accounting for 1.2% by GVA and 1.4% by employment. Looking at the UK more broadly, the creative industries annually contribute to the economy by around £100 billion.[175]

Long-term growth path: Our forecast indicates that the share of the sector in the economy is set to shrink by 2030, both in terms of GVA (from 1.2% to 0.9%) and employment (from 1.4% to 1%).[176] The decline in creative industries is particularly driven by publishing activities (SIC 58) and programming / broadcasting activities (SIC 60), which have been on a gradual, long-term, decline from the early 2000s through to 2018.

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[171] Future Screens NI, 2020, About. Retrieved from: https://www.futurescreens.org/about

[172] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf and interviews

[173] Ulster University, 2020, Cognitive Analytics Research Lab: Research. Retrieved from: https://www.ulster.ac.uk/cognitive-analytics-research/research

[174] Ulster University, 2017, Ulster University one of eight UK universities in major data science partnership with the BBC. Retrieved from: https://www.ulster.ac.uk/news/2017/october/ulster-university-one-of-eight-uk-universities-in-major-data-science-partnership-with-the-bbc.

[175] Creative industries clusters

[176] Economic forecast of this study

Opportunity for AI

● **Global role for AI**: The creative tech sector is the fastest growing part of the wider creative industries.[177] The biggest potential for AI within this sector lies in the areas of generative technology, animation, gaming and AR/VR (also see section "AR/VR"). Generative tech includes tech that can generate text, sound or images given prompts. In the area of style transfer, key impact areas are in animation, emotive avatar work and virtual production. The number of AI companies in the sector is highest in the USA, followed by the UK, which highlights the strong potential for AI in the sector in the UK.

The direct application of AI in the creative industries is still relatively low.[178] This is partly due to the recent entrance of AI to the sector, and partly due to the inherently human and unpredictable nature of the creative process, though this may be changing. Some early reports of Generative Pre-trained Transformer 3 (GPT-3) describe it as a stimulus to creative processes. The opportunity of AI at present is limited to supporting technology rather than transforming the creative process.

● **Complementary initiatives**: A range of complementary initiatives support the development of AI in the sector in NI. Creative industries are part of both Sector Deals, even though with a more indirect focus on AI: The Screen and Media Innovation Lab (SMIL), a collaboration between Ulster University and Queen's University Belfast, will provide a research facility including areas such as animation, immersive- and games-development, through an investment of £40 - £48m.[179] The creative industries have a separate Sector Deal under the UK Industrial Strategy.[180] The Derry / Londonderry City Deal will primarily support it through the Virtual and Artificial Reality Centre at NWRC. The cross-sectoral creative partnership Future Screens NI received £13m investment from the Arts and Humanities Research Council to deliver technical skills and growth across areas such as animation and immersive technologies.[181] Another initiative to support AI developments in the

[177] Matrix, 2018, Matrix Creative Technology Report 2018. Retrieved from:
https://matrixni.org/wp-content/uploads/2018/04/MATRIX-Creative-Technologies-report.pdf

[178] Nesta, 2020, The Art in the Artificial: AI and the creative industries. Retrieved from:
https://www.pec.ac.uk/assets/publications/PEC-and-Nesta-research-report-The-art-in-the-artificial.pdf

[179] EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from:
http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

[180] UK Government, 2018, Industrial Strategy: Creative Industries Sector Deal. Retrieved from:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/695097/creative-industries-sector-deal-print.pdf

[181] Matrix, 2018, Future Screens NI wins £13m AHRC investment. Retrieved from:
https://matrixni.org/future-screens-ni-wins-13m-ahrc-investment/

sector is the "Immersive Tech NI"-community that provides a platform to explore immersive technologies. It has an active Meetup group with over 300 members.[182]

◉ **Opportunity for distinct impact:** The strength of NI's creative tech sector in the areas of animation and gaming provide some opportunities for distinct impact. In this regard, a few interviewees point to the significant potential for the use of AI in animation and features, which is already a strength of the NI economy.[183]

◉ **Investment opportunities:** The sector is recognised in both City Deals, the UK Industrial Strategy and UKRI's Creative Industries Clusters Programme, launched in November 2019. Through funding from UKRI's Clusters Programme and the Belfast Region City Deal, £38m has gone into Future Screens NI, a partnership between NI's creative companies, UU and QUB to create the SMIL[184]. NI Screen administers funding specifically, also in AI, games, animation and interactive content.[185] Despite this, the research suggests that funding remains a challenge in this sector, partly as a result of low levels of awareness and the closing of the Creative Industries Innovation Fund in 2015.[186]

◉ **Industry readiness:** There are more than 1,300 creative tech businesses based in NI, particularly focused on immersive tech, gaming, user experience and animation. However, the majority of these are specialised microbusinesses.[187] The infrastructure to support creative industries in NI is lower than in other UK regions[188], a challenge that will also affect the industry readiness with regards to the adoption of AI.

182 Matrix, 2018, Matrix Creative Technology Report 2018. Retrieved from: https://matrixni.org/wp-content/uploads/2018/04/MATRIX-Creative-Technologies-report.pdf

183 Stakeholder interview

184 Arts and Humanities Research Council, 2020, Creative Industries Clusters Programme. Retrieved from: https://creativeindustriesclusters.com

185 Northern Ireland Screen, 2020, Creative frontiers: capturing the AI revolution on screen. Retrieved from: https://www.northernirelandscreen.co.uk/news/creative-frontiers-capturing-ai-revolution-screen/

186 Matrix, 2018, Matrix Creative Technology Report 2018. Retrieved from: https://matrixni.org/wp-content/uploads/2018/04/MATRIX-Creative-Technologies-report.pdf

187Matrix, 2018, Matrix Creative Technology Report 2018. Retrieved from: https://matrixni.org/wp-content/uploads/2018/04/MATRIX-Creative-Technologies-report.pdf

188 EY, 2019, Belfast Region City Deal Overview of Innovation Pillar Project. Retrieved from: http://www.manufacturingni.org/media/uploads/Belfast%20Region%20City%20Deal-%20High%20Level%20Project%20Overview.pdf

3.1.6 Employment and business support activities

> The trade-off between efficiency gains and job loss is key to consider when looking at this sector. Given AI's negative impact on jobs in this sector, it is not a very attractive sector to focus on for the AICC. This is further exemplified in the absence of a specific niche that NI could fill on a global scale.
>
> **Overall assessment:**
>
> ● State of the research base
>
> ● Economic state of the sector in NI
>
> ● Opportunity for AI

This sector covers a variety of activities that support general business operations, such as day-to-day office administration services, and employment, including search and placement activities.

State of the research base

● **Volume:** Employment and business support activities were not explicitly mentioned in the Turing Institute report as a category. There is no further evidence of a significant body of AI research specifically focused on employment and business support activities. This does not exclude that current research being done has applicability in the employment and business support sector.

● **Applicability**: See above.

● **Capability and community**: There is no identified evidence for research groups focused on the employment and business support sector.

Economic state of the sector in NI

●● **GVA & employment:** This sector covers a variety of activities. With 1.9%, it currently accounts for a relatively small share of NI's economy by GVA. As a labour-intensive sector, its share in terms of employment is considerably higher, currently standing at 4.5%.

● **Long-term growth path**: The sector is estimated to expand its share in NI's economy over the next ten years, both in terms of GVA and employment. GVA is set to grow in absolute terms by c.71%. This marks the largest increase in absolute GVA in comparison to other sectors subject to this study. Its share in NI's economy by GVA is set to grow to 2.9% in 2030, and in terms of employment to 5.7%.[189]

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[189] Economic forecast of this study

Opportunity for AI

◉ **Global role for AI**: There is significant potential for automation in the sector to achieve efficiency gains. This includes analysis of business processes, classification and data filing as well as chat and text interfaces. AI is already being used in hiring processes through the scanning of applications to counter discriminating practices.[190] Chatbots and AI-based customer service assistants are already being used by many companies.[191] However, the majority of these opportunities come at the cost of making jobs redundant.

◉ **Complementary initiatives**: Desk research and interviews did not point to distinct cross-stakeholder initiatives to foster AI adoption in the sector in NI. The Belfast Region and Derry / Londonderry City Deals did not focus on strengthening innovation in business operations.

◉ **Opportunity for distinct impact:** Given that the current AI applications in the sector have very broad applicability across different business processes, this study does not identify a distinct opportunity for NI to have an impact at global scale.

◉ **Investment opportunities:** According to a report by TechNation, enterprise software was the fourth largest area receiving VC investment in the UK in 2019, with funding amounting to c. US$1.5 billion.[192] Public funding for the development of AI in the sector, specifically in NI, appears to be low - with no pledge for investment made in either City Deals for this area. SureCert, a NI-based innovative platform connecting candidates and recruiters online has received c. £49k towards a feasibility study on rapid digitised staff onboarding for the care sector.[193]

◉ **Industry readiness:** While industry adoption of AI technologies offers efficiency gains, the application of AI in the sector is likely to remove jobs by automating simpler customer service processes. Beyond the company SureCert, which actively integrates AI in its processes, the research did not point to a particularly strong base of AI-focused companies in this sector in NI.

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[190] Falon Fatemi, 2019, 3 ways artificial intelligence is transforming business operations. Retrieved from: https://www.forbes.com/sites/falonfatemi/2019/05/29/3-ways-artificial-intelligence-is- transforming-business-operations/#6c2246186036

[191] Inside Big Data, 2019, 5 ways AI is already being used to transform business operations. Retrieved from: https://insidebigdata.com/2019/04/26/5-ways-ai-is-already-being-used-to-transform-business- operations/

[192] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020

[193] UK Government, 2020, Innovate UK funded projects since 2004: Retrieved from: https://www.gov.uk/government/publications/innovate-uk-funded-projects

3.1.7 Energy

> While AI provides significant opportunities to cut costs, improve energy demand / supply match and support the adoption of renewable energy sources, it is still nascent in the sector. Interviewees and desk research do not point to a particular niche for NI to fill in order to have an impact at a global scale.
>
> **Overall assessment:**
>
> ◉ State of the research base
>
> ◉ Economic state of the sector in NI
>
> ◉ Opportunity for AI

Across the world, the energy sector faces a range of challenges: rising demand, changing demand patterns, insufficient analytics for energy management, and the need to rapidly increase the share of renewable energy.[194] AI applications can address some of these.

State of the research base

◉ **Volume:** Energy was not explicitly mentioned in the Turing Institute report as a category. There is no identified evidence of a significant body of AI research specifically focused on energy. This does not exclude that current research being done has applicability in the energy sector.

◉ **Applicability:** See above.

◉ **Capability and community:** UU's Cognitive Analytics Research Lab (CARL) brings together industry and government to work on intelligent data analytics. Energy is one of the key sectors, though there has yet not been a significant cluster of research in the area.[195]

Economic state of the sector in NI

◉◉ **GVA & employment:** The energy sector does not play a significant role in the economy of NI, beyond delivering on domestic energy needs, and with exports and imports accounting for a marginal amount of generated and consumed

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[194] International Finance Corporation, 2020, Artificial Intelligence in the Power Sector. Retrieved from: https://www.ifc.org/wps/wcm/connect/bd3a196d-a88f-45af-bbc6-e0b00790fba8/EMCompass_Note_81-05-web.pdf?MOD=AJPERES&CVID=n72pj5g

[195] Ulster University, 2020, Cognitive Analytics Research Lab: Research. Retrieved from: https://www.ulster.ac.uk/cognitive-analytics-research/research

electricity.[196] The sector currently makes up 1.2% of GVA and only 0.3% of employment. According to Invest NI, the region has more than 150 companies with the capability of providing innovative products in the energy and water supply chains.[197] The challenge with regards to NI's energy sector is summarised in the Industrial Draft Strategy as the "trilemma to ensure security of supply, cost control and the achievement of affordable decarbonisation".[198]

◉ **Long-term growth path**: The share of the sector is estimated to stay relatively stable at 1.2% of GVA and a contribution to employment at 0.3%.[199]

Opportunity for AI

◉ **Global role for AI**: The application of AI in energy is nascent. Nevertheless, AI applications offer significant opportunities to address the rising challenges in the sector by cutting energy waste, lowering energy costs, facilitating the use of renewable energy sources, and improving the operation and control of power systems.[200]

◉ **Complementary initiatives**: Complementary initiatives targeting the support of AI adoption in NI's energy sector are scarce. Sustainable technologies and renewable energy are included in the Derry / Londonderry City Deal as a priority area, but the Deal does not provide further details on the specifics of future initiatives in the area.[201]

◉ **Opportunity for distinct impact:** Interviewees see an opportunity for impact given the need for the sector to rapidly transform to achieve sustainability objectives. With regards to renewable energy sources, c. 40% of NI electricity supply already comes

[196] Department for the Economy, 2020, Energy in Northern Ireland 2020. Retrieved from: https://www.economy-ni.gov.uk/sites/default/files/publications/economy/Energy-In-Northern-Ireland-2020.pdf

[197] InvestNI, 2020, Renewables and Energy. Retrieved from: https://www.investni.com/invest-in-northern-ireland/renewables-and-energy

[198] Department for the Economy, 2017, Economy 2030: a consultation on an Industrial Strategy for Northern Ireland. Retrieved from: https://www.economy-ni.gov.uk/sites/default/files/consultations/economy/industrial-strategy-ni-consultation-document.pdf

[199] Economic forecast of this study

[200]International Finance Corporation, 2020, Artificial Intelligence in the Power Sector. Retrieved from: https://www.ifc.org/wps/wcm/connect/bd3a196d-a88f-45af-bbc6-e0b00790fba8/EMCompass_Note_81-05-web.pdf?MOD=AJPERES&CVID=n72pj5g

[201] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

from renewable sources, with wind energy accounting for 83%.[202] One opportunity in this area could be to make Belfast Harbour a green and smart port. This is supported by the objective of the UK's Maritime Strategy to cut carbon emissions from shipping to zero by 2050.[203] However, desk research and interviewees did not identify significant AI-specific activities in this field, or the sector more broadly, thus making it unlikely that NI could have a distinct impact on this on a global level in the near future.

- **Investment opportunities:** There is some funding coming into the sector in the UK. In 2017, the UK government announced an investment of £84 millions of funding for AI and robotics research, and smart energy innovation. Funding was aimed to support the development of robotics technology to improve safety of off-shore wind and nuclear energy and smart energy systems innovation, but no significant funding was awarded to NI-based research or industry.[204] The Derry / Londonderry City Deal includes sustainable technologies and renewable energy as an investment priority in the field of Innovation and Digital, but neither specifies the investment size, nor the extent to which this will focus on AI[205].

- **Industry readiness:** The impact of AI in energy is still nascent, and adoption at scale is limited so far. A key challenge with regards to industry readiness concerns the ability to access source data to develop effective AI solutions. This will require effective collaboration with data holders, e.g. owners of electricity grids. In the specific case of NI, this challenge is mitigated given that Network Distributors, Producers and Operators are all operating under the umbrella of one organisation.

[202] Action renewables, 2019, The rise and fall of fossil fuels: What is Northern Ireland doing to make its energy supply more sustainable. Retrieved from: https://actionrenewables.co.uk/news-events/post.php?s=the-rise-and-fall-of-fossil-fuels-what-is-northern-ireland-doing-to-make-its-energy-supply-more-sustainable

[203] Department for Transport, 2019, Maritime 2050: Navigating the Future. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872194/Maritime_2050_Report.pdf

[204] UK Government, 2017, Funding for £84 million for artificial intelligence and robotics research and smart energy innovation announced. Retrieved from: https://www.gov.uk/government/news/funding-for-84-million-for-artificial-intelligence-and-robotics-research-and-smart-energy-innovation-announced

[205] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf

3.1.8 Finance incl. FinTech

> There is high AI maturity in the sector, both globally and specifically in NI. Significant VC investment in the area highlights the future growth prospect for the sector. Given its strength in NI and its global competitiveness, there is opportunity for distinct impact if NI succeeds in leveraging larger players in the sector, the decent number of start-ups and its history of building software. The strength of the sector is also recognised by several interviewees.
>
> **Overall assessment:**
>
> ⊙ State of the research base
>
> ⊙ Economic state of the sector in NI
>
> ⊙ Opportunity for AI

Financial services include banking services, insurance, stock and investment services. FinTech refers to the use of technology to enable automated banking services. With increased digitisation, FinTech has developed into a sector that houses start- and scale-ups and has motivated traditional financial institutions to change their operations.

State of the research base

⊙ **Volume:** "Economy", which includes both finance and trade, is rated as medium on scale of AI publication activity (UU: low, QUB: low). Research into FinTech is only done out of UU. There is evidence for a stronger research base in cyber security which has application to the FinTech sector (see section "Cryptography and cyber security").[206]

⊙ **Applicability:** The quality of "Economy" publications is high (UU: high, QUB: high).[207] Interviewees point to research outside the two universities with high applicability (also see below). Research applicable to FinTech (inside and outside of universities)

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[206] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[207] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

appears to have a strong focus towards cyber security, with research conducted in a range of companies that are part of the NI cyber security cluster.[208]

◉ **Capability and community**

- UU's Cognitive Analytics Research Lab (CARL) brings in industry and government to work on intelligent data analytics. Financial technology is one of the key sectors, and has attracted some research around capital markets.[209]

- QUB's Institute of Electronics, Communications & Information Technology (ECIT) hosts research relevant to FinTech, with a strong focus on cyber security. The Centre for Data Science and Scalable Computing (DSSC) at QUB focuses on big data, with applications for financial data.[210] The Centre for Secure Information Technologies (CSIT) is a National Innovation and Knowledge centre for cyber security.[211] The Global Institute for Innovation, part of the Belfast Region City Deal aims to specifically support the FinTech sector through ECIT/CSIT.[212]

- There have been some spinouts from the universities related to finance[213] such as Yedup (real time news / social media analytics)[214] and Analytics Engines (data platform with applications in fraud detection).[215]

Economic state of the sector in NI

◉◉ **GVA & employment:** Financial services, incl. FinTech currently account for 3.9% to the economy in NI by GVA and 2.4% by employment. While a small share, growth in recent years has outstripped London, with the NI sector growing 6.1% between 2016 and 2017. Banking accounts for the largest financial services' sectors in terms of

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[208] NI Cyber, 2020, Northern Ireland Cyber Security Cluster. Retrieved from: https://www.nicyber.tech/

[209] Ulster University, 2020, Cognitive Analytics Research Lab: Research. Retrieved from: https://www.ulster.ac.uk/cognitive-analytics-research/research

[210] Turing report and Queen's University Belfast, 2020, DSSC. Retrieved from: https://www.qub.ac.uk/ecit/DSSC/

[211] Queen's University Belfast, 2020, CSIT. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/

[212] EY, 2020, Belfast Region City Deal: Global Innovation Institute Outline Business Case (Draft).

[213] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[214] Yedup, 2020, Yedup. Retrieved from: https://yedup.com/

[215] Analytics Engines, 2020, Analytics Engines. Retrieved from: https://analyticsengines.com/

employment and office presence. FinTech makes up 15% of the sector and 2% of total businesses.[216]

◉ **Long-term growth path**: The Department for the Economy of NI identifies the financial services sector as a key part of its economic strategy and a pillar for growth.[217] Our forecasts indicate that the sector's GVA is set to grow by 11%, although it is not expanding its share of NI's economy. The share of employment is expected to decline to 2.3%.[218]

Opportunity for AI

◉ **Global role for AI**: AI is already widely applied in the sector, with specific applications in risk management, alpha generations and stewardship in asset management.[219] AI in FinTech alone accounts for US$ 6.6bn globally, very high in comparison to the size of AI in other sectors analysed[220].

AI's transformative potential lies in enhancing efficiency and productivity through automation; reducing human biases and errors caused by psychological or emotional factors; and improving the quality of management information by spotting either anomalies or longer-term trends that cannot be easily picked up by current reporting methods. The value of AI within the global FinTech sector is estimated to grow at 23% CAGR over the next years.[221]

◉ **Complementary initiatives**: The region has a strong reputation as a leading global location for financial services.[222] Initiatives that bring academia and industry

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[216] Department for the Economy, year unknown, Mapping NI's financial services sector. Retrieved from: https://www.economy-ni.gov.uk/articles/mapping-nis-financial-services-sector

[217] Department for the Economy, year unknown, Mapping NI's financial services sector. Retrieved from: https://www.economy-ni.gov.uk/articles/mapping-nis-financial-services-sector

[218] Economic forecast of this study

[219] Oliver Wyman, 2019, Artificial Intelligence applications in financial services. Retrieved from: https://www.oliverwyman.com/our-expertise/insights/2019/dec/artificial-intelligence-applications-in-financial-services.html

[220] Businesswire, 2020, *Artificial intelligence in Fintech.* Retrieved from: https://www.businesswire.com/news/home/20200619005338/en/Artificial-Intelligence-in-Fintech---Global-Market-Growth-Trends-and-Forecasts-to-2025---Assessment-of-the-Impact-of-COVID-19-on-the-Industry---ResearchAndMarkets.com

[221] Businesswire, 2020, *Artificial intelligence in Fintech.* Retrieved from: https://www.businesswire.com/news/home/20200619005338/en/Artificial-Intelligence-in-Fintech---Global-Market-Growth-Trends-and-Forecasts-to-2025---Assessment-of-the-Impact-of-COVID-19-on-the-Industry---ResearchAndMarkets.com

[222] InvestNI, 2020, Northern Ireland - a Centre of Excellence for FinTech. Retrieved from: https://fintech.global/globalregtechsummit/wp-content/uploads/2020/09/FinTech-NI.pdf

together are primarily located within universities' research centres, such as CARL and DSSC (see above). Catalyst has also established a sectoral focus on FinTech (including cyber and RegTech), which is specifically focused on AI as part of its Belfast Digital Innovation partnership.[223] Last year, a FinTech envoy for Northern Ireland was appointed.[224]

Beyond this, the sector benefits from a well-established cyber cluster that primarily focuses on FinTech. Interviewees highlight that the cyber security cluster has contributed to the growth of NI's FinTech sector.

◉ **Opportunity for distinct impact:** Many interviewees attribute the development of the cyber cluster as a primary driver of FinTech in NI. There is some opportunity for distinct impact given NI's strong local industry in the sector, as recognised in the Turing Institute report. This was also suggested by interviewees and is reflected in Belfast ranking second among the top-ten FinTech locations of the future in the 2019/2020 FDI league table.[225] Interviewees point to particular strengths in the field of developing software for the industry.

◉ **Investment opportunities:** Looking at the UK as a whole, the sector has experienced a significant increase in VC funding over the past few years. In 2019, it was the largest sector for UK Venture Capital investments, with funding exceeding US$ 5 billion and funding doubling from 2018.[226] NI has seen some notable funding successes; however the Department for the Economy argues that FinTech has been arguably underweight.[227] The Global Innovation Institute, which will receive £52.4m via the Belfast Region City Deal, will focus on Fintech, Professional Services and the Cyber Security sector alongside its core One Health mission.[228]

◉ **Industry readiness:** Financial services' firms are generally well resourced and bring high technical readiness to adopt new solutions enhancing the opportunity for AI in this sector - if a provider can supply something effective. In NI, banking makes up the biggest share of businesses (47%), followed by financial advisors (22%) and insurance (15%). FinTech currently makes up 2% of total businesses, comprising of 15 established companies. There are both internationally-owned and indigenous

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[223] Steve Orr, 2020, Clusters - what and how.

[224] UK Government, 2019, New Fintech envoy appointed for Northern Ireland. Retrieved from: https://www.gov.uk/government/news/new-fintech-envoy-appointed-for-northern-ireland

[225] fDi, 2019, Fintech Locations of the Future 2019/20: London tops first ranking. Retrieved from: https://www.fdiintelligence.com/article/75404

[226] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020

[227] Department for the Economy, year unknown, Mapping NI's financial services sector. Retrieved from: https://www.economy-ni.gov.uk/articles/mapping-nis-financial-services-sector

[228] EY, 2020, Belfast Region City Deal: Global Innovation Institute Outline Business Case (Draft).

companies active in the field. Companies include First Derivatives, Liberty IT, SR Labs (provider of low latency market data and market access solutions for the financial industry), and Wombat Technologies (now part of SR Labs). In FinTech, NI "has some outstanding anchor tenants" and "an increasing stream of indigenous companies".[229] Another indicator for the strength of industry readiness is that the local software industry has already developed capabilities to support the FinTech companies.

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[229] Department for the Economy, year unknown, Mapping NI's financial services sector. Retrieved from: https://www.economy-ni.gov.uk/articles/mapping-nis-financial-services-sector

3.1.9 Human health and social work

In comparison to other sectors subject to this study, the health and social care sector offers a wide range of opportunities for the adoption of AI with many existing cross-cutting initiatives and companies active in the field. There is some distinct value within NI's centralised healthcare data. However, given the multitude of ongoing activities, a sectoral focus of the AICC is unlikely to have a significant impact. In addition, the industry readiness at the end of the supply chain in healthcare settings is a key challenge when it comes to leveraging the potential of AI in the sector.

Overall assessment:

◉ State of the research base

◉ Economic state of the sector in NI

◉ Opportunity for AI

The health sector is large and broad, and encompasses primary-, secondary- and residential care, and social work. As such, there is extremely broad potential for AI.

State of the research base

◉ **Volume:** the scale of AI publication activity for medicine is assessed as high (UU: high, QUB: medium). However, most of the research at both universities is in biomedical R&D.[230] Distinct research into human health happens in health innovation and personalised medicine.

◉ **Applicability:** The quality of publications in the medicine cluster is rated as high (UU: high, QUB: medium).[231] In addition, the capabilities listed below have strong links to and application within healthcare, although much research is in biomedical R&D.

◉ **Capability and community**

• UU's Connected Health Innovation Centre (CHIC) is a partnership between UU and QUB that will receive funding under the Belfast Region City Deal. CHIC aims to aid economic development in Northern Ireland in the area of health. It works

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[230] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[231] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

with business and health stakeholders on AI, IoT and other technologies and has a long history in AI, especially in diagnostics and imaging for health[232]. It is mostly funded by Invest NI and has a membership of 30 companies. Its main focus areas are: vital signs sensing development, integrated care, assisted living, point of care diagnostics and healthcare analytics.[233]

- iREACH is part of the Belfast Region City Deal focused on improving healthcare in Northern Ireland. It is envisioned to apply AI, although the reach of this is not clear.[234]

- The Centre for Personalised Medicine (CPM) at UU is a cross-border collaboration encompassing academic partners, public healthcare providers and healthcare service companies to advance research for personalised clinical decision-making.[235]

- There are several spinouts from the universities related to human health[236], including Almac (treatment prediction)[237] and Nightingale Analytics (predictive tool for dementia)[238].

Economic state of the sector in NI

◉◉ **GVA & employment:** The health- and social care sector is the third largest sector of the NI economy in terms of GVA, accounting for 10.5% of the economy. It is an even more important sector for NI's economy in terms of employment where it is the second largest sector, accounting for 16.4%.

◉ **Long-term growth path**: The sector is projected to experience growth between 2018-2030, both in terms of GVA and employment in the NI economy. In absolute

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[232] Stakeholder interview

[233] Northern Ireland Connected Health Innovation Centre, 2020, About. Retrieved from: https://www.ni-chic.org/about

[234] Belfast region city deal: innovation and digital, 2020, iREACH. Retrieved from: https://www.brcd-innovation.co.uk/projects/ireach

[235] Turing report and Ulster University, 2020, Centre for Personalised Medicine - Clinical Decision Making and Patient Safety (CPM). Retrieved from: https://www.ulster.ac.uk/research/topic/biomedical-sciences/research/centre-for-personalised-medicine

[236] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[237] Almac group, 2020, Almac. Retrieved from: https://www.almacgroup.com/diagnostics/

[238] Nightingale analytics, 2020, Nightingale analytics. Retrieved from: https://www.nightingaleanalytics.co.uk/

terms, its GVA is set to grow by 24%.[239] However, growth may be the result of worsened public health and an ageing society. The COVID-19 pandemic has drawn additional attention to the challenges faced by the increased strain put on public healthcare systems.

Opportunity for AI

- **Global role for AI**: The sector has very broad potential for AI, in areas such as: diagnosis and disease management (for example in diabetes care); diagnostic medical imaging (e.g. through identifying imaging abnormalities), self-management for preventative or low-level care (e.g. chatbots for mental healthcare); lifestyle interventions to improve community health; and administrative and basic care applications (e.g. UK's *Babylon Health[240]* or *AttendAnywhere[241]*).

The current value of AI in the sector globally amounts to c. US$ 2.5bn. However, given its potential for impact, forecasts suggest that use of AI will grow significantly in the sector - with its value expected to increase by c. 41% CAGR over the next years.[242]

- **Complementary initiatives**: There are several complementary initiatives that are part of the Belfast and Derry / Londonderry City Deals. Through the Belfast Region City Deal, £45-55m will go to the creation of a Digital Healthcare Technology Hub and Living Labs that will enhance medical device design and software / prototyping through collaboration across industry and academia. Through this, it aims to drive sector growth and enhance productivity in medical device and related industries.[243]

The Derry / Londonderry City Deal plans to establish a Clinical Translational Research and Innovation Centre (C-TRIC). While focusing on aspects covered by the biomedical R&D sector in this study, there are also initiatives that aim to change the way in which healthcare is provided. Its Medical Procedure Human Interface Technology Lab (MedPHIT) focuses on innovation in the training of doctors and healthcare workers in medical procedures.[244]

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[239] Economic forecast of this study

[240] Babylon Health, 2020, Babylon Health. Retrieved from: https://www.babylonhealth.com/

[241] Attend Anywhere, 2020, Attend Anywhere. Retrieved from: https://www.attendanywhere.com

[242] Grand View Research, 2019, Artificial Intelligence in Healthcare Market. Retrieved from: https://www.grandviewresearch.com/industry-analysis/artificial-intelligence-ai-healthcare-market

[243] EY, 2020, *Belfast Region City Deal: Global Innovation Institute Outline Business Case (Draft)*.

[244] Derry City & Strabane, 2018, Delivering Inclusive Growth. City Deal for the Derry/Londonderry region.

HIRANI, NI's Health Innovation Research Alliance is another complementary initiative that works to support the biomedical R&D sector as well as the human health sector by promoting Life and Health sciences capabilities in NI.[245] Catalyst has also established a sectoral focus on data-driven health in its Belfast Digital Innovation partnership.[246]

● **Opportunity for distinct impact:** Northern Ireland has a single integrated health- and social care system that has been in operation for 40 years, and provides a unique dataset in the UK. The UK Government considers this "cradle to grave" record for more than 500,000 people a unique selling point to industry.[247] While data at a first look suggests potential for the development of new AI solutions, interviewees highlight that it comes with considerable drawbacks: i) data is currently not legally available,[248] ii) NI's population is small and relatively homogenous iii) data quality has not been fully evaluated vi) there is a lack of commercial pathways for academic work[249]. This limits the opportunity for this asset to translate into opportunities for distinct impact on a global scale.

● **Investment opportunities:** As outlined above, there is public investment coming into the sector through the Belfast Region City Deal and the Derry / Londonderry City Deal. HealthTech (excluding biomedical R&D) was the third largest sector for VC funding in the UK in 2019, amounting to c. 2.3 billion USD.[250]

● **Industry readiness:** There are a multitude of companies active in the space in the UK, including established companies such as Kainos, and more early stage startups. In NI, companies active in the field include Voscuris (clinical reporting)[251] and, as well as the previously mentioned university spin-outs that developed from research in the life sciences and are now using AI technologies in the wider health and social care sector including Heartsine, NeuroCONCISE, Intelesens, BrainWaveBank.

The key challenge in terms of AI industry-readiness does not lie on the side of companies developing AI solutions but on the application-side in healthcare settings, such as hospitals, GPs, home care settings and care homes. These generally have a low readiness to adopt AI solutions at scale at the moment.

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[245] HIRANI, 2020, About HIRANI. Retrieved from: https://www.hira-ni.com/about

[246] Steve Orr, 2020, Clusters - what and how.

[247] UK Government, 2017, Life Sciences Industrial Strategy. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/650447/LifeSciencesIndustrialStrategy_acc2.pdf

[248] Stakeholder interview

[249] Stakeholder interview

[250] TechNation, 2020, Report 2020. Retrieved from: https://technation.io/report2020

[251] Voscuris, 2020, Voscuris. Retrieved from: https://www.voscuris.com/

3.1.10 ICT and Telco

Based on the current role of the sector in NI, there are within-reach opportunities to employ AI technologies to enhance the sector with incremental changes, which could also support job growth. However, opportunities for the AICC to drive impact at global scale are limited as i) a number of initiatives already exist that connect industry and academia, ii) most current AI research is focused on hardware, while the economic value for NI is suggested to be more on software services, and iii) the ICT sector in NI is not sufficiently distinct from others around the world.

Overall assessment:

• State of the research base

• Economic state of the sector in NI

• Opportunity for AI

As the sector encompasses sub-sectors such as computer programming and information service activities, the development of AI is core. Northern Ireland's key ICT strengths include software engineering, application development, cyber security, data analytics and advanced networks & sensors.

State of the research base

• **Volume**: The scale of AI publication activity for "hardware" is high (UU: high, QUB: low). "Hardware" research includes high-performance computing, scalable architectures, cloud computing and partly covers the ICT and telco sector. Research out of UU mainly focuses on bio-inspired AI (hardware research), while QUB has a strong focus on high-performance computing as well as cloud and edge computing.[252] In addition, research is being conducted via Seagate, Kainos and the BT Innovation Centre.

• **Applicability**: The quality of "hardware" publications is rated as high (UU: high, QUB: high).[253] Through the additional research by non-academic actors as listed above, research is highly applicable.

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[252] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[253] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

◉ **Capability and community**

- The Centre for Wireless Innovation at QUB's School of Electronics, Communications and Information Technology is the largest centre in the UK for research on physical layer wireless.[254]

- The £28m British Telecom Ireland Innovation Centre (BTIIC) in Belfast will conduct research on the intersection between AI, IoT and telecommunications (see below).[255] BT partnered with UU, creating a number of new research positions in the Centre.[256]

Economic state of the sector in NI

◉◉ **GVA & employment:** With over 1,200 digital ICT companies in Northern Ireland, the sector accounts for over £870m of economic output and the sector has grown by 32% over the last five years.[257] In terms of GVA and employment, it is still a relatively small sector of NI's economy, currently accounting for 3% of GVA and 2.2% of employment.

◉ **Long-term growth path**: The sector is expected to continue on its strong growth path. In comparison to other sectors analysed in this report, the forecast points to the highest growth in absolute GVA terms over the next 10 years in this sector, as GVA is anticipated to grow by 51%. The sector's share in the economy is also increasing to 4.1% by GVA and to 3.5% by employment.[258]

Opportunity for AI

◉ **Global role for AI**: Given that the ICT and telco sector encompasses sub-sectors such as computer programming and information service activities, digital innovation and the development of AI is inherent to the sector. Key opportunities for the adoption of AI centre around automation, predictive analysis and data analytics, smart machines, including advanced networks and sensors.

◉ **Complementary initiatives**: There are a range of initiatives that complement AI activities in the sector. The Global Innovation Institute, via £52.4m in funding through the Belfast City Region Deal, aims to become a cross-disciplinary digital innovation

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[254] Queen's University Belfast, 2020, CWI. Retrieved from: https://www.qub.ac.uk/ecit/CWI/

[255] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[256] Ulster University, 2020, BT Ireland Innovation Centre. Retrieved from: https://www.ulster.ac.uk/research/topic/computer-science/btiic

[257] Matrix, year unknown, Digital ICT. Retrieved from: https://matrixni.org/sectors/digital-ict/

[258] Economic forecast of this study

hub that will also benefit the ICT sector. In 2017, the BT Group, a British multinational telecom holding company, established a £28 million Innovation Centre in Belfast. In collaboration with Ulster University, the BT Ireland Innovation Centre (BTIIC) conducts research at the intersection between Artificial Intelligence, the Internet of Things and Telecommunications.[259]

⦿ **Opportunity for distinct impact:** Northern Ireland's core ICT strengths include software engineering, application development, cyber security, data analytics and advanced networks & sensors.[260] With the exception of cyber security, an area in which NI is recognised for its strengths in unclonable chips, hardware and post-quantum cryptography, NI's expertise in ICT and Telco more broadly does not provide the region with an opportunity that would allow for distinct impact on a global scale. Specific opportunities in the cross-cutting area of cyber security are further assessed in Chapter 3.2.2 of this report.

⦿ **Investment opportunities:** The sector has benefited from considerable investment in recent years and will benefit indirectly from funding of the Belfast City Region Deal going into the development of the Global Innovation Institute. In 2015, NI was the leading foreign direct investment (FDI) region Europe for software development centres and IT technical support centres.[261] As described above, a £28m investment has gone into fostering digital innovation in the sector through the BTIIC.

⦿ **Industry readiness:** Industry readiness for the adoption of AI in this sector is high, given the general focus of the sector on digital innovation. This is further highlighted by the multitude of companies active in the sector. Over 1,200 digital ICT companies exist in NI incl. multinational companies with local branches, such as Liberty, IBM, SAP and Seagate, as well as local companies such as Kainos.[262]

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[259] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[260] Matrix Digital ICT Panel, 2016, Matrix Digital ICT Report 2016: foresight & horizon scanning. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

[261] Matrix Digital ICT Panel, 2016, Matrix Digital ICT Report 2016: foresight & horizon scanning. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

[262] Matrix Digital ICT Panel, 2016, Matrix Digital ICT Report 2016: foresight & horizon scanning. Retrieved from: https://matrixni.org/wp-content/uploads/2016/03/2016-Matrix-Digital-ICT-Report.pdf

The existing businesses could move up the value chain to build new AI solutions, such as Seagate Technology's Sage2 project[263]. Alternatively, these businesses may become supporting actors to AI development and management, potentially being the closer fit with the current business model. Taking on a supporting role may encompass activities such as providing data engineers, QA, test, deployment, and business change.

A challenge to the industry readiness is the ability of the sector to recruit and retain AI talent, though this is a relevant challenge across all sectors, further developed on in Section 1.3.2.

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[263] Sai Narasimhamurthy, year unknown, Sage2 Project Addresses I/O and Storage Needs of AI and Deep Learning. Retrieved from: https://blog.seagate.com/enterprises/sage2-project-addresses-i-o-and-storage-needs-of-ai-and-deep-learning/

3.1.11 Professional and research services excl. biomedical

> There are opportunities for efficiency improvements via the adoption of AI in this sector. However, given the lack of the limited research base in NI in the sector, as well the absence of evidence pointing towards distinct investment opportunities and industry focusing on the sector in NI, it is not considered a relevant sector for the AICC to focus on.
>
> **Overall assessment:**
>
> ◉ State of the research base
>
> ◉ Economic state of the sector in NI
>
> ◉ Opportunity for AI

This is a medium-sized, but fragmented sector of NI's economy, covering a diversity of activities, including legal and accounting activities, advertising, market research and other professional, scientific and technical activities.

State of the research base

◉ **Volume:** Professional and research services (excl. biomedical) was not explicitly mentioned in the Turing Institute report as a category. There is some research on the role of AI in law and legal service delivery, although this is a small project.[264] There is no further identified evidence of a significant body of AI research specifically focused on professional and research services. This does not exclude that current research being done has applicability in the professional and research services sector.

◉ **Applicability**: See above

◉ **Capability and community**: The Legal Innovation Centre at the UU law school brings together academics from the school of law and the faculty of computing and engineering to do research on e.g. automation of legal analysis to streamline the delivery of legal services. It partners with Allen & Overy, Baker McKenzie, the Belfast City Council and Invest NI.[265]

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[264] Ulster University, 2020, Artificial Intelligence. Retrieved from:
https://www.ulster.ac.uk/legalinnovation/research/artificial-intelligence

[265] Ulster University, 2020, About the Legal Innovation Centre. Retrieved from:
https://www.ulster.ac.uk/legalinnovation/about

Economic state of the sector in NI

● ● **GVA & employment:** Activities within this sector include specialised professional and technical activities which require a high degree of training and make specialised knowledge and skills available to users. While encompassing a diversity of different sub-markets, this sector comprises a small aggregate share of NI's economy, accounting for 3.5% by GVA and 3.9% by employment.

● **Long-term growth path**: The sector is expected to growth. GVA in absolute terms is estimated to grow by 19% over the next ten years, with its share growing slightly to 3.8% of NI's economy by GVA. Employment in the sector is set to grow more substantially by 38%, expanding its share in the economy to 5.2% by employment.[266]

Opportunity for AI

● **Global role for AI**: While this sector covers a range of sub-markets, AI tools can be powerful for niche applications in a blended professional services offer that does not cut jobs but rather supports specialised professionals. Natural language processing is an AI specialism of high relevance for the sector, especially for sub-areas such as legal services, as it can be used to 'read' and process large quantities of text, e.g. contracts.

In the field of architectural and engineering services, AI solutions could support trained professionals to spot issues and propose solutions. These AI solutions offer potential to better profit margins for similar levels of human effort. In this context, the potential of AI is conditioned to the firm having relatively exclusive access to the tool.

● **Complementary initiatives**: Desk research and interviewees did not point to complementary initiatives in the sector that already focus on leveraging the potential of AI through multi-stakeholder initiatives.

● **Opportunity for distinct impact:** Desk research and interviewees did not suggest that NI has a distinct opportunity for impact at scale given the current role of the sector in NI.

● **Investment opportunities:** This research did not point to significant investment opportunities in the field. The sector is not a particular focus of the Belfast Region and Derry / Londonderry City Deals.

● **Industry readiness:** Within the UK, and more specifically NI, there is some industry readiness given that a few companies work on solutions that can benefit this sector, such as Kainos and BroadSoft, initially located at SciencePark Belfast and recently acquired by Cisco.

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[266] Economic forecast of this study

A key consideration when it comes to industry readiness in this sector is the extent to which the adoption of AI may cause job losses. At the lower end of professional and technical tasks, the usage of AI tools that automate and standardise processes will inevitably pose a risk of making the jobs for more mundane tasks redundant.

3.1.12 Public administration, education and defence

> Given that the public sector is much less technically developed than the private sector (globally and in NI), gains in the short term are limited. While there is some potential for a distinct opportunity for NI to adopt AI to address its border control problem, this comes at considerable challenges in terms of ethical considerations and the limited industry readiness.
>
> **Overall assessment:**
>
> ⦿ State of the research base
>
> ⦿ Economic state of the sector in NI
>
> ⦿ Opportunity for AI

The public sector comprises a large range of activities including government, but also education, defence and border patrol. Recent developments including Brexit and COVID-19 make it a sector in flux.

State of the research base

⦿ **Volume:** The scale of AI publication activity for government was assessed as low (UU: low, QUB: low). A handful of people work out of UU and QUB on government research with AI applications[267].

⦿ **Applicability**: The quality of government publications is rated as high (UU: high, QUB: high).[268] However, while main research focuses on applying AI to the policy making process as well public health policy, it is unclear to what extent AI research has been taken up by the government.

⦿ **Capability and community** - There is no evidence for specific clusters working on public administration. However, given the breadth of this sector it is likely that some other research might intersect with the government.

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[267] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[268] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

Economic state of the sector in NI

◉◉ **GVA & employment:** The public sector is the second largest sector of NI's economy by GVA (13.8%) and third largest by employment (15.8%). It employs a significant part of Northern Ireland's workforce and comprises a large range of activities including government, education, defence and border patrol.

◉ **Long-term growth path**: Recent developments including Brexit and COVID-19 make it a sector in flux. Estimates suggest that the public sector will shrink over the next ten years both in terms of GVA and employment: GVA by 18% to c. 10.2% and 12.7% by employment.[269]

Opportunity for AI

◉ **Global role for AI**: While a handful of governments have successfully used AI and digital technology to streamline, expand, and improve some services while lowering costs, most have been slow to pursue full digital transformations.[270] Much of the public sector globally is much less technically developed than the private sector. This means that in the medium term (1-5 years), gains are more likely to come from simpler introduction of software and automation than full AI.

A study of the adoption of AI by governments across Europe finds an imbalance between "the transformative potential and effective adoption and use of AI solutions in government". The study finds that the UK public sector has adopted eight AI functions across the areas of general public services, public order and safety, economic affairs and health. The UK ranks close to average with the number of functions in comparison to other countries in Europe.[271]

AI could have high impact on public sector efficiency via automation, forecasting, voice- and text processing. Advanced machine learning algorithms could have the potential to significantly improve the operating model of the public sector. The COVID-19 pandemic has accelerated the need for the public sector to consider broader process changes, and might reduce reluctance to adopt new technologies.[272]

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[269] Economic forecast of this study

[270] BCG, 2020, Now is the Time for AI-Powered Governments. Retrieved from: https://www.bcg.com/publications/2020/ai-powered-governments

[271] EU Joint Research Centre, 2020, AI Watch: Artificial Intelligence in public services: Overview of the use and impact of AI in public services in the EU. Retrieved from: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120399/jrc120399_misuraca-ai-watch_public-services_30062020_def.pdf

[272] BCG, 2020, Now is the Time for AI-Powered Governments. Retrieved from: https://www.bcg.com/publications/2020/ai-powered-governments

● **Complementary initiatives**: To support uptake of AI within the public sector, the UK Government, as part of its AI Sector Deal, has created a £20 million GovTech fund to foster innovation and support businesses that aim to solve public sector problems using innovative digital technologies.[273] Beyond this, coordinated initiatives bringing together different stakeholders to foster AI in the sector, specifically in NI, appear limited.

● **Opportunity for distinct impact:** There is a specific opportunity for distinct impact of AI in Northern Ireland, as it will be faced with a particularly hard border control problem due to Brexit, with strong incentives to automate better, e.g. in the area of Digital Identity. Integrating AI into border control would need significant data engineering and software expertise, which might be attractive to local software players to become the support system for this. However, ethical considerations pose key challenges with regards to the AI solutions in the public sector. For example, predictive border control has a history of bias and questionable science.

● **Investment opportunities:** The UK's £20m GovTech fund provides funding for businesses that aim to solve public sector problems using innovative digital technologies. As of now, 15 public sector problems have been funded across the UK, with themes ranging from waste tracking, identifying terrorist imagery, and cutting traffic congestion.[274] There is no specific funding for the development of AI in NI's sector provided through the City Deals or other significant investment programmes.

● **Industry readiness:** The public sector is a very challenging and expensive area for successful development of AI solutions. Services are disparate, data typically limited and hard to access, and ethical challenges are complex. This has been demonstrated by enormous and rather unprofitable investments such as by Google in state-provided health (e.g. Moorfields), citywide data (e.g. Sidewalk) and civic platforms. These challenges also hold true for the public sector in Northern Ireland. As a result, the sector receives a low rating for industry readiness.

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[273] UK Government, 2019, AI Sector Deal. Retrieved from:
https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal

[274] UK Government. Current GovTech Catalyst projects. Retrieved from:
https://www.gov.uk/guidance/current-govtech-catalyst-projects

3.1.13 Trade (wholesale and retail)

> In e-commerce, AI opportunities are already fairly dominated by big platform players such as Amazon that operate on a global scale. Therefore, there would need to be a specific niche where there is little competition with these big players if exploring the feasibility of impactful AI solutions in NI. However, this study did not point to such a distinct niche opportunity in NI's sector at the moment.
>
> **Overall assessment:**
>
> ⦿ State of the research base
>
> ⦿ Economic state of the sector in NI
>
> ⦿ Opportunity for AI

Trade (wholesale and retail) is the largest sector of NI's economy by GVA. Wholesale and retail is also labour-intensive: it is the third-largest sector of the economy by employment.

State of the research base

⦿ **Volume**: "Economy", which includes both finance and trade, is rated medium on scale of AI publication activity (UU: low, QUB: low). The "Economy" cluster also includes trade, but there is no focus on this within the UU research and very little in the QUB research.[275]

⦿ **Applicability**: The quality of "Economy" publications is high (UU: high, QUB: high). However, this is almost exclusively focused on finance. There is no evidence of significant NI research conducted for the trade sector.[276] However, other AI research might be significantly applicable to this sector (e.g. image processing, big data).

⦿ **Capability and community**: There is no evidence for any clusters specifically focusing on trade.

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[275] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[276] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

Economic state of the sector in NI

◉ ◉ **GVA & employment:** Trade (wholesale and retail) constitutes the largest sector of NI's economy by GVA, amounting to 14.1% of GVA. It is also a labour-intensive sector, making it also the largest sector by employment, amounting to a share of 17% of employment. Retail is the largest sector of NI's private sector economy. It provides over 140,000 jobs and makes up around 15% of Northern Ireland's economic output.[277]

◉ **Long-term growth path**: The sector's GVA is estimated to grow by 32% over the next ten years, thereby also expanding its share of the economy to 16.7%. In terms of absolute GVA growth over the next ten years, it ranks third, after biomedical R&D, and ICT and telco sector. Employment is reduced to a 15% share of employment in NI's economy. This indicates that the sector will grow more productive per head (as trade moves increasingly online and away from expensive city centres).[278]

Opportunity for AI

◉ **Global role for AI**: AI contributes considerable value to the global trade market. The global AI market size in retail alone amounts to c. US$ 2.7 billion in 2020 and is forecasted to grow at a CAGR of 32.7% during 2020-2026.[279]

The main opportunities for applying AI are in e-commerce, where it can be developed for the use in specialist areas such as product recommendations, optimising supply chains or wholesale. However, e-commerce opportunities are already fairly dominated by big platform players such as Amazon that operate on a global scale. While physical trade is not likely to be hugely affected by AI, the rise of digital technology is challenging conventional retailers to consider hybrid business models.[280]

◉ **Complementary initiatives**: Desk research and interviewees did not point to complementary initiatives in the sector that already focus on leveraging the potential of AI through multi-stakeholder initiatives.

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[277] TradeNI, 2019, Vision 2030. Retrieved from: http://www.manufacturingni.org/media/uploads/2205%20-%20Trade%20NI%20Vision%202030%20document%20web%20version.pdf

[278] Economic forecast of this study

[279] Cision PR Newswire, 2020, Artificial Intelligence (AI) in retail market size is projected to reach USDG 14.7 billion by 2026 - Valuates reports. Retrieved from: https://www.prnewswire.com/news-releases/artificial-intelligence-ai-in-retail-market-size-is-projected-to-reach-usd-14-7-billion-by-2026---valuates-reports-301090880.html

[280] Cision PR Newswire, 2020, Artificial Intelligence (AI) in retail market size is projected to reach USDG 14.7 billion by 2026 - Valuates reports. Retrieved from: https://www.prnewswire.com/news-releases/artificial-intelligence-ai-in-retail-market-size-is-projected-to-reach-usd-14-7-billion-by-2026---valuates-reports-301090880.html

- **Opportunity for distinct impact:** Research underpinning this study did not identify an opportunity for distinct impact for NI's trade sector globally on AI. Given the dominance of global players, such as Amazon, it would be very difficult for NI's SME-based economy to break into the AI market in this sector.

- **Investment opportunities:** The retail sector is not a specific focus of the Belfast or Derry / Londonderry City Deal, thus there will not be investment directed into this sector via this route. On a global level, the retail sector has benefited from some VC investment.

- **Industry readiness:** Given the limited evidence around the adoption of AI technologies by NI-based companies in the sector, industry readiness appears limited. When considering industry readiness, it is important to remember that many initiatives for AI in the sector are mostly job-destroying rather than job-creating.

3.1.14   Transportation and storage

Given that the sector is fairly traditional and only accounts for a small share of the NI economy, the opportunity for AI impact at scale is limited. Given the geographic position of NI and the importance of its ports, there is some opportunity for distinct impact in the development of a smart port. However, this would be a very narrow focus if the AICC were to focus on this.

Overall assessment:

● State of the research base

● Economic state of the sector in NI

● Opportunity for AI

This sector includes the movement of goods as well as e.g. packaging and inventory management.

State of the research base

● **Volume:** Transport was not explicitly mentioned in the Turing Institute report as a category. There is no further evidence of a significant body of AI research specifically focused on transport. This does not exclude that current research being done has applicability in the transport sector.

● **Applicability**: See above.

● **Capability and community**: No evidence for any clusters specifically focusing on transportation and storage, however, other AI research might be highly applicable to this sector (e.g. image processing, big data).

Economic state of the sector in NI

● ● **GVA & employment:** The sector currently has a medium contribution to the economy, with 3.9% share of GVA and 3.5% of employment.

● **Long-term growth path**: The sector is stagnating in terms of GVA, with a slightly declining share of the economy by GVA to 3.5%. In terms of employment, it is estimated to grow to 4.1%, indicating that it is becoming less productive on a per employed capita basis.[281]

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[281] Economic forecast of this study

Opportunity for AI

⦿ **Global role for AI**: The sector has relatively high potential for AI, but with a limited reach so far. Likely AI applications include demand prediction, route- and packaging optimisation, (which goods to combine on a vehicle), predictive maintenance of vehicle fleet, driver scheduling and rescheduling, and autonomous vehicles.

Artificial intelligence can enable trains, trucks, ships and planes to function autonomously, with the potential of reducing human errors that for instance could lead to traffic accidents. In road transportation, AI is already being successfully applied to take on certain driving functions through the use of sensors. In road traffic management, AI can analyse traffic patterns and volume and direct drivers to the fastest routes.[282]

Applying AI in shipping could provide an opportunity to improve the physical infrastructure and modernise ports - an area for significant opportunity in NI.

⦿ **Complementary initiatives**: NI's Draft Industrial Strategy 2030 highlights that investments in areas including transport as key to build a competitive modern economy in NI.[283] Beyond this, there do not appear to be initiatives that would be complementary in the field of AI adoption in the sector. Interviewees did not point to AI activities in the sector in NI.

⦿ **Opportunity for distinct impact:** Given the changes to the transportation and shipping sector driven by Brexit, there could be an opportunity for Northern Ireland to become an exemplar of a modern AI-enhanced port. Aiming to become a smart port, Belfast Harbour has launched a three-year investment programme to support the application of digital solutions, including 5G, AR and autonomous vessels.[284]

⦿ **Investment opportunities:** The support for the adoption of AI in this sector is not a specific focus of neither Belfast or Derry / Londonderry City Deal, thus there will not be investment directed into this sector via this route.

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[282] European Parliamentary Research Service, 2020, Artificial intelligence in transport: current and future development, opportunities and challenges. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/635609/EPRS_BRI(2019)635609_EN.pd f

[283] Department for the Economy, 2017, Economy 2030: a consultation on an Industrial Strategy for Northern Ireland. Retrieved from: https://www.economy-ni.gov.uk/sites/default/files/consultations/economy/industrial-strategy-ni-consultation-document.pdf

[284] J O'Halloran, 2019, VR over 5G helps Belfast Harbour vision to become smart port. Retrieved from: https://www.computerweekly.com/news/252472584/VR-over-5G-helps-Belfast-Harbour-vision-to-become-smart-port

● **Industry readiness:** The industry is fairly traditional so it would require new sensors or other data creation to make the opportunity for AI solutions workable. However, the industry is used to an amount of data tracking, e.g. telematics and digital tachographs, which will be key to the success of AI solutions.

3.2 Cross-cutting perspectives

Beyond the traditional sectors, this research also considered opportunities within "cross-cutting" perspectives. These are AI or AI-enabled technologies that can be applied across a wide range of sectors. As current assessments show that AI's greatest potential lies with implementing AI into existing businesses to foster new ways of working, efficiency, accuracy and thinking[285], focusing on cross-cutting perspectives could help NI companies develop their AI capabilities, agnostic of a specific sector. The three cross-cutting perspectives identified in the first project phase as having the highest potential for Northern Ireland are augmented and virtual reality, cryptography and cyber security, and Internet of Things. The following section outlines the findings of the in-depth assessment for these.

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[285] Kai-Fu Lee, 2020, Artificial Intelligence and the Future of Work: A Chinese Perspective. Retrieved from: https://www.bbvaopenmind.com/en/articles/artificial-intelligence-and-the-future-of-work-chinese-perspective/

3.2.1 Augmented / virtual reality (AR/VR)

AR and VR have applicability across sectors and are expected to develop rapidly over the next decade. AR and VR development in Northern Ireland is nascent, with a range of new initiatives recently started - most with a focus on creative industries. However, as AR and VR development is still in very early stages in most sectors, there is as of yet no distinct opportunity for impact.

Overall assessment:

◉ State of the research base

◉ Economic state of the sector in NI

◉ Opportunity for AI

Immersive technologies include augmented reality (AR), which adds digital elements to a live view through the use of a mobile device, and virtual reality (VR), which refers to a complete immersion experience in a virtual world through the use of VR goggles. It has links to the creative industries, but with wide application ranging from training to healthcare, to product development.

State of the research base

◉ **Volume:** Historically, there has not been significant, cross-cutting research on virtual- or augmented reality out of QUB and UU. This is likely to change with initiatives such as the Creative Industries Institute (see below), which has conducted research, and will likely increase the volume of AR/VR research.

◉ **Applicability**: While there is no existing significant body of research, the new initiatives listed below have a strong emphasis on industry collaboration and applicability.

◉ **Capability and community**

- The Creative Industries Institute (CII) at Ulster University brings together research in creative disciplines, and will focus on developing research in VR and AR.[286]

- Future Screens NI works with UU and QUB and a range of industrial partners to deliver technical skills, opportunity and growth to broadcast, animation, games and immersive technologies. This will include some capacities in VR and AR.[287]

- The Screen and Media Lab (SMIL) that will be established as part of the Belfast Region City Deal will specialise in four strands, of which one is immersive

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[286] Ulster University, 2020, Creative Industries Institute. Retrieved from: https://www.ulster.ac.uk/cii

[287] Future Screens NI, 2020, About. Retrieved from: https://www.futurescreens.org/about

technologies. It aims to connect to a wider range of sectors, such as MedTech, FinTech, advanced manufacturing, and hard- and software innovation.[288]

- The Virtual and Augmented Reality Centre (VARC) at North West Regional College focuses on creative and cultural sectors with applicability to SMEs.[289]

- UU's Intelligent Systems Research Centre (ISRC), part of CARL, is developing new contexts for computers through wearables and technology. It has spun out the award-winning NeuroCINCIS Ltd. to develop AI-enabled technology.[290]

- The Virtual Reality and Robotics group at QUB's School of Electronics, Electrical Engineering and Computer Science is a small research group working on various applications of virtual reality in e.g. health and environment.[291]

- QUB's Centre for Intelligent Autonomous Manufacturing Systems (i-AMS) is an interdisciplinary team with researchers that work to help shape the manufacturing plant of tomorrow's world. It works across a spectrum of topics including VR and AR.[292]

Economic state of the sector in NI

◉◉ **GVA & employment:** Currently, AR and VR do not play a significant role in the NI economy. In the UK, the estimated boost to GDP by AR and VR is 0.2%, with 0.1% of jobs enhanced.[293] It is likely these numbers are lower in the NI as there is more activity around some AI hubs in other parts of the UK.

◉ **Long-term growth path**: Economic impact of AR and VR will multiply in size over the next couple of years. It is projected to grow from a 0.2% boost of the economy in

[288] Belfast region city deal: innovation and digital, 2020, Screen and Media Innovation Lab. Retrieved from: https://www.brcd-innovation.co.uk/projects/smil

[289] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf and interviews

[290] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[291] Queen's University Belfast, 2020, Virtual Reality and Robotics. Retrieved from: https://www.qub.ac.uk/research-centres/EPIC/Research/VirtualRealityandRobotics/

[292] Queen's University Belfast, 2020, i-AMS Vision. Retrieved from: https://www.qub.ac.uk/sites/iams/Vision/

[293] PriceWaterhouseCoopers, 2019, Seeing is believing: how VR and AR will transform business and the economy. Retrieved from: https://www.pwc.com/seeingisbelieving

2020 to 2.4% in 2030. UK jobs enhanced are expected to grow over tenfold from 0.1% (2020) to 1.2% of jobs enhanced in 2030.[294]

Opportunity for AI

⦿ **Global role of AI:** AR and VR have a wide range of applications across sectors, most notably in product and service development, healthcare (e.g. for learning for high-risk procedures), development and training, process improvements (e.g. construction workers using AR to flag possible construction faults), and retail and consumer engagement.[295] The hardware for VR/AR is still developing. There are several established headset brands, such as Oculus, but also some open platforms, like Android, which means that adoption of VR/AR solutions would not necessarily require hardware partnerships.[296] As adopting the solutions does not require significant access to data sources to get started with a new application, it is more "forgiving" than other applications in, for instance, the FinTech sector. Some key barriers are the focus on the cost of the hardware instead of the ROI. Even though cost has dropped significantly, VR/AR is often viewed as a "nice to have", rather than key technology. Consumer distrust in the application and reluctance to engage with it is another barrier.[297]

⦿ **Complementary initiatives**: There have been a number of established initiatives for AR and VR recently aimed to enhance Northern Ireland's VR and AR capabilities. Under the City Deals, these will be even further extended[298]. Most initiatives have a focus on opportunities for the creative industry. Currently, the Catapult Immersive Lab Belfast provides a space for learning, testing and showcasing VR and AR solutions.[299] The CII at Ulster University and the £13m Future Screens NI are both

[294] PriceWaterhouseCoopers, 2019, Seeing is believing: how VR and AR will transform business and the economy. Retrieved from: https://www.pwc.com/seeingisbelieving

[295] PriceWaterhouseCoopers, 2019, Seeing is believing: how VR and AR will transform business and the economy. Retrieved from: https://image.s50.sfmc-content.com/lib/fe31117075640475701c74/m/1/b7b1cff0-265b-498a-b370-cdd8bf362e2f.pdf

[296] ARPost, 2018, Top Players in the Augmented Reality and Virtual Reality Space. Retrieved from: https://arpost.co/2018/01/15/top-players-augmented-reality-virtual-reality-space/

[297] PriceWaterhouseCoopers, 2019, Seeing is believing: how VR and AR will transform business and the economy. Retrieved from: https://image.s50.sfmc-content.com/lib/fe31117075640475701c74/m/1/b7b1cff0-265b-498a-b370-cdd8bf362e2f.pdf

[298] Matrix, 2018, Matrix Creative Technology Report 2018. Retrieved from: http://matrixni.org/wp-content/uploads/2018/04/MATRIX-Creative-Technologies-report.pdf

[299] Digital Catapult, 2020, Immersive labs: discover the potential of immersive technologies. Retrieved from: https://www.digicatapult.org.uk/labs/immersive-labs

leveraging AR and VR for the creative industries.[300] Through the Derry / Londonderry City Deal, the Virtual and Augmented Reality Centre (VARC) at North West Regional College will be established, which will mainly focus on SMEs in the creative and cultural sectors.[301] The Screen and Media Innovation initiative (SMII) will be established under the Belfast Region City Deal will focus on VR and AR and aim to connect it to a wider range of sectors, such as MedTech, FinTech, advanced manufacturing, and hard- and software innovation.[302]

◉ **Opportunity for distinct impact:** There are no indications of an opportunity for distinct impact driven by the conditions in Northern Ireland.

◉ **Investment opportunities:** Funding opportunities for AR and VR are mainly focused on the creative sector. UKRI's Audience of the Future fund focuses on virtual, augmented and mixed reality in, for example, entertainment, sports, museums, shops and classrooms.[303] Within the UKRI Creative Industries cluster programme, which will commit £120m over the next 5 years, Future Screens NI has been awarded funding for e.g. immersive technologies.[304] Further funding is expected under the City Deals, for example for the VARC and SMII.

◉ **Industry-readiness:** The applicability across sectors makes AR and VR as relevant for NI's sectors as it is in other countries. There are multiple NI companies already working on VR and AR, such as RETiNiZE (digital studio)[305], Sentireal (training using AR/VR)[306], Edgeways (digital studio)[307] and Yellow Design (creative agency also working with advanced manufacturing).[308] While the range of initiatives outlined

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[300] Ulster University, 2020, Creative Industries Institute. Retrieved from: https://www.ulster.ac.uk/cii and Future Screens NI, 2020, About. Retrieved from: https://www.futurescreens.org/about

[301] Derry City & Strabane District Council, 2018, Delivering inclusive growth: city deal for the Derry-Londonderry city region. Retrieved from: https://www.derrystrabane.com/getmedia/14715373-d8cd-44de-957a-e806234a3dac/6525_DCSDC_GrowthDeal_A4_Sept_Amended_PRINT-(1).pdf and interviews

[302] Belfast Region City Deal: Innovation and Digital, 2020, Screen and Media Innovation Lab. Retrieved from: https://www.brcd-innovation.co.uk/projects/smil

[303] UKRI, 2020, Audience of the future. Retrieved from: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/audience-of-the-future/

[304] UKRI, 2020, Creative industries clusters. Retrieved from: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/creative-industries-clusters/ and Future Screens NI, 2020, R&D for the Creative Industries in Northern Ireland. Retrieved from: https://www.futurescreens.org/

[305] RETiNiZE, 2020, About. Retrieved from: https://www.retinize.com/

[306] Sentireal, 2020, What we do. Retrieved from: https://www.sentireal.com/what

[307] Edgeways, 2020, Edgeways. Retrieved from: http://www.edgeways.co.uk/

[308] Yellow Design, 2020, AR & VR. Retrieved from: https://www.yellowdesign.tv/ar-vr/advanced-manufacturing/

above have a focus on applicability of AR and VR (although mostly in creative industries) VR and AR so far is in very early stages in all sectors except for the creative sector.

3.2.2 Cryptography and cyber security

> Northern Ireland has a well-established cyber security cluster that combines academic excellence with cyber security innovation in large and small, specialised companies. The main focus of this specialisation is on the financial/FinTech sector. Interviewees suggest a distinct opportunity for the AICC to further develop this AI capacity.
>
> **Overall assessment:**
>
> ◉ State of the research base
>
> ◉ Economic state of the sector in NI
>
> ◉ Opportunity for AI

Cryptography and cyber security can benefit from AI by various types of threat detection, secure storage and transmission of information. It has clear links with the FinTech- and insurance sector but can be more broadly applied to, for instance, digital identifiers in the sub-sector of border security.

State of the research base

◉ **Volume:** The scale of AI publication activity in cyber security NI is rated as high (UU: low, QUB: high). There is a relatively high volume of cyber security researchers in both universities, as well as some with a specific focus on cryptography, including more speculative topics such as post-quantum cryptography.[309] There is also a significant amount of commercial R&D through the NI Cyber Security Cluster.

◉ **Applicability**: The quality of research publications is assessed as high (UU: medium, QUB: high).[310] Through collaborations with industry as well as private R&D, there is research that can be commercialised.

◉ **Capability and community**

- QUB's Centre for Secure Information Technologies (CSIT) is a National Innovation and Knowledge centre, bringing together 90 staff for cyber security, and is highly regarded by NI and UK stakeholders. It focuses on driving research breakthroughs

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[309] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[310] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

in secure information technologies, and connecting these to innovation and commercialisation. Key areas are secure connected devices, networked security systems, industrial control systems security and security intelligence. It has attracted funding from UKRI and Horizon 2020.[311] CSIT applies a membership model to connect with companies, which include Allstate, Seagate and Thales.[312]

- UU's Intelligent Systems Research Centre (ISRC) focuses on cyber security to develop secure and connected technologies.[313]

- There is additional research in this area through the cyber security cluster, which was also highlighted by interviewees.[314]

Economic state of the sector in NI

◉◉ **GVA & employment:** Thanks to the Northern Ireland cyber security cluster, the share of employment and GVA is slightly higher compared to some parts of the UK. However, as part of the total NI economy, GVA and employment is relatively minor. Companies are often registered outside of Northern Ireland, but have cyber security R&D capacity in the region, making it hard to estimate GVA. The UK-wide GVA of cyber security is estimated to £3.77bn, or about 0.2% of total GVA. Government estimates show that 1.4% of NI employment is in cyber security.[315]

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[311] Queen's University Belfast, 2020, CSIT. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/

[312] Queen's University Belfast, 2020, CSIT Full members. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/CSITMembers/FullMembers/

[313] Ulster University, 2020, About Intelligent Systems Research Centre. Retrieved from: https://www.ulster.ac.uk/research/topic/computer-science/intelligent-systems-research-centre/about

[314] Department of Finance, 2018, Cyber Security - A strategic framework for action. Retrieved from: https://www.finance-ni.gov.uk/sites/default/files/publications/dfp/Cyber%20Security%20-%20A%20strategic%20Framework%20for%20Action.pdf

[315] Ipsos Mori, Perspective Economics and QUB CSIT for UK DCMS, 2020, UK Cyber Security Sectoral Analysis 2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/861945/UK_Cyber_Sectoral_Analysis__2020__Report.pdf

- **Long-term growth path**: Cyber security has gone through rapid economic growth and UK GVA has increased by 60% over the past two years.[316] The market size of Europe's cyber security market is expected to double over the next seven years.[317]

Opportunity for AI

- **Global role of AI:** Cyber security has gained attention over the past years across industries and in both the private and public sector, which has increased the demand for cyber security activity.[318] AI in cyber security is applied in two, polar, ways: while it has led to new ways of securing and encrypting content, criminals increasingly use AI to circumvent traditional security measures, such as through voice mimicking.[319] Uptake and application is especially high in the FinTech sector, where there is an interest to buy AI solutions to counter cyber security threats, such as network attacks, email phishing and server vulnerabilities. Applications of AI in cyber security can include detecting anomalies and vulnerabilities in code and help in observing and defending against cyber-attacks as they happen.[320]

- **Complementary initiatives:** The Northern Ireland Cyber Security Cluster promotes the development of cyber security technologies and brings together over 60 companies that work in finance, banking, insurance, legal, telecom, threat intelligence, defence and healthcare.[321] Interviewees suggest that the cluster has led to the growth of the FinTech sector in NI, which will be further supported by a focus of the Belfast Region City Deal on the sector. In addition, multiple companies

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[316] Ipsos Mori, Perspective Economics and QUB CSIT for UK DCMS, 2020, UK Cyber Security Sectoral Analysis 2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/861945/UK_Cyber_Sectoral_Analysis__2020__Report.pdf

[317] Fortune Business Insights, 2020, Technology & Media: Cyber security market. Retrieved from: https://www.fortunebusinessinsights.com/industry-reports/cyber-security-market-101165

[318] McKinsey & Company, 2019, Perspectives on transforming cybersecurity. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/McKinsey%20Solutions/Cyber%20Solutions/Perspectives%20on%20transforming%20cybersecurity/Transforming%20cybersecurity_March2019.ashx

[319] World Economic Forum, 2019, AI is the latest weapon cybercriminals are exploiting. Retrieved from: https://www.weforum.org/agenda/2019/09/4-ways-ai-is-changing-cybersecurity-both-in-attack-and-defense/

[320] National Science & Technology Council, 2020, Artificial intelligence and cybersecurity: opportunities and challenges. Retrieved from: https://www.nitrd.gov/pubs/AI-CS-Tech-Summary-2020.pdf

[321] NI Cyber, 2020, Northern Ireland Cyber Security Cluster. Retrieved from: https://www.nicyber.tech/ NI Cyber Security Centre, 2020, About us. Retrieved from: https://www.nicybersecuritycentre.gov.uk/about-us-0

not founded in Northern Ireland have based their cyber security R&D in the region.[322] The membership model of CSIT at QUB enables a strong connection between the research base and Northern Irish companies.[323]

◉ **Opportunity for distinct impact:** The existing research capabilities in cyber security and the cyber security cluster put Northern Ireland in a good position for cyber security. Sitting alongside major hubs for cyber companies and investment, such as London, NI is recognised for its niche in cyber security.[324] Particular strengths are unclonable chips, hardware and post-quantum cryptography, with potential to take off in the next couple of years.[325]

◉ **Investment opportunities:** Cyber security has managed to attract significant funding to Northern Ireland. Since 2017, £22m in investments have been secured, compared to £6m in Scotland and £25m in Wales.[326] CSIT has managed to combine academic research with private-sector investment.[327] There are several UKRI funding opportunities for cyber security for example in commercialising quantum devices - one of the focus points of UKRI's Industrial Strategy Challenge fund. It is looking at secure encryption and keeping data safe under the pioneer fund projects.[328] Cyber security has further been identified by UKRI's EPSRC as a priority for the global uncertainties programme.[329] Lastly, as cyber security and cyber risk are high on the

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[322] Ipsos Mori, Perspective Economics and QUB CSIT for UK DCMS, 2020, UK Cyber Security Sectoral Analysis 2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/861945/UK_Cyber_Sectoral_Analysis__2020__Report.pdf

[323] Queen's University Belfast, 2020, CSIT Full members. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/CSITMembers/FullMembers/

[324] Ipsos Mori, Perspective Economics and QUB CSIT for UK DCMS, 2020, UK Cyber Security Sectoral Analysis 2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/861945/UK_Cyber_Sectoral_Analysis__2020__Report.pdf

[325] Department of Finance, 2018, Cyber Security - A strategic framework for action. Retrieved from: https://www.finance-ni.gov.uk/sites/default/files/publications/dfp/Cyber%20Security%20-%20A%20strategic%20Framework%20for%20Action.pdf

[326] Ipsos Mori, Perspective Economics and QUB CSIT for UK DCMS, 2020, UK Cyber Security Sectoral Analysis 2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/861945/UK_Cyber_Sectoral_Analysis__2020__Report.pdf

[327] Queen's University Belfast, 2020, CSIT membership model. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/CSITMembers/Membershipmodel/

[328] UKRI, 2020, Commercialising quantum technologies. Retrieved from: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/quantum-technologies/

[329] UKRI EPSRC, 2020, Cybersecurity. Retrieved from: https://epsrc.ukri.org/research/ourportfolio/themes/globaluncertainties/subthemes/cybersecurity/

agenda of an increasingly large number of companies, there is a high likelihood of further private investment, especially for the financial sector.

⦿ **Industry-readiness:** There is a relatively large number of companies working on cyber security in Northern Ireland, although not all are headquartered in the region. Notable companies include tech companies such as Kainos and Seagate, finance and insurance companies, such as Allstate's Northern Ireland branch, and First Derivatives, and security and defence companies, such as BAE Systems and Thales.[330] It also includes more specialised companies, such as Angoka, Anomali, Cyphra and SaltDNA[331]. There is scope for a wider service industry around this area, with solutions not necessarily having to be operated by AI experts. This means that local businesses could also join the ecosystem. However, some interviewees point out that there might not be an SME base or end users in NI for this specialisation, or that the current SME-base is not connected enough.[332]

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[330] Queen's University Belfast, 2020, CSIT Full members. Retrieved from: https://www.qub.ac.uk/ecit/CSIT/CSITMembers/FullMembers/

[331] NI Cyber, 2020, Member companies. Retrieved from: https://www.nicyber.tech/companies

[332] Stakeholder interview

3.2.3 Internet of Things and sensors

> The Internet of Things and sensors area is a widely applicable area of AI. There is some knowledge and complementary initiatives in Northern Ireland, but activity is scattered. The sector does not hold a big opportunity vis-a-vis some other sectors.
>
> **Overall assessment:**
>
> ⦿ State of the research base
>
> ⦿ Economic state of the sector in NI
>
> ⦿ Opportunity for AI

The Internet of Things describes physical objects and sensors that rely on software and technology which connects to other devices and systems over the Internet. It has wide applications in many industries.

State of the research base

⦿ **Volume:** The scale of AI publication activity in NI for Internet of Things is assessed as high (UU: high, QUB: N/A). Many people work on IoT and sensors-research in different disciplines, although this exclusively sits within UU.[333]

⦿ **Applicability**: The quality of publications is high (UU: high, QUB: N/A). The range of research in this area is broad, including activity IoT, smart sensors, brain-computer interfaces (BCI) and activity recognition etc.[334] However, there is no clear place where the research is brought together for commercial application.

⦿ **Capability and community**: While there are no specific research centres designated to IOT and sensors, there is capability across different departments ranging from health-, to computer science and chemistry. IoT will be one of the focus areas of the BT Ireland Innovation Centre.[335]

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[333] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[334] Matrix Northern Ireland Science Industry Panel (prepared on behalf of the Alan Turing Institute), 2019, Artificial Intelligence research in Northern Ireland: 2019 report. Retrieved from: https://matrixni.org/wp-content/uploads/2019/06/Artificial-Intelligence-Research-in-Northern-Ireland.pdf

[335] Ulster University, 2020, BT Ireland Innovation Centre. Retrieved from: https://www.ulster.ac.uk/research/topic/computer-science/btiic

Economic state of the sector in NI

⦿⦿ **GVA & employment:** Given the wide applicability of IoT across sectors, there is little ability to evidence the current employment within IoT, as can be done for traditional sectors. Global market estimates for the value of IoT vary widely depending on the source consulted. Data points include an estimate from US$ 151bn (2018, IoT analytics), and forecasts of US$ 520bn (2021, Bain) or US$ 1.2tn (2022, IDC).[336]

⦿ **Long-term growth path**: Gartner finds that IoT connections have been growing about 20% per annum between 2018 and 2020, with particularly high uptake in utilities and physical security.[337] The amount of IoT devices is forecasted to triple in 2023 compared to 2018.[338]

Opportunity for AI

⦿ **Global role of AI:** While in theory, there is much potential for IoT and sensors, the sector so far has not seen significant consistent growth (e.g. in application for smart cities). Sensors and their support structures are relatively expensive, hard to install and manage, non-standardised, and often require significant business change to gain the benefit. This poses significant hurdles for their adoption.[339] IoT and sensors have application in a large number of sectors and are less sector-specific than some other cross-cutting technologies.

⦿ **Complementary initiatives:** IoT is a focus area of the Insight SFI Centre in the Republic of Ireland, with a specific focus on smart urban applications as well as

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[336] L. Columbus (Forbes), 2018, 2018 roundup of internet of things forecast and market estimates. Retrieved from: https://www.forbes.com/sites/louiscolumbus/2018/12/13/2018-roundup-of-internet-of-things-forecasts-and-market-estimates/

[337] L. Goasduff (Gartner), 2019, Gartner says 5.8 billion enterprise and automotive IoT endpoints will be in use in 2020. Retrieved from: https://www.gartner.com/en/newsroom/press-releases/2019-08-29-gartner-says-5-8-billion-enterprise-and-automotive-io#:~:text=Gartner%2C%20Inc.,a%2021%25%20increase%20from%202019.&text=Utilities%20will%20be%20the%20highest,to%20reach%201.37%20billion%20endpoints

[338] McKinsey & company, 2019, Growing opportunities in the Internet of things. Retrieved from: https://www.mckinsey.com/industries/private-equity-and-principal-investors/our-insights/growing-opportunities-in-the-internet-of-things

[339] N. Ismail, 2017, The Internet of Things: Success or bust? Retrieved from: https://www.information-age.com/iot-success-bust-123468534/

public services.[340] The £28m BT Innovation Centre in Belfast will conduct research on the intersection between AI, IoT and telecommunications in partnership with UU.[341]

◉ **Opportunity for distinct impact:** IoT might be more accessible to SMEs, on which the NI economy is highly reliable, than some other AI applications.[342] As most sensors are currently manufactured in China, given the increasing distrust towards Chinese hardware for sensitive applications, moving to produce sensors locally may provide an opportunity to increase trust in these applications. The ability to implement AI securely on a sensor network would be highly beneficial in a number of these cases. Beyond this, it may also become relevant for the AMME sector if NI becomes a manufacturer of sensors.

The implications of Brexit for the border on the island could provide an opportunity for distinct impact, with sensors being relevant for tracking or security (e.g. motion, vibration, CCTV or other types of surveillance).

◉ **Investment opportunities:** Funding for IoT for healthcare services and manufacturing distribution was previously obtained through Digital Catapult.[343] Sensors is a funding area of the EPSRC, with over £48m available, although so far UU and QUB have only secured one grant each under this area.[344] The potential for private sector investment is less clear: over the past years there has been a shift as early investments in IoT did not turn out to be as profitable as expected. However, a significant and growing number of companies are using sensors.[345]

◉ **Industry-readiness:** There is little evidence of a cluster with specialised IoT knowledge in the private sector. Companies involved in IoT technology include

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[340] Science Foundation Ireland, year unknown, Insight: SFI Research Centre for Data Analytics. Retrieved from: https://www.sfi.ie/sfi-research-centres/insight/

[341] British Telecom, 2017, BT chooses Northern Ireland for £28.6 million innovation centre and creation of 50 graduate jobs. Retrieved from: http://home.bt.com/tech-gadgets/tech-news/bt-belfast-northern-ireland-innovation-centre-11364232902959

[342] McKinsey & company, 2019, Growing opportunities in the Internet of things. Retrieved from: https://www.mckinsey.com/industries/private-equity-and-principal-investors/our-insights/growing-opportunities-in-the-internet-of-things

[343] Digital Catapult, 2020, Digital Catapult announces new IoT regional patterns in Sunderland, Ulster and Bournemouth. Retrieved from: https://www.digicatapult.org.uk/news-and-insights/press/digital-catapult-announces-new-iot-regional-partners-sunderland-ulster-bournemouth

[344] UKRI EPSRC, 2020, Sensors and instrumentation. Retrieved from: https://epsrc.ukri.org/research/ourportfolio/researchareas/instrumentation/

[345] K. Schwab, 2018, Is the Internet of Things dead, or is it growing up? Retrieved from: https://www.rga.com/news/articles/is-the-internet-of-things-dead-or-is-it-growing-up

Kainos[346] and British Telecom[347], and smaller companies such as See.Sense, which was supported through Digital Catapult.[348] As the technology is more easily available to SMEs, there is some focus on how to incorporate this in their business.[349] In addition, there's anecdotal evidence of uptake in the public sector, for example through the use of sensors in wastewater facilities.

[346] Kainos, 2020, Internet of Things (IoT). Retrieved from: https://www.kainos.com/what-we-do/iot

[347] British Telecom, 2017, BT chooses Northern Ireland for £28.6 million innovation centre and creation of 50 graduate jobs. Retrieved from: http://home.bt.com/tech-gadgets/tech-news/bt-belfast-northern-ireland-innovation-centre-11364232902959

[348] See.Sense, 2020, About us. Retrieved from: https://seesense.cc/pages/about-us

[349] SmartCitiesWorld news team, 2018, IoT helps Northern Ireland tackle key challenges. Retrieved from: https://www.smartcitiesworld.net/news/news/iot-helps-northern-ireland-tackle-key-challenges-2910

insights from
the economic
model forecast

4 Insights from the economic model forecast

The economic model that is shared together with this narrative report has informed the assessment of the economic state of the sectors in NI as outlined in the previous chapter. Beyond this, it provides a scenario-based projection for the impact of AI on GVA and employment under a set of manually-adjustable assumptions. Overall, the model foresees a 3.3% GVA boost and 11% of jobs meaningfully affected by AI by 2030 in the sectors subject to this study, which collectively account for about 80% of the NI economy.

4.1 Sectoral contribution to NI's economy now and in 2030

The sectors covered in this study together amount to 78% of 2018 GVA in NI. The graph in Figure 1 provides an overview of the current and forecasted sectoral share of the sectors.

Figure 1: Sectoral development of GVA and employment affected 2018 and 2030
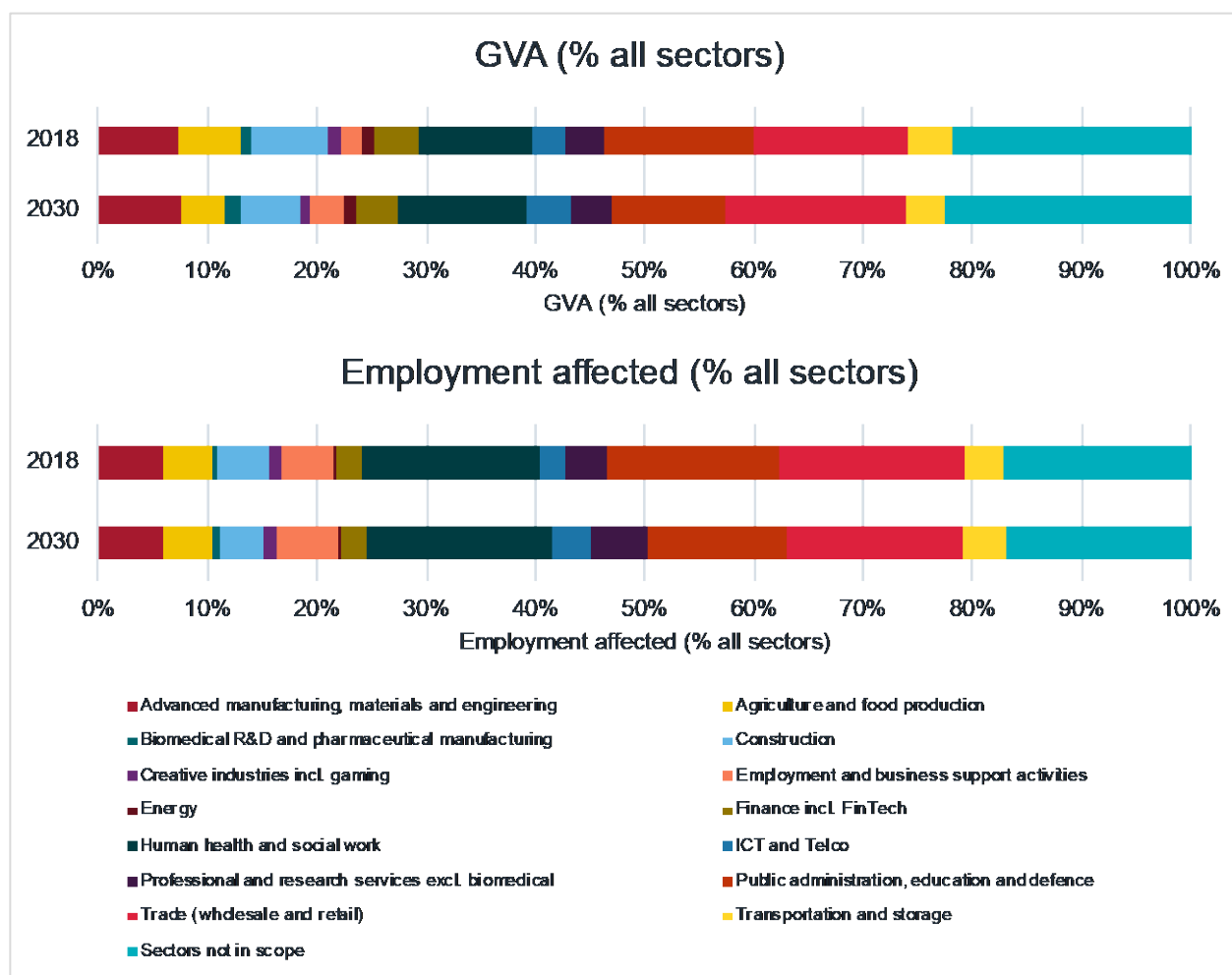
The forecasts to 2030 are driven by an examination of the trends in historical data, principally from 2008 to 2018. At the level of the sectors analysed in this study, the allocative share of the economy tends to adjust only incrementally over 5-10 year periods, although occasional years can see sharp moves in isolated areas, e.g. due to business closures, reclassifications or business relocations.

The largest sectors are 'trade (wholesale and retail)', 'public administration, education and defence' and 'human health and social care'. These are also the top-three sectors in terms of employment, although the human health sector employs slightly more people than the public administration, education and defence sector.

Sector allocation is set to change slightly over the next decade. Sectors with the largest gains include 'employment and business support activities', 'ICT and telco' and 'biomedical R&D and pharmaceutical manufacturing'. Sectors that are projected to shrink most relative to others are 'agriculture and food production', 'creative industries incl. gaming' and 'public administration, education and defence'. The decline in the 'creative industries' sector is driven particularly by publishing activities (SIC 58) and programming / broadcasting activities (SIC 60), which have been on a gradual, long-term decline from the early 2000s through to 2018.

In line with recent historical trends, the 'ICT and telco' sector is projected to increase its share of people employed, although the biggest absolute increase in employment will be in 'employment and business support services' and 'professional and research services excl. biomedical'.

Combining the sectoral trend projections for GVA and employment points towards relative shifts in per capita productivity. For instance, relative productivity over the forecast period is expected to decline in 'agriculture and food production', 'energy', 'ICT and telco', and 'transportation and storage' sectors. This reflects recent trends, given shifts towards labour intensity, lower cost labour and commodification relative to other industries which are better able to draw on new technologies, shifts in cost base or capital investments to increase GVA per hour worked. Meanwhile, productivity may increase in retail and wholesale trade, reflecting ongoing reductions in shopfront/staffing while sustaining sales via a delivery-focused or self-service business model. Modest increases are also anticipated in sectors with significant, ongoing potential for automation to enhance GVA while reducing relative employment requirements, such as finance, business support, and biomedical R&D.

4.2 Impact of AI on key sectors globally

The estimate of the impact of AI on sectors globally is constructed from multiple sources (see Chapter 2.2). The PwC report "*The macroeconomic impact of artificial intelligence*" gives key insights into which GDP gains of selected key sectors are attributed to either product enhancements or increased productivity, as well as general estimates per sector for 2030 (see Figure 2).

Based on this study's economic model, from the sectors that are listed in the model, projections show that globally, 'biomedical R&D and pharmaceutical manufacturing' (accounting for 8.5% of GVA by 2030), 'creative industries incl. gaming' (8.0%) and 'finance incl. Fintech' and 'transportation and storage' (7.0%) are most affected by AI. In terms of employment, the sectors that are most affected globally are 'transportation and storage' (28.5% of employment by 2030 affected) and 'biomedical R&D' and 'employment and business support activities' (22.5%).

Figure 2: PwC estimates: GDP gains in 2030 resulting from AI by selected industry sector (% of GDP)[350]
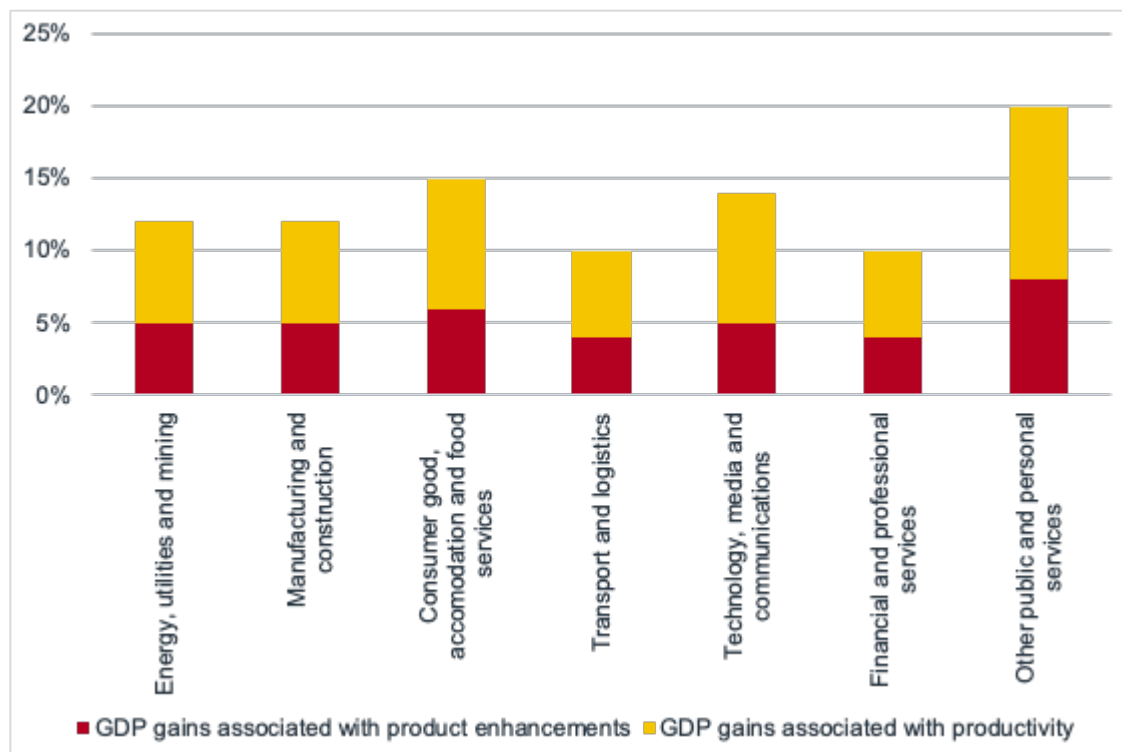
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[350] PricewaterhouseCoopers, 2018, The macroeconomic impact of artificial intelligence. Retrieved from: https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf, p. 52.

4.3 Impact of AI on key sectors in Northern Ireland

The impact of AI per sector in Northern Ireland provided in the economic model is based on the global estimate, adjusted based on specific local strengths and shortcoming (see Chapter 2.2 for methodology).

For the midpoint forecast of the impact of AI on key sectors of NI in 2030, 'biomedical R&D and pharmaceutical manufacturing' (8.5%), 'Finance incl. FinTech' (7.7%) and 'creative industries' (7.6%) are the three industries with the highest GVA boost due to AI relative to the other sectors. However, as other sectors contribute a larger share to NI's GVA, the impact on GVA in 2030 in absolute terms is highest in trade (£0.3bn), AMME (£0.2bn) and 'human health and social work' (£0.2bn).

Employment in 2030 will be mostly affected by AI in the following sectors: 'Transportation and storage' (26%), 'biomedical R&D' (23%) and AMME (19%). In absolute terms, employment in trade and human health are most affected, again driven by the large starting scale of these sectors, accounting for 17% and 16% of 2018 employment respectively.

Figure 3: AI impact on NI sector GVA and employment at 2030 (%)
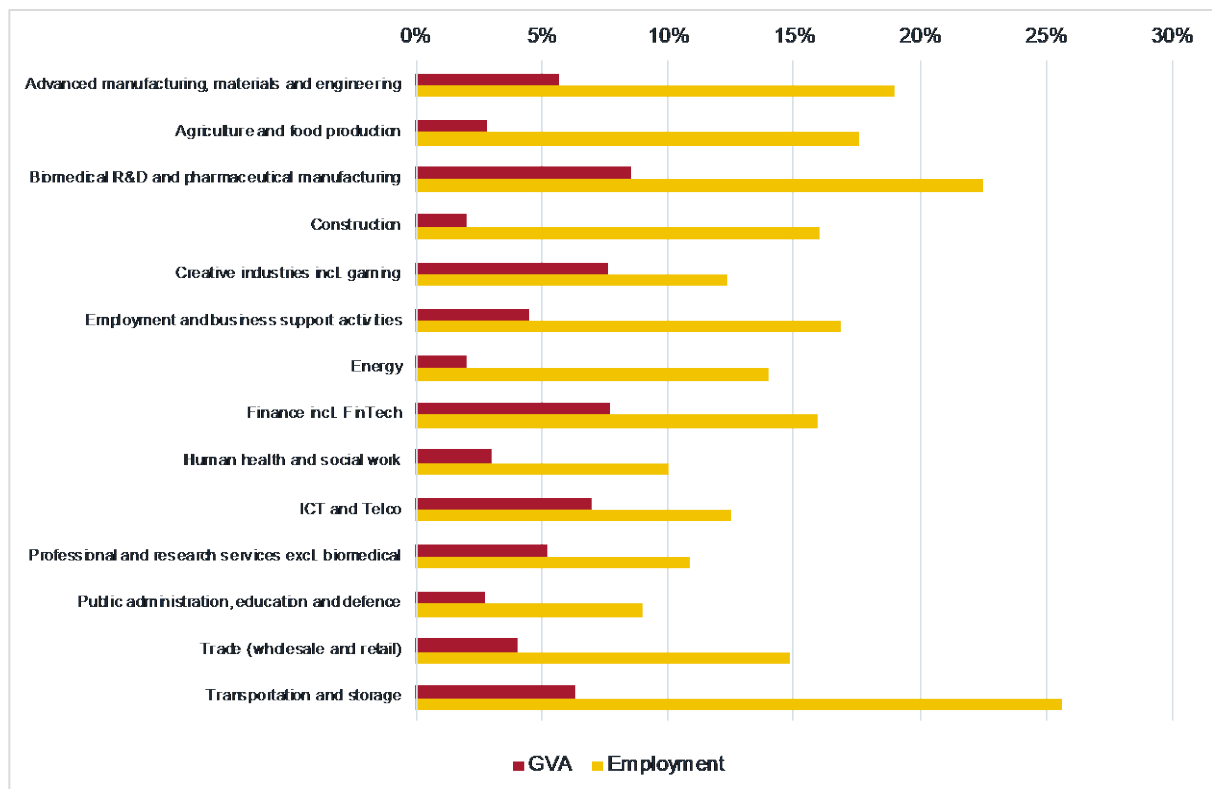
implications and
recommendations

5 Implications and recommendations

The objective of this foresight study was to provide an evidence base with regards to opportunities and challenges for AI across key sectors of NI's economy, and to develop recommendations with regards to the sectoral approach of the AICC.

5.1 Reflections of findings

The in-depth assessment outlined in Chapter 3 identified several sectors that stand out highly across most categories. Opportunities and challenges with regards to the adoption of AI across those sectors are briefly summarised in **Table 4** below:

Table 3: Overview of sectors with highest relative attractiveness

Sector	Assessment	Opportunities and challenges
AMME	⊚⊚⊚	AMME is a significant driver of NI's economy and AI offers significant potential to reshape the sector in areas such as robotics and 3D printing. To leverage its transformative potential, it will be key for sector leaders to embrace AI solutions and to focus on the sub-sectors where NI's expertise is highly specialised and exportable, such as in the area of machinery and transport equipment.
Biomedical R&D and pharmaceutical manufacturing	⊚⊚⊚	While a small sector in NI's economy, there are already a range of complementary initiatives in NI, and the UK more broadly, to expand the opportunities for impact of AI across life sciences. There is opportunity to build on existing local strengths, e.g. around diagnostics. However, given the multitude of initiatives, it would be challenging for new initiatives to have a distinct impact at a national and international level.
Cryptocurrency and cybersecurity	⊚⊚⊚	NI has a well-established cyber security cluster that combines academic excellence with cyber security innovation in large and smaller, specialised companies. Stakeholders made the connection between the

		academic cyber cluster and the emergence of the FinTech cluster.
		However, it is currently too small in terms of investment capital and the number of companies to compete distinctively nationally and regionally.
Finance incl. FinTech	🟢🟡🟢	The sector is characterised by high AI maturity, both globally and in NI specifically. Given its strength in NI, there is some opportunity for distinct impact.
		To build on this opportunity, it will be crucial that NI leverages the sector's largest players and start-ups, and builds on its expertise in building software.
Human health and social work	🟡🟢🟢	The sector offers a wide range of opportunities for the adoption of AI. It is one of the largest sectors of NI's economy, with many cross-cutting initiatives and companies active in the field.
		However, a key challenge for impact is the current lack of industry readiness in healthcare settings.

While ICT and Telco also received a 'green' rating across two categories of the evaluation framework, namely for its 'economic state' and 'the opportunity for AI', it is not included in the overview above given that its positive rating was strongly driven by the fact that many AI technologies, that can be applied across a range of sectors, are inherent to the sector.

Considering the current state of NI's economy, its research base and the potential impact of AI, the five sectors that have emerged from the analysis are the most attractive sectors in relative terms. However, the foresight exercise and stakeholders consulted suggest that in absolute terms, these sectors may not provide a sufficiently robust or distinct platform for the AICC to deliver impact at scale for Northern Ireland.

This becomes apparent when looking at the general state of the research base in NI, the economic context and the current ability of these sectors to leverage the transformative potential of AI to have a distinct impact:

- **The state of the research base**: Across the high performing sectors, research activities are being undertaken, and the City Deals have recognised these

research activities and the opportunities for improving collaboration across research clusters in these areas. However, the amount of sector-specific research is limited and AI research clusters are still of comparatively small scale. Research is generally less differentiated than in some other AI research clusters across the UK and the question of distinctiveness in AI was raised as a *"hugely difficult question for NI"*[351]. Successful translational partnerships to date have been cross-sectoral, with sector skills and competences provided by commercial partners.

- **The economic context in NI**: The largest sectors of the NI economy by GVA - health and social care, public administration and trade - are labour intensive with limited potential for AI. For the health and social care sector this holds true when looking at the industry readiness at the end of the supply chain in healthcare settings. The economic structure of NI as a SME driven, relatively lower global trade economy can be challenging to the adoption of AI. Together, these factors mean that *"the absorptive capacity of the local economy is low"* when it comes to AI according to some interviewees. In each of the high performing sector, whilst there are one or two large and recognised players with in-house AI capacity, there may not be enough scale to sustain a sector-led approach.

- **The transformative potential of AI**: AI in NI is still an emerging field. The five sectors that have been identified as relatively attractive are characterised by generally high AI maturity on a global scale. Yet globally, *"for almost every industry, there are well established precedents of machine learning"* [352] and a sectoral approach risks *"targeting an already saturated marketplace"*.[353] These sectors hence face strong competition which will make it difficult for them to achieve impact at scale. These sectors are also already supported through a variety of initiatives and partnerships. This is also reflected in the sectors' alignment with the City Deals. There is an opportunity for the AICC to enhance these existing initiatives. The case for a distinct, AICC-owned sector focus is less clear.

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[351] Stakeholder interview

[352] Stakeholder interview

[353] Stakeholder interview

5.2 Implications for NI's AICC sector approach

There are different approaches that the AICC could take towards supporting sectors of NI's economy. Based on this study's findings, the following section provides an overview of three different approaches and their implications for the AICC:

- **Proactive:** The AICC could select 2-3 sectors that this study has identified as relatively attractive. The practical implications of this would be that a significant share of the AICC's engagement with academia and industry would be with actors from these sectors. The AICC could develop specific sector-expertise through hiring specialised researchers. While the AICC would have a very focused profile, this comes at the cost of engagement with actors from other sectors and cross-sectoral learning. The AICC would be less able to facilitate the transfer of cross-sectoral technologies and skills beyond the 2-3 selected sectors. Another disadvantage of this sectoral approach is that the AICC would be less able to foster co-production and learning beyond the limited set of actors engaged in the selected sectors.

- **Responsive:** This approach foresees that the AICC does not launch with a specific sector focus that narrows its activities towards a few sectors. Rather, it would focus its activities on building an AI focused cluster that is open to actors from all sectors. This approach has the advantage that the AICC would not have to narrow its focus in its early stages, given that AI is still emerging across sectors in NI. This offers the advantage that the AICC could facilitate the transfer of knowledge and skills across a wider range of sectors, thus effectively fostering cross-sectoral collaboration and mutual learning. This could for instance take the form of supporting several seed projects that foster transferable skills. It would thereby build on one of the key strengths of NI which is the interconnectedness of its communities. The AICC could support activities that ensure effective community building in areas where there is opportunity to further strengthen community ties, for instance across universities. The AICC would use foresighting to assess emerging opportunities as they arise. If it becomes apparent that there have been new developments that provide promising niche opportunities for impact at scale, the AICC could adapt its activities to actively support AI growth in this area. It would also not restrict the AICC to support areas that are already being supported across a range of initiatives. Rather, it would allow the AICC to be open to new developments and seize opportunities as they develop. It would also allow the AICC to remain responsive to supporting the priorities for the post-COVID-19 recovery of NI.

- **Neutral:** This approach foresees the AICC would launch without a specific sector focus and would not foresee revisiting the AICC's approach to sectors in the future. Rather, the AICC would aim to remain a hub that brings stakeholders from all sectors with an interest in AI together. The neutral approach offers the advantage of not narrowing the AICC's focus earlier on (similar to the responsive approach), but as its sectoral approach would not be revisited later one, it might come at the risk of overlooking emergent opportunities as they develop. It would

also make it less responsive to supporting the priorities for a post-COVID-19 recovery as these priorities emerge.

While the in-depth assessment identified sectors that are relatively attractive compared to other sectors, the analysis and interviews with stakeholders led us to conclude that it is not advisable at the onset of the AICC to adopt a proactive sector approach.

Several interviewees, including those close the research base and global cutting-edge proactive, suggested that the only viable sector-led approach would be to focus on areas that are currently underinvested in AI research and practice, which include areas such as sustainability, smart agriculture, regtech and autonomy verification/validation. These more narrowly defined areas are not sectors as such and build less on the research, skills and experience in NI. Instead, they focus on claiming the remaining "white space" in the AI landscape. To drive impact in these areas, it would be crucial to build partnerships with global firms, develop academic leadership and enable regulatory sandboxing. While this approach may be more attractive, it comes at a higher risk. The AICC would need to establish itself before pursuing a global niche like this.

If the AICC were to take on a proactive approach towards sectors, this study suggests that it would be difficult for the AICC to add a distinctive advantage for the development of AI in NI. Across sectors, one of the key strengths of NI is the interconnectedness of its communities. There is untapped potential to leverage this strength to support cross-sectoral learning and AI growth across different areas and industries. Most AI skills are transferable and many AI technologies can be applied across different sectors. As AI is still an emerging field in NI, and given the developing research base and the fact that NI is a SME-driven economy, a proactive approach would make it challenging for the AICC to support impact at scale.

Instead, a responsive sector approach has the advantage of allowing the AICC to focus its activities on developing a strong AI focused cluster that strengthens collaboration and the skills base and supports actors across sectors. This could for instance be achieved by supporting several seed projects that focus on the development of transferable skills that can then be applied across sectors. Given that AI growth will continue across sectors organically, the AICC can revisit the decision to focus its activities on specific sectors at a later point, when there is established momentum behind specific sectors that offer (niche) opportunities for impact at scale.

5.3 Recommendations

- **Build an AI focused cluster with a responsive approach to sectors:** This study finds that here is significant potential in building an AI focused cluster. It recommends to build an AI cluster on an open-call basis. As such, activities of the AICC could be focused on promoting sector cohesion, co-production and learning. As AI is an enabling technology, this open and responsive approach will support the creation of an AI-enabled environment in NI where specific focus areas and leadership can emerge over time. This approach also recognises the interconnectedness of NI's communities as a key strength with untapped potential. Another crucial consideration that has informed this recommendation is that many AI technologies and skills are sector-agnostic. As such, this approach will allow the AICC to support the development of transferable skills and technologies that have the potential to spur innovation across sectors, for instance through supporting seed projects that foster the development of transferable skills. Taking a responsive approach to sectors means that AICC can initially focus on strengthening cross-sectoral learnings, while remaining open to sector-specific opportunities should these develop over time.

- **Strengthen collaboration across actors, sectors and borders:** Given the multitude of existing initiatives and partnerships, there is an opportunity for the AICC to support and enhance AI collaboration within and across academia and industry, both in Northern Ireland and across its borders. Through this, the AICC could support activities that aim to foster effective community building in areas where this is currently limited. Several interviewees have pointed to particular opportunities in strengthening ties with relevant actors in the Republic of Ireland given that i) many global technology and leading pharma companies have branches in the RoI, ii) interviewees from the RoI see potential for further collaboration between NI and the RoI, and iii) the similar geographical and economic context in the RoI.

- **Build on the 'levelling up' agenda:** Many interviewees point to opportunities around the UK's 'levelling up' agenda. While specific priorities and the size of funding provided through this have not yet been established, there is opportunity to strengthen NI's voice in the UK wide AI conversation through this agenda. In this regard, taking a responsive sector approach also means that the AICC will be able to respond more flexibly to funding opportunities arising through the 'levelling up' agenda.

- **Align activities to national strategies and the AI Council:** This study further recommends that the AICC aligns its activities to the priorities of national AI strategies and the priorities of the AI Council. The UK's AI Council is an independent expert committee that advices the Government and high-level leadership on the AI ecosystem to inform AI policy. Its members include the Alan Turning Institute Chief Executive, Professor Adrian Smith, as well as Professor Máire O'Neill from Queen's University Belfast in Northern Ireland. Building on this, aligning the AICC's activities to the AI Council and national strategies will ensure

that the AICC can effectively take part in wider conversations around the strategic direction of AI developments. The AICC will also be able to better respond to funding opportunities that emerge from these strategies.

5.4 Concluding remarks

The findings outlined in this report aim to provide the foundation for further discussion and decision-making within Matrix and the Department for the Economy around the AICC's approach to sectors of the economy of NI.

After the submission of this draft report, its findings and recommendations will be discussed with project partners from the Department for the Economy and Matrix.

appendices

Appendix I: List of interviewees

- **Dr Jayne Brady**, Belfast City Council, Belfast Digital Innovation Commissioner/ Matrix Ex-Officio Member

- **Tim Brundle**, Ulster University, Director of Research and Impact/ Matrix Ex-Officio Member

- **Gary Campbell**, Invest NI, AI Sector Lead/ Member of AI AICC Advisory Board

- **Pat Dempsey**, Insight, SFI Research Centre for Data Analytics, Strategic Projects Director

- **Sara El-Hanfy**, Innovate UK, Innovation Lead – Machine Learning and Data

- **Prof Mark Ferguson**, Science Foundation Ireland, Director General

- **Dr Rob Grundy**, MATRIX, Chair

- **Prof Chris Johnson**, Queen's University Belfast, Faculty Pro-Vice-Chancellor, School of Electronics, Electrical Engineering and Computer Science

- **Dr Adrian Johnston**, Digital Catapult, Director (NI)

- **Prof Liam Maguire**, Ulster University, Executive Dean of the Faculty of Computing, Engineering and the Built Environment/ Member of the AICC Advisory Panel

- **Eoin McFadden**, Dept for the Economy, Head of Innovation Strategy Unit/Member of AICC Advisory Board

- **Prof Jim McLaughlin**, Ulster University, Professor in the University of Ulster School of Engineering, Director of the Engineering Research Institute and Director of NIBEC as well as a Matrix Panel Member together with Prof **Dewar Finlay,** Research Director – Electrical and Electroinic Engineering, Metallurgy and Materials, and Prof **Chris Nugent,** Head of School of Computing

- **Leo Murphy**, North West Regional College, CEO / President/ Matrix Ex-Officio Member

- **Steve Orr**, Catalyst Inc, Chief Executive Officer/ Matrix Ex-Officio Member

- **Joann Rhodes**, HIRANI, CEO

- **Scott Rutherford**, Queen's University Belfast, Director of Research and Enterprise/ Matrix Ex-Officio Member

- **Prof Adrian Smith**, Alan Turing Institute, CEO

Appendix II: SIC code mapping of sectors

Table 4: Overview of all 2-digit SIC categories, the sector they map to in this report and reason for exclusion if applicable.

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report
A1	Agriculture and hunting	709	1.68%	Agriculture and food production
A2	Forestry and logging	11	0.03%	N/A
A3	Fishing and aquaculture	50	0.12%	Agriculture and food production
B5	Mining and quarrying, excluding support activities	98	0.23%	N/A
B6	Combined with 5, 7, 8		0.00%	N/A
B7	Combined with 5, 6, 8		0.00%	N/A
B8	Combined with 5, 6, 7		0.00%	N/A
B9	Mining support service activities	1	0.00%	N/A
CA10	Manufacture of food products	1,116	2.64%	Agriculture and food production
CA11	Manufacture of beverages and tobacco products	1,070	2.54%	Agriculture and food production
CA12	Combined with 11		0.00%	Agriculture and food production
CB13	Manufacture of textiles	112	0.27%	N/A
CB14	Manufacture of wearing apparel	67	0.16%	N/A
CB15	Manufacture of leather products	1	0.00%	N/A
CC16	Manufacture of wood products, except furniture	114	0.27%	N/A
CC17	Manufacture of paper products	133	0.32%	N/A
CC18	Printing and reproduction of recorded media	66	0.16%	N/A
CD-CE19	Manufacture of coke, refined petroleum and chemicals	224	0.53%	N/A
CD-CE20	Combined with 19		0.00%	N/A
CF21	Manufacture of pharmaceutical products	266	0.63%	Biomedical R&D and pharmaceutical manufacturing
CG22	Manufacture of rubber and plastic products	248	0.59%	Advanced manufacturing, materials and engineering

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report
CG23	Manufacture of other non-metallic mineral products	219	0.52%	Advanced manufacturing, materials and engineering
CH24	Manufacture of basic metals	52	0.12%	N/A
CH25	Manufacture of fabricated metal products	518	1.23%	Advanced manufacturing, materials and engineering
CI26	Manufacture of computer, electronic and optical products	575	1.36%	Advanced manufacturing, materials and engineering
CJ27	Manufacture of electrical equipment	173	0.41%	Advanced manufacturing, materials and engineering
CK28	Manufacture of machinery and equipment	590	1.40%	Advanced manufacturing, materials and engineering
CL29	Manufacture of motor vehicles	208	0.49%	Advanced manufacturing, materials and engineering
CL30	Manufacture of other transport equipment	375	0.89%	Advanced manufacturing, materials and engineering
CM31	Manufacture of furniture	138	0.33%	N/A
CM32	Other manufacturing	89	0.21%	Advanced manufacturing, materials and engineering
CM33	Repair and installation of machinery and equipment	59	0.14%	N/A
D35	Electricity, gas, steam and air conditioning supply	502	1.19%	Energy
E36	Water supply and sewerage	347	0.82%	N/A
E37	Combined with 36		0.00%	N/A
E38	Waste collection, treatment and disposal activities	338	0.80%	N/A
E39	Remediation and other waste management services	10	0.02%	N/A
F41	Construction of buildings	621	1.47%	Construction
F42	Civil engineering	847	2.01%	Construction
F43	Specialised construction activities	1,349	3.20%	Construction
G45	Motor trades	707	1.68%	Trade (wholesale and retail)
G46	Wholesale trade	1,583	3.75%	Trade (wholesale and retail)

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report
G47	Retail trade	3,516	8.33%	Trade (wholesale and retail)
H49	Land transport	938	2.22%	Transportation and storage
H50	Water transport	210	0.50%	Transportation and storage
H51	Air transport	87	0.21%	Transportation and storage
H52	Warehousing and transport support activities	294	0.70%	Transportation and storage
H53	Postal and courier activities	101	0.24%	Transportation and storage
I55	Accommodation	276	0.65%	N/A
I56	Food and beverage service activities	770	1.82%	N/A
J58	Publishing activities	69	0.16%	Creative industries incl. gaming
J59	Motion picture, video and TV programme production	38	0.09%	Creative industries incl. gaming
J60	Programming and broadcasting activities	78	0.18%	Creative industries incl. gaming
J61	Telecommunications	451	1.07%	ICT and Telco
J62	Computer programming and consultancy	816	1.93%	ICT and Telco
J63	Information service activities	10	0.02%	ICT and Telco
K64	Financial service activities	1,246	2.95%	Finance incl FinTech
K65	Insurance and pension funding	256	0.61%	Finance incl FinTech
K66	Activities auxiliary to finance and insurance	174	0.41%	Finance incl FinTech
68IMP68	Real estate activities, excluding imputed rental	1,273	3.02%	N/A
M69	Legal and accounting activities	764	1.81%	Professional and research services excl. biomedical
M70	Head offices and management consultancy	203	0.48%	Professional and research services excl. biomedical
M71	Architectural and engineering activities	288	0.68%	Professional and research services excl. biomedical
M72	Scientific research and development	200	0.47%	Biomedical R&D and pharmaceutical manufacturing

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report
M73	Advertising and market research	79	0.19%	Professional and research services excl. biomedical
M74	Other professional, scientific and technical activities	80	0.19%	Professional and research services excl. biomedical
M75	Veterinary activities	63	0.15%	N/A
N77	Rental and leasing activities	201	0.48%	N/A
N78	Employment activities	507	1.20%	Employment and business support activities
N79	Travel agency and tour operator activities	28	0.07%	N/A
N80	Security and investigation activities	46	0.11%	N/A
N81	Services to buildings and landscape activities	236	0.56%	N/A
N82	Office administration and business support activities	310	0.73%	Employment and business support activities
O84	Public administration and defence	3,555	8.42%	Public administration, education and defence
P85	Education	2,280	5.40%	Public administration, education and defence
Q86	Human health activities	3,009	7.13%	Human health and social work
Q87	Residential care activities	948	2.25%	Human health and social work
Q88	Social work activities	517	1.23%	Human health and social work
R90	Creative, arts and entertainment activities	38	0.09%	Creative industries incl. gaming
R91	Libraries, archives, museums and other cultural activities	50	0.12%	Creative industries incl. gaming
R92	Gambling and betting activities	250	0.59%	Creative industries incl. gaming
R93	Sports, amusement and recreation activities	150	0.36%	N/A
S94	Activities of membership organisations	226	0.54%	N/A
S95	Repair of computers, personal and household goods	25	0.06%	N/A
S96	Other personal service activities	358	0.85%	N/A
T97	Households as employers and own use production	83	0.20%	N/A

SIC category	SIC name	2018 £M GVA	% of GVA	Sector name in report
T98	Combined with 97		0.00%	N/A

matrix.

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