

*ON THE EDGE OF TOMORROW*

# ***CANADA'S AI AUGMENTED WORKFORCE***



Research by



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## Preface

ICTC is a national centre of expertise for the digital economy. With over 25 years of experience in research and program development related to technology, ICTC has the vision of strengthening Canada's digital advantage in the global economy. Through forward-looking research, evidence-based policy advice, and creative capacity building programs, ICTC fosters innovative and globally competitive Canadian industries, empowered by a talented and diverse workforce.

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## Glossary of Terms

The Glossary of Terms presents an overview of terminology used but not fully expanded upon in the text.

**Artificial Intelligence (AI):** a multi-disciplinary subject, involving methodologies and techniques from various fundamental disciplines such as mathematics, engineering, natural science, computer science, and linguistics, to name a few. Over the last few decades, AI has evolved into a number of technological areas such as planning, natural language processing, speech processing, machine learning, vision recognition, neural networks and robotics, among others.

**Machine Learning:** Machine learning is an application of AI algorithms that provides systems with the ability to automatically learn and improve from past experiences without being explicitly programmed. ML focuses on allowing computers to learn automatically without human intervention,<sup>1</sup> a process that involves ML algorithms built on mathematical models that are based on sample or 'training data' in order to make predictions or decisions. While machine learning has a long history, the ability to apply complex mathematical calculations to big data (faster and with more repetitions) is a more recent development.<sup>2</sup> Machine learning is a subset of the broader field of AI.<sup>3</sup>

**Neural Networks:** A network of algorithms designed to recognize patterns. Neural networks are computing systems made of numerous simple, interconnected processing elements that respond to external inputs (loosely modeled after the neuronal structure of the brain).<sup>4</sup> They can interpret sensory data through a type of perception to label or cluster inputs, and are most often used to help cluster and classify data, and group unlabelled data according to similarities among the inputs. These systems learn to perform tasks by considering examples without specific programming (by analyzing example data).

**Deep Learning:** an AI field closely associated with the use of artificial neural networks. Deep Learning refers to the depth of multiple layers or stacks of neural networks.

**Natural Language Processing (NLP):** Technology used to aid computers in understanding human natural language. NLP is a type of AI involved in the interaction between computers and humans, using natural (rather than coding) language with an objective to read, decipher, and understand the languages. The majority of NLP techniques utilize machine learning in this process.<sup>5</sup> Examples of NLP include language translation applications, digitized call-centre applications that can respond to requests, and digital personal assistants such as Siri or Alexa.

**Machine Vision:** A field of technologies and methods used to provide imaging-based automatic inspection and analysis. This may refer to software, hardware, integrated systems and methods to integrate technology to solve physical, medical or industrial problems. Machine Vision often employs cameras, analog-to-digital conversion and signals processing, and can be described as giving a computer the ability to see.<sup>6</sup> This field has rapidly developed through the use of specialized neural networks to help machines identify and understand images.<sup>7</sup>

**Robotics:** The branch of science that deals with the development of robots, or machines that can substitute humans or replicate human actions. If AI acts as a 'brain,' robotics would refer to the 'body.'<sup>8</sup>

<sup>1</sup>What is Machine Learning? A definition." Expert Systems. March 7, 2017. <https://expertsystem.com/machine-learning-definition/>

<sup>2</sup>Machine Learning: What it is and why it matters." SAS. Accessed January 2020. [https://www.sas.com/en\\_us/insights/analytics/machine-learning.html](https://www.sas.com/en_us/insights/analytics/machine-learning.html)

<sup>3</sup>Nicholson, Chris. "Artificial Intelligence (AI) vs. Machine Learning vs Deep Intelligence." Pathmind (formerly Skymind). Accessed January 2020. <https://skymind.ai/wiki/ai-vs-machine-learning-vs-deep-learning>

<sup>4</sup>Rouse, Margaret. "Artificial neural network (ANN)." TechTarget. August 2019. <https://searchenterpriseai.techtarget.com/definition/neural-network>

<sup>5</sup>Garbade, Dr. Michael J. "A Simple Introduction to Natural Language Processing." Medium. October 15, 2018. <https://becominghuman.ai/a-simple-introduction-to-natural-language-processing-ea66a1747b32>

<sup>6</sup>Rouse, Margaret. "Machine vision (computer vision)". TechTarget. July 2016. <https://searchenterpriseai.techtarget.com/definition/machine-vision-computer-vision>

<sup>7</sup>El-Ouazzane, Remi. "Why machine vision is the next frontier for AI." Venture Beat. December 5, 2015. <https://venturebeat.com/2015/12/05/why-machine-vision-is-the-next-frontier-for-ai/>

<sup>8</sup>Sharma, Ashok. "Artificial Intelligence vs Robotics: All the Facts You Need to Know." Medium. September 9, 2019. <https://medium.com/datadriveninvestor/artificial-intelligence-vs-robotics-all-the-facts-you-need-to-know-1079e01e05e2>

**Artificial General Intelligence (also known as AGI or Strong AI):** An artificial-intelligence construct (or level of AI) that has mental capabilities and functions that mimic the human brain. In practice, this would be the ability of a machine to perform any task that a human can.<sup>9</sup> Philosophically, this could refer to any AI system that acts like it has a mind. While it might be theoretically possible to replicate the functioning of a human brain, this level of complexity remains far beyond our current reach. Some AI experts believe that this level of capability (and even beyond it to a super consciousness or 'Singularity') is inevitable given exponential developments in the field, while others believe that Generalized AI (or AGI) will never be reached given that human intelligence is multidimensional and that the human brain is impossible to model.<sup>10</sup>

**Artificial Narrow Intelligence (also known as ANI or Weak AI):** AI that is focused on one narrow task. Digital AI assistants like Siri or Alexa are examples of this narrow intelligence, as they are highly limited to pre-defined functions. For these applications, there is no self-awareness and genuine intelligence that can operate outside of the pre-determined use cases. In some cases, this could be seen as 'Assistive AI' or the automation of specific tasks via technology or novel software developments. It often relies on the use of vast amounts of data coupled with predictive analytics and machine learning to develop algorithms. Examples of ANI at work include AI embedded in self-driving cars, predictive text, Spotify's 'made for you' playlists, and facial recognition. These more limited or dedicated functions represent what is possible with today's AI technology.

**Automation:** The use of technology to automate a process or procedure to be performed with minimal human assistance. This can refer to physical means (for example, hydraulics, mechanical, or pneumatic) or digital processes (using electrical devices and computers). Typically, complicated systems use a combination of these techniques.

**Robotic Process Automation (RPA):** The automation of business workflows or processes that emulate human interactions within a user interface (emulating the functioning of human tasks such as cursor moves or button clicking). It can be used for implementing actions from an 'AI' brain. This can sometimes incorporate machine learning and deep-learning algorithms.<sup>11</sup>

**Explainable AI:** A growing field in machine learning that aims to address how AI decisions are made (to peer through the black box decision-making algorithms). It is sometimes referred to as transparent artificial intelligence and often includes a level of traceability or auditability. It involves the examination of the steps or models used by an AI making a decision and may involve questions like why an AI makes a specific prediction or decision, why it did or did not pursue another pathway, and why the predictive decisions have succeeded or failed. A simplistic comparison to human activity would be to 'show your work' in a math problem.

Some efforts in this area (explainability) focus on using machine-learning algorithms that are inherently explainable, such as simple decision trees or classification models that involve traceability and transparency (without sacrificing too much performance or accuracy). It is much more challenging to explain the operations of more powerful algorithms where there may be a trade-off between performance, accuracy and explainability.<sup>13</sup> Like humans, neural networks make mistakes and it can be challenging for us to understand how they have failed, given the inability for the AI to communicate the decision-making processes itself.

<sup>9</sup>Joshi, Naveen. "How Far Are We From Achieving Artificial General Intelligence?" *Forbes*. June 10, 2019.

<https://www.forbes.com/sites/cognitiveworld/2019/06/10/how-far-are-we-from-achieving-artificial-general-intelligence/#54f502256dc4>

<sup>10</sup>373 experts opinion: AGI/singularity by 2060." *AIMultiple*. January 1, 2020.

<https://blog.aimultiple.com/artificial-general-intelligence-singularity-timing/>

<sup>11</sup>Nicholson, Chris "AI Applications in Robotic Process Automation (RPA)." *Pathmind (formerly Skymind)*. Accessed January 2020.

<https://skymind.ai/wiki/robotic-process-automation-rpa>

<sup>12</sup>Casey, Kevin. "What is explainable AI?" *The Enterprisers Project*. May 22, 2019.

<https://enterpriseproject.com/article/2019/5/what-explainable-ai>

<sup>13</sup>Schmelzer, Ron. "Understanding Explainable AI". *Forbes*. July 23, 2019.

<https://www.forbes.com/sites/cognitiveworld/2019/07/23/understanding-explainable-ai/#28ea76af7c9e>

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## Executive Summary

Artificial Intelligence (AI) is frequently identified as one of the most promising areas of technological development. The ability to generate efficiencies, identify hidden patterns or insights, and automate tasks combine to create a transformative technology that may fundamentally alter both the labour market and business operations. Although progress in the field of AI has fluctuated since its inception, we are increasingly witnessing its potential across the economy and labour market. Prior to the 2008 recession, for many businesses the notion of AI and, in some cases, even basic automation existed more as a concept rather than a tool. Yet, following this period of significant economic downturn, businesses around the world began actively looking to AI and applying it to real-life challenges, which ended up boosting productivity and labour demand. Here, AI began to develop roots in our economy and its development accelerated when combined with increased network connectivity, the availability and affordability of powerful sensors, the advent of big data, and the exponential growth of computational power.

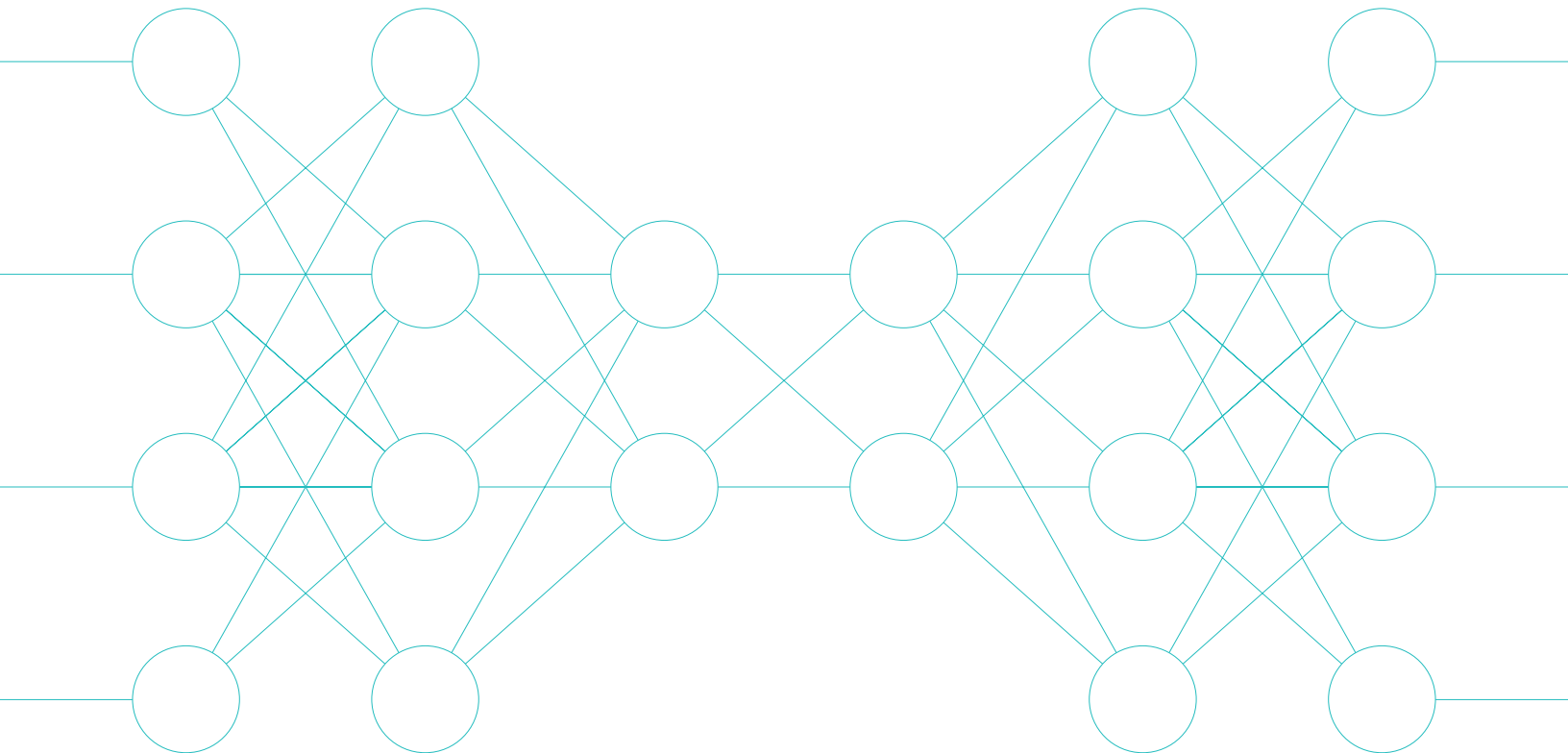
The growing reliance on AI—even in the rudimentary sense of automation and assistive technology—brings with it not only opportunities but significant questions about labour market disruption. This includes concerns about labour augmentation and changes related to skill needs, capabilities, and the tasks and responsibilities of workers.

In this context, ICTC's AI Labour Augmentation Model showcases which occupations are most likely to be augmented by AI<sup>13</sup>. This is done by examining how prone to augmentation a number of occupations are or will be in the future. While the overall "risk" of augmentation increased notably for many roles since the 2008 recession as more businesses began leveraging AI and assistive technology, there are a number of important nuances as to which jobs will be impacted, who is working in these roles, and what correlation this has with wages. For example, although many low-wage jobs, such as customer-service representatives or entry-level administrative roles can be augmented by AI, augmentation does not rest solely with occupations in low-wage brackets. In fact, ICTC's AI Labour Augmentation Model finds that a number of high-wage occupations, such as auditors or financial analysts, for example, are equally susceptible to augmentation.



AI brings immense potential to reshape the Canadian labour market and transform business practices. However, as AI continues to disrupt on many levels, it is critical to develop strategies to ensure that its benefits are not divisive; that it is deployed and used responsibly. This guiding ethical framework coupled with the growing importance and demand for explainability must be at the core of every discussion on AI. This ethical framework is currently an area in which Canada excels and can continue to showcase leadership on a global level. Maintaining this momentum is crucial.

In the process of assessing and understanding the potential benefits of AI, labour market changes and shifting skill needs are at the centre of the debate. Investigating and understanding labour augmentation and rapidly-developing skill needs brought on by AI will be crucial. The knowledge derived from this research is needed today to develop the training and upskilling pathways that Canadians can utilize to prepare themselves for the future. This understanding combined with advancing Canada's leadership in the space of ethical and explainable AI form the ingredients needed for a Canadian AI strategy that is inclusive, transparent and truly innovative.



## Introduction and Background

Artificial Intelligence (AI) is a rapidly growing field that has benefited from the convergence of different information technologies and the broader digitization of the world around us. The ubiquity and increasing performance of sensors, computational power, connectivity, data storage, and advanced software algorithms have combined to enable AI developments that have long been merely imagined. This study highlights the growth and impact of AI in Canada through an examination of trends in AI development, Canadian strengths in this field, socioeconomic impacts and labour changes, and the potential application of AI across a variety of sectors.

During the research process, ICTC examined a variety of data sources, including Stats Canada, O\*NET, and OECD iLibrary to gain a rudimentary understanding of the different types of AI, their applications across the economy, and their ability to impact the labour market. This was combined with invaluable insights extracted from in-depth Key Informant Interviews (KIIs) with subject-matter experts in the field of AI along with feedback and insights gained from a project-advisory committee that assessed and validated findings. This combination of research supported the overall findings of this report as well as the creation of the AI Labour Augmentation Model, which classifies how likely a number of Canadian occupations are to be augmented by AI. Given that this is still a nascent market in Canada with many organizations just now ramping up activities, a forecast for employment is not provided in this report due to challenges ensuring base-level reliability and accuracy. ICTC will continue to monitor and evaluate these trends, capturing data on labour-market changes and skill needs relevant to future short and long-term employment demand. The overall aim of this mixed-method engagement was to examine the opportunities that AI can offer across the Canadian economy while also highlighting future skill needs and augmentation that will be driven by the increasing implementation of AI.

- ▶ **Section I** provides an explanation of two important types of AI: Artificial General Intelligence (AGI) and Artificial Narrow Intelligence (ANI).
- ▶ **Section II** examines the concepts of AI-enabled labour productivity and paints a picture of the Canadian AI ecosystem. It highlights regional hubs, showcases trends in public and private investments in AI, and tracks the growth of AI companies reflected in industry collaborations and projects.
- ▶ **Section III** explores labour market trends in AI-related positions, such as future job growth and wages.
- ▶ **Section IV** provides an in-depth analysis of ICTC's AI Labour Augmentation Model, highlighting the Canadian occupations most likely to be impacted by AI. Demographic, wage, and historical analyses of the AI Augmentation Score are presented.
- ▶ **Section V** offers snapshots of AI applications and opportunities across a variety of strategic growth sectors in Canada.
- ▶ **Section VI** investigates the concepts of transparency, ethics, and explainability in AI, highlighting Canada's strengths and opportunities for global leadership in this area.

# ***WHAT IS AI AND HOW WILL IT CHANGE THE NATURE OF WORK?***

AI is the science of designing computer systems that exhibit characteristics associated with human intelligence. This includes learning, thinking, reasoning, strategizing, and problem solving. While its conceptual origins date back to the 1950s, the field of AI has continued to evolve over the years, with periods of rapid development alternating with years of relative stagnation.

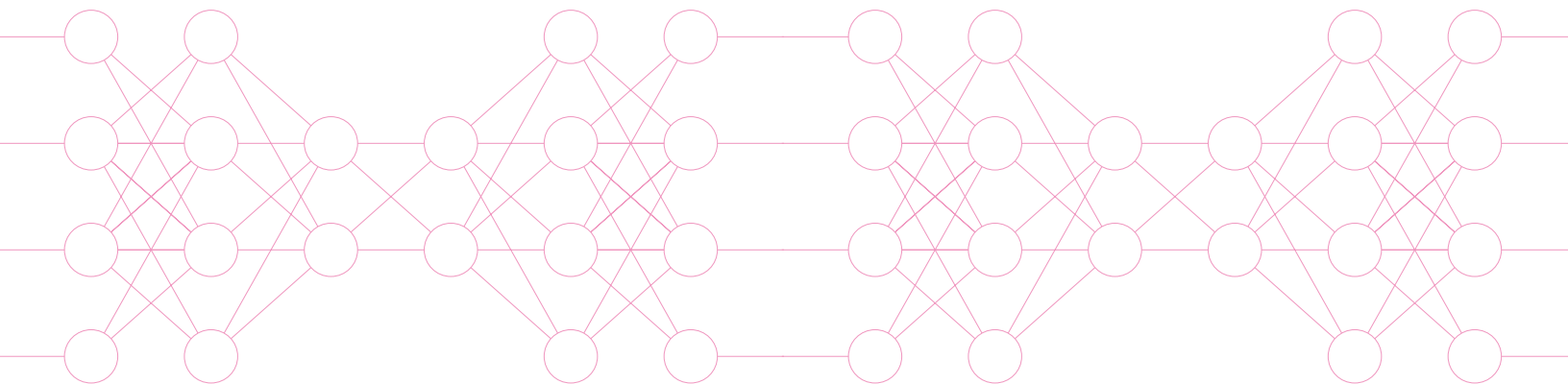
AI is a multi-disciplinary subject that involves methodologies and techniques from various fields, including mathematics, engineering, natural science, computer science, and linguistics. Over the last few decades, we have seen the continued evolution of AI activities such as machine learning and neural networks. These techniques have benefited different areas of application, like natural language processing, speech processing, and robotics, to name a few. AI-empowered applications like these have subsequently been applied to a range of industries, including finance, manufacturing, health, and clean technology.

However, while "AI" is often categorized as one sole concept, there is an enormous difference between artificial general intelligence (AGI or "strong AI") and artificial narrow intelligence (ANI or "weak AI"). Strong AI refers to genuine machine intelligence that is capable of generating original solutions to a wide range of problems and situations, similar or superior in creativity and versatility to the human mind. Since these machines would be capable of rapidly programming themselves, many speculate that the arrival of AGI could quickly be followed by a period of exponential growth in machine intelligence, or as some call it "Technological Singularity." Although experts vary in their estimates, the general consensus seems to be that we are likely still many years away from the development and everyday use of a generalized (strong) AI, and some speculate that it may never arrive at all.

On the other hand, narrow (or weak) AI already impacts many aspects of our society and economy. Narrow AI is utilized in the development of assistive technologies as simple as your smartphone's auto-filling text, Spotify's "made for you" playlists, automated scheduling reminders, or smart thermostats. In contrast to "strong AI," "weak" or narrow AI is not truly capable of solving a diverse set of cognitive problems like a human; rather, its intelligence is context-dependent and limited to addressing specific challenges.

While narrow AI may not be capable of tackling all original or complex problems, its economic impacts have already been profound. This type of AI is perhaps best thought of as an important but incremental step in the decades-running IT revolution. Consider that it took roughly 50 years from Michael Faraday's invention of the electric dynamo in 1831 to Edison's invention of the incandescent bulb. From there, it was another 50 years until half of US households had electrical wiring in their homes, and another 25 years passed before the consumer electrics proliferation of the 1950s. Analogously, over three decades ago, economist Robert Solow quipped that "you can see the computer age everywhere but in the productivity statistics"; but fast-forward to 2011 where venture capitalist Marc Andreessen declared "software is eating the world." Since the 2008 global economic recession, we have seen exponential growth in connectivity, data generation and collection, computational power and software sophistication. Much of this growth is attributed to narrow AI.

As it is unclear when or if we will reach the full theoretical potential of strong or generalized AI, this paper provides an understanding of the impact and labour augmentation of narrow AI—including machine learning and predictive analytics—often employed in the development of assistive technologies.



# AI AROUND THE WORLD AND IN CANADA – WHERE DO WE STAND?

Globally, the field of AI is fast-growing and the excitement for its future potential is evidenced, in part, by its growing adoption and implementation. Over the last few years, the number of companies emerging in this space, or that are incorporating AI tools into their existing operations in an effort to boost productivity, has risen dramatically.

A recent study from Boston Consulting Group (BCG) investigated the adoption of AI across seven countries. In its analysis, this study found that approximately 40–50% of companies<sup>14</sup> operating in these countries are considered “active players” when it comes to developing AI pilots or adopting AI to meet business needs.<sup>15</sup> Similarly, a recent study by PwC built on the primary assumption that AI will drive productivity gains by automating business processes found that substantial economic gains are likely to occur as a result of AI. This study projected that AI adoption and implementation will lead to economic gains across the economy, totaling an additional 10% in GDP across all industries by 2030.<sup>16</sup>

## Canada’s Biggest Strength in AI: Innovative, Ethical and Responsible Research

Canada shows significant strength in the area of AI-related research<sup>16</sup> and is frequently identified among the global leaders in this space. As early as 1982, Canadian researchers began thinking about the ways in which AI would impact both the Canadian and global economy, and how it would fundamentally alter our way of life. That year, the Canadian Institute for Advanced Research (CIFAR) was developed, allowing researchers to work across disciplines in the area of AI. Under this organization, groups like Learning in Machines & Brains have produced some of the most cited research in AI in the world. Key examples of world-renowned publications from CIFAR researchers include a number of deep-learning studies from AI pioneers such as Yoshua Bengio and Geoffrey Hinton. Other key researchers in this space include Joelle Pineau, head of the Facebook AI Research lab in Montreal and thought leader on challenges related to AI and data-driven systems, as well as AI Impact Alliance founder Valentine Goddard, lawyer and recognized expert on the ethical and social implications of AI.<sup>17</sup>

<sup>14</sup>across consumer, energy, financial services, health care, industrial, technology, media, telecom, and professional services.

<sup>15</sup>Duranton, Sylvain, Jörg Erlebach, and Marc Pauly. “Mind the (AI) Gap: Leadership Makes the Difference” Boston Consulting Group. December 2018. [http://image-src.bcg.com/Images/Mind\\_the%28AI%29Gap-Focus\\_tcm108-208965.pdf](http://image-src.bcg.com/Images/Mind_the%28AI%29Gap-Focus_tcm108-208965.pdf)

<sup>16</sup>Gillham, Jonathan et al. “The macroeconomic impact of artificial intelligence”. PwC. February 2018. <https://www.pwc.co.uk/economic-services/assets/macro-economic-impact-of-ai-technical-report-feb-18.pdf>

<sup>17</sup><https://valentinegoddard.com/>

Canada's journey in AI research does not end with CIFAR but extends far beyond those borders. Growth and investment in this area has led to the creation of innovative research think tanks and institutes around the country along with the emergence of leadership in discussions of ethics, responsibility and transparency.

This work allowed Canada to be among the first countries to announce the development and framing of a national strategy for AI in the spring of 2017. Backed by an investment of \$125 million over five years, Canada aims to increase the number of highly-skilled researchers and graduates, enhance research capabilities and collaboration, and demonstrate global leadership in AI.

A year later in 2018, a study by the newly-minted organization Element AI highlighted that Canada was third in the world when it came to the concentration of AI researchers.<sup>18</sup> At this rate, Canada far surpassed countries like France and Germany, which have long been considered leaders in this space. A year later, the spring of 2019 saw the announcement of Canada's Digital Charter, a document that lays the foundation of rules to govern the digital sphere in Canada, including but not limited to key technologies like AI.<sup>19</sup>

Canadian efforts in the development of AI research as well as ethical AI spearheaded by important developments like the Montreal Declaration are also showcased in industry outputs themselves. A 2018 study surveying large, medium and small AI companies around the world found that Canadian companies had the highest proportion of AI ethics committees in the world.<sup>20</sup> Key players, including Microsoft Canada, have aimed to become industry leaders in ethics, privacy and the societal implications of this technology, while others, such as Amazon and Salesforce, have funded federal research into 'algorithmic fairness' and created new roles, such as 'ethical AI architects' and 'chief ethical and human use officers.'

The depth of Canada's efforts in ethical AI is a reflection of the historic strength of research in the field. While ethical considerations are often highlighted in research, public policy, regulations, and corporate strategies, it is also needed in the workplace for the responsible development of the technology. Canada is growing its presence in this space and making significant inroads into the discussion of top considerations that shape and steer the development of the technology around the world. Key clusters of activity are rapidly developing across the country to support the evolution of this research and solidify Canada's leadership role in the space. The following offers a snapshot of top jurisdictions in Canada that are spearheading these discussions.

<sup>18</sup>Galang, Jessica. "Element AI Global Talent Report Finds Canada Has Third-Largest Concentration of AI Researchers". Betakit. February 7, 2018. <https://betakit.com/element-ai-global-ai-talent-report-finds-canada-has-third-largest-concentration-of-ai-researchers/>

<sup>19</sup>Minister Bains announces Canada's Digital Charter". Innovation, Science and Economic Development Canada. May 21, 2019. <https://www.canada.ca/en/innovation-science-economic-development/news/2019/05/minister-bains-announces-canadas-digital-charter.html>

<sup>20</sup>Organizations Are Gearing Up for More Ethical and Responsible Use of Artificial Intelligence, Finds Study". Accenture. September 25, 2018. <https://www.accenture.com/ca-en/company-news-release-artificial-intelligence-finds-study>

## Montreal

Montreal is a global leader for AI research, with notable strengths in the area of Deep Learning. SCALE.AI, the body behind Canada's AI innovation supercluster, focuses especially on research related to supply chains and logistics,<sup>21</sup> helping Canadian companies utilize and benefit from the technology. A beneficiary of the SCALE.AI cluster, Local Line is a Canadian online food wholesale and logistics company. With funds from the supercluster, Local Line is currently developing a project whose aim is to reduce transportation costs for farmers and generate efficiencies via the use of AI algorithms to forecast shipping dates. Another example of an innovative SCALE.AI project is one run by Ray-Mont Logistics, whose goal is to utilize AI to develop a smart shipping terminal.<sup>22</sup>

### The Montreal Institute for Learning Algorithms (MILA): a Home to Over 300 AI Researchers

The Montreal Institute for Learning Algorithms (MILA) is a fast-emerging global leader in the AI space. MILA is comprised of over 300 researchers and doctoral students in AI-related fields, tackling topics like deep learning, deep nets, computer vision, neural networks and more. Currently, MILA possesses the largest concentration of AI researchers in the world.<sup>23</sup>

The strong AI research capabilities available at Montreal-based institutions like MILA have contributed to the establishment of other research labs like Element AI, the Facebook AI Research lab and Samsung's AI Research Centre.

Element AI is a leading research organization that partners with multinational businesses to provide consulting services around cybersecurity, financial services, insurance, supply chains, and manufacturing. IVADO Labs, also based in Montreal, is an AI service whose aim is to more effectively move advanced AI technologies from academia to commercialized products. Facebook's AI Research lab produces fundamental research ranging from national security, to media, and medical imaging. Lastly, Samsung's AI Centre in Montreal focuses on research in machine learning, language understanding, and the next generation of semi-conductor development.<sup>24</sup>

<sup>21</sup>Simpson, Meagan. "Scale AI supercluster officially receives \$290 million in funding". *ITBusiness.ca*. Dec 7, 2018. <https://www.itbusiness.ca/news/scale-ai-final-supercluster-to-officially-receive-funding-announces-290-million-from-federal-and-quebec-governments/107569>

<sup>22</sup>SCALE.AI starts off with first projects". *Innovation, Science and Economic Development Canada*. June 27, 2019. <https://www.canada.ca/en/innovation-science-economic-development/news/2019/06/scaleai-starts-off-with-first-projects.html>

<sup>23</sup>Why Artificial Intelligence Giants are Heading North to Montréal". *Montréal International*. Accessed December 2019. <https://www.montrealinternational.com/app/uploads/2019/04/montreal-artificial-intelligence2.pdf>

<sup>24</sup>Samsung Electronics Expands SAIT AI Lab Montreal to Spur AI Research for Next-Generation System Semiconductor." *Samsung*. May 2, 2019. <https://news.samsung.com/global/samsung-electronics-expands-sait-ai-lab-montreal-to-spur-ai-research-for-next-generation-system-semiconductor>

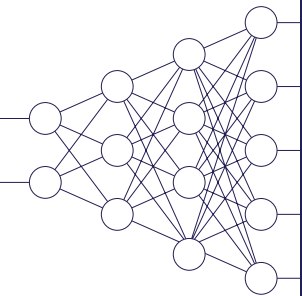


## Toronto

Toronto is another world-class centre of expertise for AI, backed by academic institutions like the University of Toronto (U of T). U of T offers a variety of program options, including Computer Science with a Minor in AI engineering, a number of AI certificates, a Master's of Management Analytics, and Canada's first engineering undergraduate program in machine intelligence. With this wide array of AI-based educational options, U of T leads in areas like AI integration with engineering, data analytics, and computer hardware optimization for AI.<sup>25</sup>

Toronto is also home to a large and fast-growing tech sector. Recently, real estate consultancy CBRE identified Toronto as the fastest-growing tech market in North America,<sup>26</sup> with the highest concentration of AI start-ups in the world.<sup>27</sup> Institutions and organizations like the Vector Institute, Uber AI Labs, and Nvidia's AI Research Lab have emerged from the growing AI market and research space cultivated in Toronto over the last number of years.

### The Vector Institute: A Pillar of Toronto's Growing AI Industry



The Vector Institute is notable for attracting top global talent for research in deep learning and machine learning, including Geoffrey Hinton, a global pioneer in machine learning. Geoffrey is world-renowned for his ground-breaking work in artificial neural networks. Vector's co-founder and Director of Research, Richard Zemel, is a highly-cited computer scientist and professor, well-known for his knowledge in machine learning and computer vision.

Over the last few years, the Vector Institute has developed partnerships with major corporations such as Scotiabank, RBC, BMO, TD, Google, Accenture, Loblaw's, and Shopify to work on a number of different initiatives, including the prevention of financial crimes via the utilization of AI methodologies and algorithms to improve cybersecurity.

<sup>25</sup>Irving, Tyler. "U of T launches Canada's first engineering undergraduate program in machine intelligence" University of Toronto. July 25, 2018. <https://www.utoronto.ca/news/u-t-launches-canada-s-first-engineering-undergraduate-program-machine-intelligence>

<sup>26</sup>Gee, Marcus. "Toronto's tech boom is transforming the city." *The Globe and Mail*. July 27, 2019. <https://www.theglobeandmail.com/canada/toronto/article-torontos-tech-boom-is-transforming-the-city/>

<sup>27</sup>Canada – A Leader in Artificial Intelligence (AI). "Invest in Canada. Accessed January 2020. [https://www.international.gc.ca/investors-investisseurs/assets/pdfs/download/Niche\\_Sector-AI.pdf](https://www.international.gc.ca/investors-investisseurs/assets/pdfs/download/Niche_Sector-AI.pdf)





## Edmonton

Edmonton is also considered a top Canadian leader in AI research and, in particular, machine learning. The Alberta Machine Intelligence Institute (AMII) currently hosts some of the world's most globally-recognized experts in machine intelligence, and the University of Alberta is a top producer of academic papers on this subject.<sup>28</sup> While initially, \$100 million over five years was promised to AMII for research and commercialization, the recent Alberta budget announced only \$35 million to "bring Alberta technologies to market" in sectors including artificial intelligence<sup>29</sup>.

### The University of Alberta: A Global Leader in AI Education

The University of Alberta was recently named one of the three hubs for the Pan-Canadian AI Strategy. Announced in the 2017 Federal budget, this \$125 million strategy focuses on bringing together Canadian AI experts and researchers to enhance Canada's thought leadership on the economic, policy and legal implications of AI, among other topics.

In existence for more than 50 years, the Department of Computing Science at the University of Alberta is one of the largest and longest-running computer science departments in Canada. The university's strengths in the field of AI span from applications of the technology to the development of theories of intelligence.

Edmonton also possesses significant strengths in the field of reinforcement learning. Notable highlights in this area includes the development of the Reinforcement Learning and Artificial Intelligence (RLAI) Lab, as well as the expansion of Google's DeepMind research office. With Edmonton becoming the home to DeepMind's first ever international office in 2018, the city was ranked third globally for AI and Machine Learning Research and fourth in Canada for Computer Science research.<sup>30</sup>

<sup>28</sup>Kerr, Katherine. "Power primer: What you need to know about Artificial Intelligence research in Edmonton". *Edmonton Economic Development*. February 15, 2018 <https://www.edmonton.com/articles/primer-ai-research-in-edmonton>

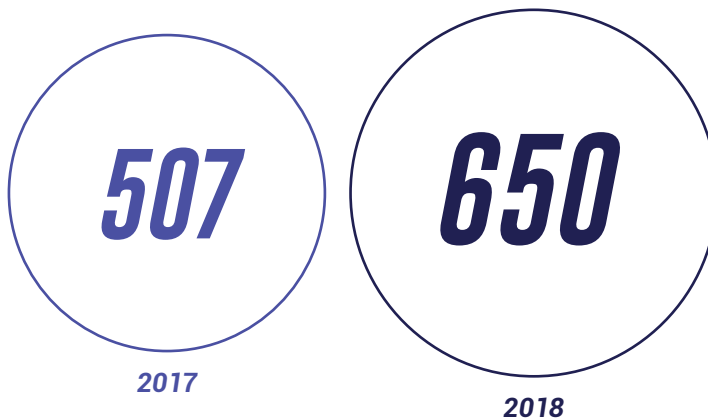
<sup>29</sup>Simpson, Meagan. "How Alberta's Tech Sector is Affected by Cuts in Much Anticipated 2019 Provincial Budget." *Betakit*. October 24, 2019. <https://betakit.com/how-albertas-tech-sector-is-affected-by-cuts-in-much-anticipated-2019-provincial-budget/>

<sup>30</sup>Edmonton is Canada's Centre for Artificial Intelligence." *Edmonton Economic Development*. Accessed January 2020. <https://www.edmonton.com/invest/sectors/artificial-intelligence>

## Canada's Growing AI Industry

In large part due to substantial strength in research and development, the proliferation of home-grown businesses in the AI space has been notable. Anchored in research by one of Montreal's AI leaders—Element AI—who to date raised over \$300 million in funding and grown to approximately 250 employees, Figure 1 showcases a nearly 30% increase in active AI-related startups in Canada from 2017-2018.<sup>31</sup> Top examples of Canadian AI startups showing substantial growth in the Canadian marketplace and internationally include Ottawa's MindBridge Ai and Vancouver's Finn.ai.

**Figure 1:** Number of active Canadian AI Start ups existing in Canada, 2017 and 2018



Source: Element AI, Canadian AI Ecosystem – 2018

At the same time, major international tech companies with a strong basis in AI have also recently been establishing operations in Canada. Montreal and Toronto have also seen significant recent investments from AI leaders like Google, Uber, Facebook and Nvidia.

In its recent study on the Canadian AI ecosystem, Element AI also estimated the presence of 50 large multinational organizations with an AI-related focus in Canada in 2018. This represents a growth of 150% from the previous year,<sup>31</sup> showcasing that international AI-based companies are increasingly viewing Canada as a top destination for investment and AI talent.

In the example of Facebook, the existing Montreal Research lab is expected to see staff expansion of 300% over the coming years to accommodate 60 new employees in addition to the existing 20.<sup>32</sup> Similarly, Uber has announced that it will be investing over \$200 million in its Toronto operations over five years, with the aim of expanding their existing research lab focused on self-driving cars.<sup>32</sup> Lastly, Nvidia opened its Toronto office building on the acquisition of a company called TransGaming. Currently employing approximately 50 staff, the company aims to quickly triple the volume of its AI research staff.<sup>33</sup> To date, it has contributed to the development of Toronto's AI research community via an investment of \$5 million in the Vector Institute for AI.

<sup>31</sup>Gagné, Jean-François. "Canadian AI Ecosystem 2018." Accessed January 2020. <https://jfgagne.ai/canadian-ai-ecosystem-2018-en/>

<sup>32</sup>McLeod, James. "Facebook expanding its Montreal AI Lab to double the number of researchers." *Financial Post*. September 20, 2019. <https://business.financialpost.com/technology/facebook-expanding-its-montreal-ai-lab-to-quadruple-the-number-of-researchers>

<sup>33</sup>State, Gavriel. "NVIDIA Opening AI Research Lab in Toronto, Following Move in Seattle." *NVIDIA*. June 13, 2018. <https://blogs.nvidia.com/blog/2018/06/13/nvidia-ai-research-lab-toronto/>

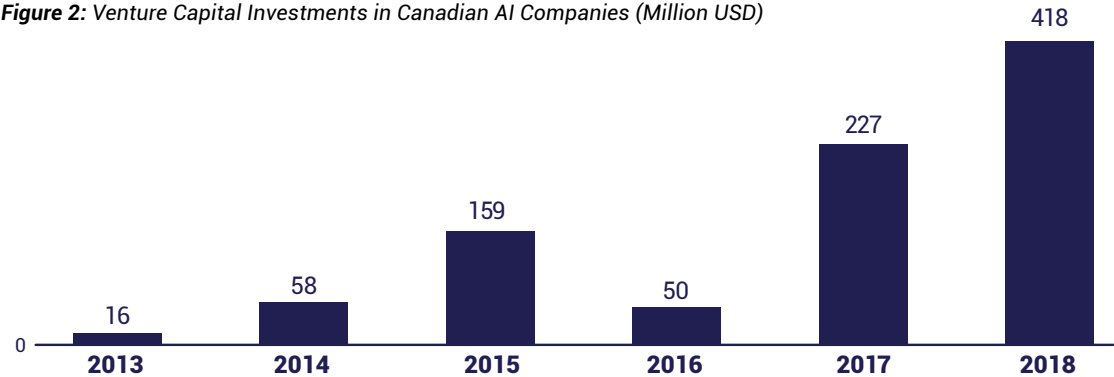
# Venture Capital and Corporate Investments

The strength and potential of Canada's burgeoning AI sector is also evidenced by the growth in venture capital investments directed towards Canadian AI companies, helping them shape, grow and mature.

Venture capital (VC) investment oriented towards earlier-stage startups is a useful metric for measuring the growth potential of a company, but increasingly we are seeing growing corporate investments and acquisitions in the Canadian AI space, which suggests a maturing ecosystem. With startups scaling, more and more, corporate actors are interested in acquiring strong research and talent along with innovative products, services, and intellectual property.<sup>34</sup>

In 2018, VC funding for Canadian AI businesses increased by approximately 50% from the previous year, with companies raising \$418 million (USD).<sup>35</sup>

**Figure 2: Venture Capital Investments in Canadian AI Companies (Million USD)**



Source: PwC | CB Insights MoneyTree™ Canada Report Q4 & Full-Year 2018

<sup>34</sup>Gagné, Jean-François. "Canadian AI Ecosystem 2018." Accessed January 2020. <https://jfgagne.ai/canadian-ai-ecosystem-2018-en/>  
<sup>35</sup>MoneyTree Canada Report: Q4 & Full-Year 2018." PwC | CB Insights. Accessed January 2020. <https://www.pwc.com/ca/en/technology/publications/pwc-cb-insights-moneytree-canada-q4-18-full-year-2018.pdf>



### SECTION III

# ***AI AND THE LABOUR MARKET – GROWING LABOUR DEMAND & SHIFTING SKILL NEEDS***

As noted by ICTC's most recent demand forecast, over 305,000 workers will be required across the Canadian digital economy by 2023.<sup>36</sup> Access to a highly-skilled talent base is a critical competitive advantage for the Canadian AI industry and key to its successful growth.

Industry growth and lucrative salaries speak to the strong demand for AI talent globally. Industry analysts and researchers at Indeed.com report that demand for roles such as machine learning engineers, data scientists, and computational linguists have doubled over the last two to three years,<sup>37,38</sup> and AI job postings overall rose by 29% from 2018 to 2019.<sup>39</sup> Similarly, researchers at LinkedIn found that the number of postings for machine learning engineers and data scientists grew nearly 10 times and more than 6 times respectively, in recent years.<sup>40</sup> This growing demand for skilled talent capable of working in AI applications and projects further accentuates the need for effective and proactive educational and training programs that can address this need.

<sup>36</sup>Cutean, A., Hamoni, R., McLaughlin, R., Ye, Z. "Canada's Growth Currency: Digital Talent Outlook 2023". Information and Communications Technology Council (ICTC). October 2019.

<sup>37,38</sup>The State of AI 2019: Divergence". MMC Ventures. Accessed January 2020. <https://www.stateofai2019.com/chapter-6-the-war-for-talent/>; Culbertson, Daniel. "Demand for AI Talent on the Rise". Indeed. March 1, 2018. <https://www.hiringlab.org/2018/03/01/demand-ai-talent-rise/>

<sup>39</sup>REPORT: Top 10 AI Jobs, Salaries and Cities". Indeed. June 28, 2019. <http://blog.indeed.com/2019/06/28/top-10-ai-jobs-salaries-cities/>

<sup>40</sup>LinkedIn's 2017 U.S. Emerging Jobs Report." LinkedIn. Dec 7, 2017.

<https://economicgraph.linkedin.com/research/LinkedIns-2017-US-Emerging-Jobs-Report>

## The Demand for AI Talent

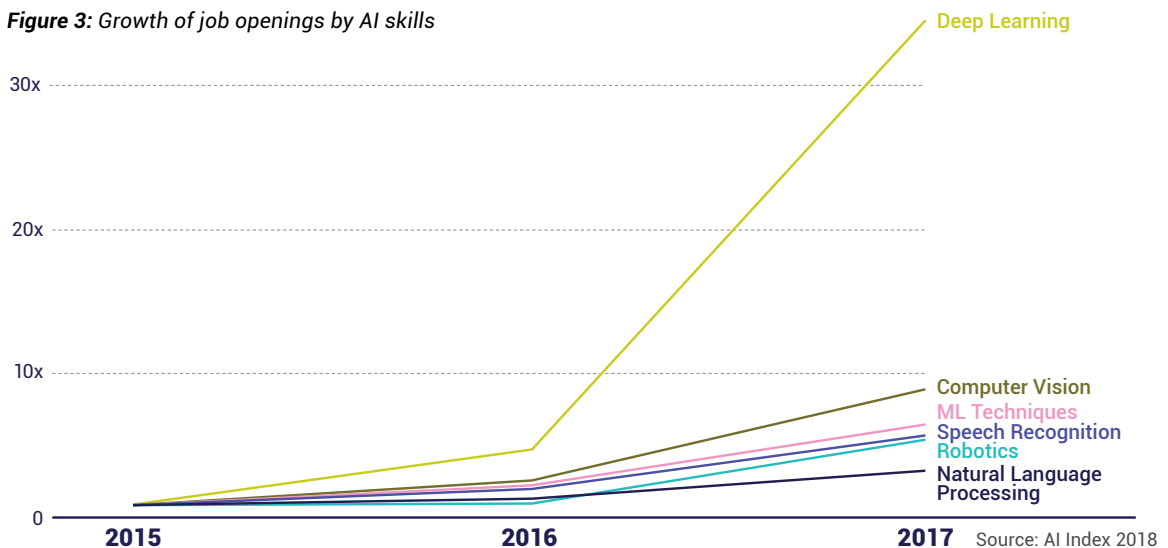
While skills and competencies for top AI roles can vary, according to research from Payscale 35% of all AI positions require a PhD, with another 26% requiring a Master's degree.<sup>41</sup> Although advanced degrees for these roles appear necessary, AI specialists, such as machine learning engineers or deep learning engineers needed to solve the most pressing challenges, are also currently in short supply,<sup>42</sup> both in Canada and around the world.

For example, Element AI estimates that globally there exist fewer than 10,000 people that possess the skills necessary to tackle the critical AI research needed for the creation of high-tech developments like self-driving cars.<sup>43</sup> Moreover, the demand for this kind of talent, although currently not extensive, comes with a substantial price tag. According to the New York Times' investigations of major tech companies, the wages of some of the most prestigious AI specialists in the US can range from \$300,000 to \$500,000 (USD) annually,<sup>44</sup> with many of these companies hiring top academics and professors on a part-time basis. In 2017, six out of 20 AI professors at the University of Washington were on leave or partial leave, working in industry,<sup>45</sup> and many of the top engineering and computer science programs at other institutions such as Stanford and Carnegie Mellon University have seen significant departures of researchers in recent years due to high—and growing—industry demand.<sup>46,47</sup>

## Rising Labour Demand Among Specific Roles and Skillsets

While demand for AI talent is high overall, certain areas of the field have seen higher growth than others. Figure 3 showcases a substantial increase in AI-related job postings in the US from 2015 to 2017 but accentuates the need in areas like machine learning and especially deep learning. During this three-year period, the demand for talent with deep learning roles grew by 34 times.<sup>48</sup>

**Figure 3: Growth of job openings by AI skills**



<sup>41</sup>Patrizio, Andy. "Artificial Intelligence Salaries: Paychecks Heading Skyward". Datamation. August 28, 2018. <https://www.datamation.com/artificial-intelligence/ai-salaries.html>

<sup>42</sup>Overby, Stephanie. "AI careers and salaries: 7 telling statistics". The Enterprisers Project. August 6, 2019. <https://enterpriseproject.com/article/2019/8/ai-artificial-intelligence-careers-salaries-7-statistics>

<sup>43</sup>Metz, Cade. "Tech Giants are Paying Huge Salaries for Scarce A.I. Talent". New York Times. Oct 22, 2017. <https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html>

<sup>44</sup>Includes base salary and stock options. <https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html>

<sup>45</sup>Metz, Cade. "Tech Giants are Paying Huge Salaries for Scarce A.I. Talent". New York Times. Oct 22, 2017. <https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html>

<sup>46</sup>Procaccia, Ariel. "Tech Giants, Gorging on AI Professors Is Bad for You". Bloomberg. January 7, 2019. <https://www.bloomberg.com/opinion/articles/2019-01-07/tech-giants-gorging-on-ai-professors-is-bad-for-you>

<sup>47</sup>Muoio, Danielle. "There's a raging talent war for AI experts and it's costing automakers millions". Business Insider. March 12, 2017. <https://www.businessinsider.com/ai-talent-poached-universities-for-self-driving-cars-2017-3>

<sup>48</sup>Yoav Shoham, Raymond Perrault, Erik Brynjolfsson, Jack Clark, James Manyika, Juan Carlos Nieves, Terah Lyons, John Etchemendy, Barbara Grosz and Zoe Bauer, "The AI Index 2018 Annual Report", AI Index Steering Committee, Human-Centered AI Initiative. December 2018. <http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf>

ICTC's consultations with Canadian AI experts identified the growing demand for AI talent that can develop new applications of AI and assess unexpected use cases or opportunities. These competencies were identified as needed across sectors, regardless of the type of AI being developed or utilized.

Specifically, ICTC's consultations with Canadian experts in the field highlighted the following five roles as examples of jobs that will be increasingly in-demand with growing AI adoption in Canada:

## DATA ENGINEERS

Develops, builds, tests and maintains software architectures (such as databases or large-scale processing systems)

### Critical skills/responsibilities

- ▶ Methodical engineering of data processes
- ▶ Data cleaning/verification
- ▶ Ability to connect different systems together (scripting languages and tools)
- ▶ Ability to recommend and implement solutions to improve data reliability, efficiency and quality.
- ▶ Software skills in tools like: SAP, Oracle, Cassandra, MySQL, Redis, Riak, PostgreSQL, MongoDB, neo4j, Hive, and Sqoop<sup>49</sup>

## DATA STEWARDS

A role within an organization responsible for planning, implementing and managing the sourcing, use and maintenance of data assets in an organization

### Critical skills/responsibilities

- ▶ Ability to develop and document procedures, guidelines and governance for data access and use.
- ▶ Coordination of efforts with data custodians or data administrators or other staff to plan and execute data usage or initiatives.<sup>50</sup>
- ▶ Acts as a central point of contact for complex data usage, often assigning decisions rights and enforcing accountability.
- ▶ Protecting data with responsibilities for privacy, security and risk management.

## BUSINESS ANALYSTS

Use data analysis to make strategic business decisions. Often involves identifying business needs, the problems faced, and how to optimize operations

### Critical skills/responsibilities

- ▶ Experience working with senior decision makers
- ▶ Strong communication/interpersonal skills
- ▶ Analytical background (including strong Excel skills)
- ▶ Financial modelling, planning, monitoring.
- ▶ Defining business requirements and reporting them back to stakeholders<sup>51</sup>

<sup>49</sup>Willems, Karlijn. "Data Scientist vs Data Engineer." DataCamp. February 23, 2017. <https://www.datacamp.com/community/blog/data-scientist-vs-data-engineer>

<sup>50</sup>Definition: Data Steward". Techopedia. Accessed January 2020. <https://www.techopedia.com/definition/29012/data-steward>

<sup>51</sup>Business Analyst job description guide." Robert Half. Accessed January 2020. <https://www.roberthalf.co.nz/our-services/finance-accounting/business-analyst-jobs>; Thompson, Jayne. "The Differences Between a Business Analyst & a Data Analyst." The Houston Chronicle. June 29, 2018. <https://work.chron.com/differences-between-business-analyst-data-analyst-17090.html>

## DATA SCIENTISTS

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Cleans, shapes, and organizes big or unstructured data. Often performs descriptive statistics and analysis to develop insights or build models to address business challenges

## Critical skills/responsibilities

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- ▶ Data visualization
- ▶ Data storytelling
- ▶ Machine Learning
- ▶ Business Understanding
- ▶ Programming languages such as: SPSS, R, Python, SAS, Stata and Julia<sup>52</sup>

## APPLICATION DEVELOPERS

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This role could include creating, maintaining and implementing source code and solutions that make up the program. This often involves looking at the software product across all aspects (rather than just the backend)

## Critical skills/responsibilities

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- ▶ Communication and co-ordination to convey ideas to coders, internal teams and management.
- ▶ Creativity to handle new problems and develop solutions
- ▶ Problem-solving skills to make decisions to move a project forward or to address client issues
- ▶ Technical skills – to understand different computer languages and utilize technical knowledge when bringing these projects together<sup>53</sup>

The arms-race to acquire AI talent is a global phenomenon, characterized by a highly mobile labour force recruited from industry and research institutions. This labour demand continues to be seen in the areas of research, data science, and a number of other occupations that drive and support this ecosystem, with top examples of in-demand jobs noted above.

However, one important observation made by ICTC's interviewees and advisory committee centred on the notion of competency in use of AI vs. design. That is, while AI-related technical skills in data science, coding, and specific machine learning methodologies are currently in-demand and will remain highly valuable, AI may eventually be commodified, turning into 'AI-as-a-Service' or an 'AI-in-a-box' software. In this scenario, once the best algorithms in the world are widely accessible, the emphasis will be on using, rather than designing AI. If the demand for workers capable of understanding how to use AI tools eventually outstrips the demand for workers who develop the tools themselves, this may fundamentally redefine the meaning of an "AI worker".

<sup>52</sup>Willems, Karlijn. "Data Scientist vs Data Engineer." DataCamp. February 23, 2017. <https://www.datacamp.com/community/blog/data-scientist-vs-data-engineer>

<sup>53</sup>What does an app developer do?" CareerExplorer. Accessed January 2020. <https://www.careerexplorer.com/careers/app-developer/>



## SECTION IV

# AI LABOUR AUGMENTATION MODEL

The following section presents the results of ICTC's AI Labour Augmentation Model, which ranks Canadian occupations by their likelihood of being augmented by AI. The AI Labour Augmentation Model was derived by rating the skills, competencies or tasks of Canadian occupations by their suitability for AI augmentation or impact. Using data obtained from the US Department of Labor and in-depth feedback on skill needs and AI capabilities provided via interviews with experts and the advisory committee, 160 different skills and risk-scores have been linked to occupations. A collection of top skill categories most susceptible to augmentation from AI can be found in Appendix IV. By aggregating the risk-scores for each important skill to every occupation, an 'AI Augmentation' score has been generated for each occupation. For a deeper methodological description, including research limitations, please see Appendix III.



## Most Augmentable Occupations

Utilizing the methodology noted above, Table 1 represents 10 of the occupations most likely to be augmented by AI.<sup>54</sup> The AI Augmentation percentile indicates the raw score for each occupation (where the highest score is 10 and the lowest is 0.) The higher the augmentation score, the more likely it is that the occupation can be augmented with AI technology. This score is designed to highlight occupations that are highly likely to be transformed and, as a result, which workers may need to adopt new skills and competencies, including increased digital literacy and competence. Although other occupations in key spaces—including natural resources, manufacturing, supply chain management and logistics—will also be subject to augmentation due to the growing adoption of AI, the following represents the occupations most immediately impacted in the near-term.

**Table 1: 10 AI Augmentable Occupations**

*AI Impact Score*

Accounting technicians and bookkeepers	<b>10</b>
Data entry clerks	<b>9.8</b>
Payroll administrators	<b>9.7</b>
Health information management occupations	<b>9.6</b>
Executive assistants	<b>9.5</b>
Court reporters, medical transcriptionists and related occupations	<b>9.4</b>
Administrative assistants	<b>9.3</b>
Medical administrative assistants	<b>9.2</b>
Financial auditors and accountants	<b>9.1</b>
Shippers and receivers	<b>8.6</b>

Source: ICTC, 2019

Generally, occupations related to administrative or simple information processing as well as physical inspection occupations are highly vulnerable to augmentation by AI. Here, skills such as simple number facility, memorization, and visualization were rated as highly likely to be disrupted by AI according to ICTC's subject-matter experts.

While many of these jobs are on the lower-skilled spectrum, certain high-skilled jobs are also likely to face augmentation in the coming years. Take the example of financial auditors. In theory, there are many components of the auditing profession that can be augmented with AI (e.g. completing balance sheets, preparing statements, etc.). However, there are also some aspects of this occupation—particularly when providing complex consulting services and advice—that require judgement calls using a more qualitative level of analysis and an ability to interact with and effectively respond to the needs of the client in real-time. The emotional intelligence, interpersonal skills, complex decision-making, and management done by financial auditing professionals prevents them from being fully automated by AI, while still bearing the high potential for augmentation.

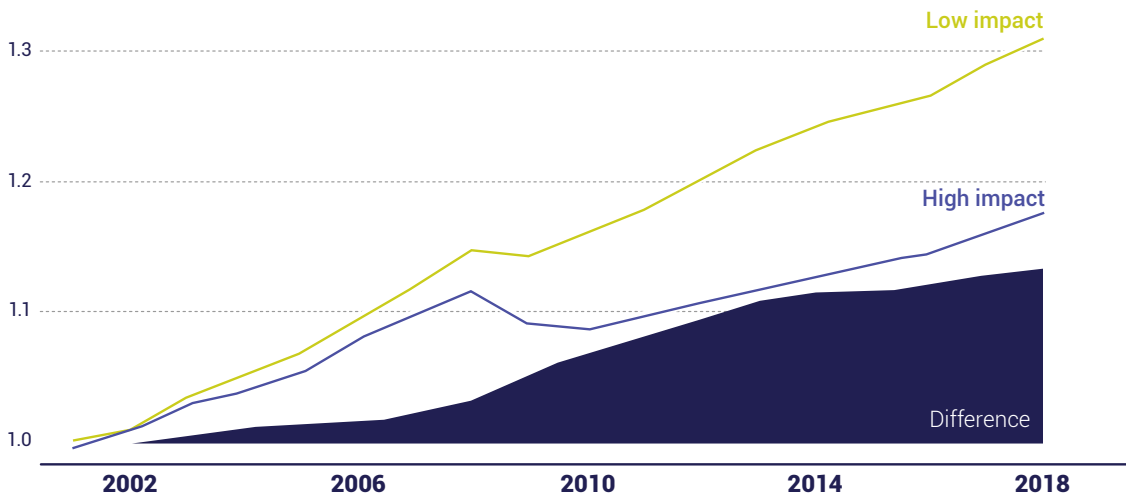
<sup>54</sup>Risk scores for each of the 160 separate skills can also be provided upon request.

## Employment History: AI-augmentable Jobs and Their Ability to Bounce Back from 2008 Economic Downturn

Following the adage of “never let a good crisis go to waste,” the aftermath of the 2008 global financial crisis saw businesses quickly restructure and revisit business models and processes. The employment layoffs of 2008-09 were mostly not refilled once the economy bounced back. Instead, many businesses used this downturn as an opportunity to pivot from labour-intensive production models to capital-intensive models. Commentators called the recovery following the 2008 recession a ‘jobless recovery.’ To an extent, this may have reflected the implementation of assistive technologies backed by narrow AI. Here, businesses used economic disruption as an opportunity to alter business processes for greater machine-driven efficiency.<sup>55</sup>

As evidenced by Figure 4 below, occupations with above-average AI Augmentation scores are seen to not only be growing slower than their counterparts since 2001, but their rate of growth slowed even further following the 2008 global recession when a structural shift in labour-intensive production models occurred. This showcases the normalized growth<sup>56</sup> of the top and bottom half of occupations, according to their AI Augmentation scores. The gap between the two trend lines widens significantly following 2009 and becomes more pronounced. Of all AI Augmentable roles, the 10% of occupations with the highest AI Augmentation Scores have essentially shown no growth in employment since the global financial crisis in 2008-09.

**Figure 4:** Normalized Employment Split at Median AI Augmentation Score



Source: ICTC, 2019 Note: Employment figures are normalized by dividing yearly value by 2001 value

Lastly, offering further evidence of a structural shift following the 2008 recession, there appears to be a relationship between AI Augmentation scores and the average annual growth rate from 2008-2018. On average, a 10-point increase in the AI Augmentation score decreases the annual growth rate by 0.28% (equivalently, moving from the lowest to highest-score occupation decreases the expected annual growth by 2.8%). However, while a statistically significant negative relationship between the AI Augmentation score and employment exists from 2008-2018, there was no relationship between these two variables between 2001-2008.

<sup>55</sup>Hershbein, Brad and Lisa B. Kahn. “Do Recessions Accelerate Routine-Biased Technological Change? Evidence from Vacancy Postings”. National Bureau of Economic Research. September 2017. <https://www.nber.org/papers/w22762.pdf>

<sup>56</sup>Normalized time series values are presented as a proportion of their 2001 value. This enables us to more plainly observe the relative growth and increasing difference over time.

# AI Augmentation & Wages: What is the Relationship?

The general assumption when it comes to AI augmentation is that low-wage jobs (and therefore assumed to be low-skilled) are most vulnerable, whereas high-wage roles are, generally speaking, not. Although skills that were rated as poorly suited for AI (originality, people management, and conflict resolution) were associated with high-wages, and more repetitive skills, rudimentary communication and numerical skills were rated as highly AI augmentable and associated with lower salaries, there are examples of high-wage, high-skill jobs that can be augmented by AI.

Consultations with experts emphasized that roles more likely to be immediately augmented by AI would be on the lower-skilled end, but this is not always the case. While the augmentable nature of the financial auditor was already briefly discussed, consider the civil engineering technologist, a relatively high-wage job. While not all aspects of this role are augmentable by AI, many tasks involving computer-assisted design (CAD) and providing standard costing estimates are augmentable. The table below are examples of high-wage, oftentimes high-skilled roles that are also relatively highly susceptible to AI augmentation.



<i>Table 2: High wage AI Augmentable Occupations</i>	<i>AI Impact Score</i>
Health information management occupations	<b>9.6</b>
Financial auditors and accountants	<b>9.1</b>
Database analysts and data administrators	<b>8.3</b>
Financial and investment analysts	<b>8</b>
Civil engineering technologists and technicians	<b>8.1</b>
Assessors, valuers and appraisers	<b>8.1</b>
Computer network technicians	<b>7.6</b>

Source: ICTC, 2019



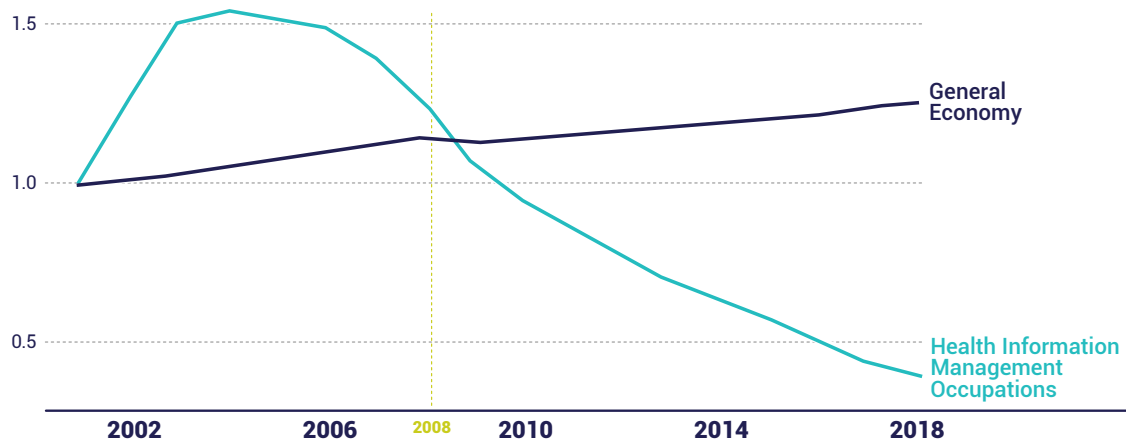
SNAPSHOT

## Health information management professionals

Health information management professionals tend to have relatively high wages in relation to their AI Augmentation Score (about 6% higher than the average Canadian wage in 2018). Health information management occupations perform tasks like classifying diseases, maintaining health records, and preparing medical statistics.

Figure 5 shows the normalized Canadian employment trend for Health Information Management Occupations vs. the General Economy. The occupation began rapidly declining in employment even before the 2008 recession. Since 2005, wages have increased while employment has declined. This inverse correlation indicates a shift in the underlying characteristics of the occupation from low-skill components (which have been replaced by AI) towards higher-skill components that AI cannot perform.

**Figure 5:** Health Information Management Occupations vs General Economy



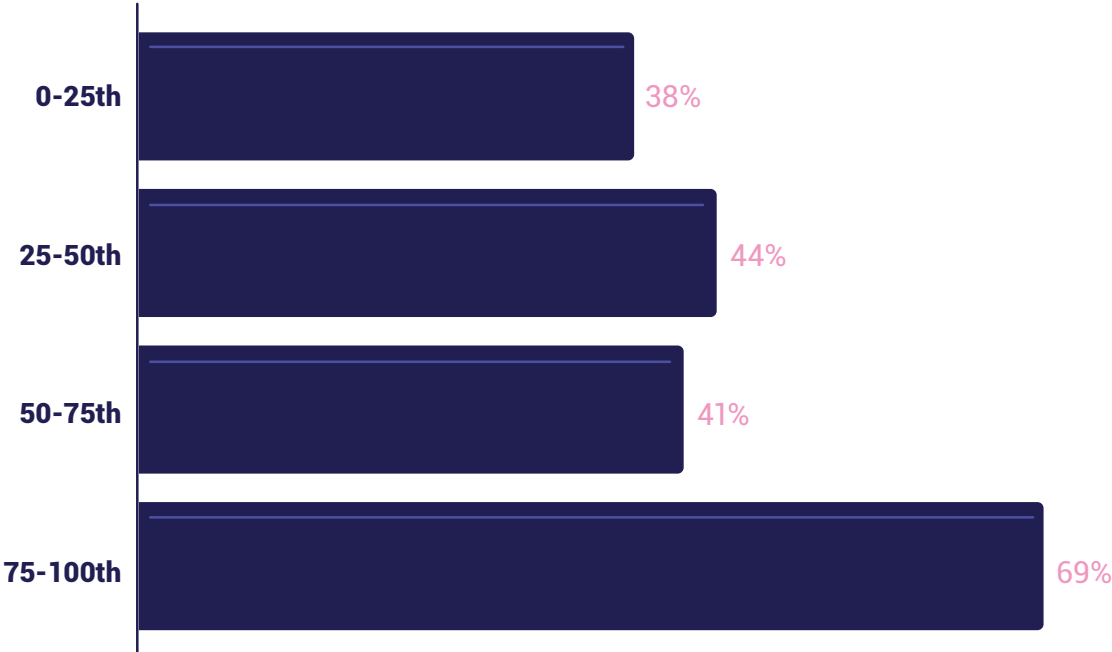
Source: ICTC, 2019

# Augmentation and Gender: What's the Relationship?

While augmentation from AI impacts a number of occupations, also noteworthy is the relationship between occupations most suitable for augmentation by AI and gender. Currently, women are much more likely to be employed in occupations with high AI Augmentation scores.

Figure 6 shows that nearly 70% of workers in occupations within the top quartile of AI Augmentation scores are women. Furthermore, all of the top 10 most AI augmentable occupations disproportionately employ women, ranging from a low of 73% for data entry clerks to 96% among health information management occupations.

**Figure 6:** Percent Female by AI Impact Score



Source: ICTC, 2019

## ***OPPORTUNITY OCCUPATIONS:*** **Least Likely to be Augmentable by AI**

Although many occupations are augmentable by AI, there are also a number of occupations that are less likely to be impacted—at least in the near-term. Occupations more likely to be 'safe' from AI augmentation involve the need to exercise qualitative decision-making and management, higher levels of human interaction, working with complex scenarios or different groups of stakeholders to harvest data, extract meaning and potentially even propose solutions.

### **Building Augmentation-Resistant Skills**

Based on a combination of consultations with experts holding a background in research and/or product development in the AI space and secondary research on past augmentation and displacement trends, ICTC identifies the following skill categories as most resistant to AI-led augmentation.

- 1** Advanced Originality: the ability to exercise creativity and flexibility to develop unusual and/or unique and innovative ideas about a given topic or situation, including the ability to uncover new problem-solving methods.
- 2** Advanced Administration and Management: the ability to apply advanced business and management principles related to strategic planning, resource allocation, human resources modeling, leadership techniques, and production methods.
- 3** Advanced Sales and Marketing: the ability to actively and creatively apply principles and methods for showing, promoting, and selling products or services. This includes marketing strategy and tactics, product demonstration, sales techniques, and sales control systems.
- 4** Critical Thinking: the use of advanced logic and reasoning to identify the strengths, weaknesses and new opportunities related to alternative solutions, conclusions or approaches to problems.
- 5** Active Learning: the ability to distill new information and exercise understanding of its various implications, for both current and future problem-solving and decision-making.
- 6** Flexible Learning Strategies: selecting and using training/instructional methods and procedures appropriate for each unique situation, in the process of learning or teaching new things.
- 7** Social Perceptiveness: an advanced awareness of others, including potential reactions, triggers, and pain points, coupled with an understanding or desire to understand why they exist.
- 8** Complex Problem Solving: the ability to identify, label and decipher complex problems and review related information to develop and evaluate options and implement solutions.
- 9** Operations Analysis: the ability to analyze specific needs and product requirements to create a design.
- 10** Troubleshooting: the ability to identify and determine causes of operating errors, and craft solutions or strategies to remedy the problems.

- 11** Systems Evaluation: the identification of measures or indicators tied to system performance and the determination of actions needed to improve or correct performance, relative to the goals of the system.
- 12** Developing Objectives and Strategies: the ability to establish long-range objectives and specify the strategies and actions needed to achieve them.
- 13** Establishing and Maintaining Interpersonal Relationships: developing constructive, collaborative and cooperative relationships with others, and maintaining them over time.
- 14** Assisting and Caring for Others: providing personal assistance, medical attention, emotional support, or other personal care to others including coworkers, customers, or patients.
- 15** Resolving Conflicts and Negotiating with Others: the ability to uncover and understand the root cause of conflicts, handle complaints, settle and mediate disputes, resolve grievances and conflicts, or otherwise negotiating with others.

As one might expect, there are more skills, knowledge areas, and work activities that are resistant to AI augmentation by narrow AI than those that likely to be augmented. In the longer term, almost all of these skills could be affected by sufficiently advanced AI, but this was not true in the recent past and is unlikely to be true in the near future.

Using these skill categories, a snapshot of 10 AI augmentation-resistant occupations are shown in Table 3 below.



<i>Table 3: 10 AI Augmentation Resistant Roles</i>	<i>AI Augmentation Score</i>
Psychologists	2.7
Registered nurses and registered psychiatric nurses	2.6
Paramedical occupations	2.1
Senior managers - financial, communications and other business services	2.0
Dentists	1.9
Professional occupations in religion	1.8
Senior government managers and officials	1.7
School principals and administrators of elementary and secondary education	1.4
Commissioned police officers	1.3
Legislators	0.2

Source: ICTC, 2019



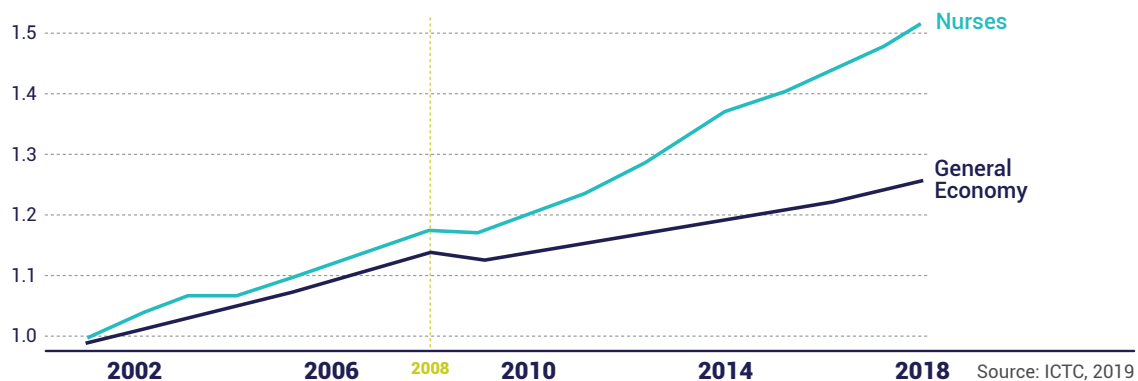
## Nurse aides, orderlies and patient service associates

Independent of AI developments, healthcare occupations are likely to grow quickly as a result of the ageing population. Demand for nursing and other healthcare occupations is likely to continue, with little augmentation to the roles. Current levels of AI are not yet suitable for subtly interpersonal, tactile, and emotionally intelligent jobs. Calming a psychologically distraught patient is likely not best left to Amazon Alexa, or her near-term progeny; nor is changing fitted sheets on a hospital bed. Moreover, human preferences and emotions also matter. While it may be possible to devise an AI capable of inserting a needle into a child’s arm, society may prefer that this job is left to a human.

At the same time, narrow AI could complement patient care activities. Significant innovations in health data collection and interlinkages, big data analytics of genomes promising novel treatments, and personalized gadgets, apps, and remote medical care are imminent. Narrow AI could assist with administrative patient charting and the provision of automated checks for negative drug interactions or conflicting care instructions. These advances would improve the quality of care, while ultimately increasing employment demand.

Figure 7 shows employment growth in nurse aides, orderlies and patient service associates take off and later diverges from the general economy after the recession of 2008.

**Figure 7: Normalized Canadian Employment Nurses vs General Economy**



With the ability of AI to augment the tasks and requirements of many roles across the economy comes the need for continuous learning and training. Lifelong learning and upskilling will help current workers prepare themselves for changes brought on by the technology and capitalize on those needs.





## SECTION V

# AI IN STRATEGIC SECTORS

While AI is often associated with the tech sector and global leaders such as Google, Nvidia, IBM, Microsoft, Apple, and Facebook, it is important to understand that these technologies are not limited to any single sector and go far beyond traditional applications in high-technology industries. Instead, with broader digitization of the economy and growing trends in data availability and connectivity, the presence of AI is increasingly seen across a number of sectors of the economy.

In this section:



Agri-foods  
& Food-tech



Health  
and Biotech



Clean  
Resources



Advanced  
Manufacturing



## Agri-foods & Food-tech

Agri-foods & food-tech is a combination of agriculture and technology subsectors, including animal genetics, industrial bioproducts, advanced crop cultivation techniques, and others.<sup>57</sup> An increasingly data-driven field, agri-foods & food-tech businesses can utilize data science tools and predictive analytics to maximize yields or optimize transportation logistics. Moreover, the use of AI and other innovations is growing in this sector, largely in response to challenges of climate change, population growth, and food security concerns<sup>58</sup>. In fact, highlighting this increasing reliance on technology to drive solutions in this space, a study from Goldman Sachs estimates that AI-powered precision farming could eventually result in a 70% yield increase worldwide by 2050.<sup>59</sup>

One example encountered during interviews with experts in this study was the potential of machine learning and machine vision/imaging to allow for quicker and more cost-effective identification of crop disease and soil sample testing. The use of drones and automated image processing for identifying disease patterns (rather than relying on manual labour) can be an opportunity for significant cost savings for agriculture businesses.

### Machine Vision for Better Food Processing and Sorting

Machine vision and AI analytics are finding applications in food processing, with companies using this technology to train cameras to identify key characteristics of food production in different lighting conditions. This is something that helps sort out products that do not meet specifications in size or colour, or could be contaminated.

Other companies utilize sensors and machine learning models to learn to identify foreign material contaminants or poor-quality produce. Coupled with data visualization technology, these results can be displayed on a dashboard used by human operators when sorting crops and providing the necessary information to move the crops onto a conveyor for processing.

With this technological intervention, produce inspectors and machinery operators will need training on interpreting the data presented by the AI software, helping them make better and more informed decisions based on that information.

AI applications can also create opportunities for assisted decision-making by helping farmers decide when to harvest crops and how to maximize supply-chain decisions via better estimates of expiry timelines. In such cases, AI can supplement the human decision-maker who possesses experience and domain knowledge with additional data-driven insights. Even if an AI program can identify a diseased crop, a decision will be required as to which actions to take from there—whether to harvest the crop, spray it, or simply destroy it. Although a technology will not replace the years of experience, knowledge of best practices, and domain knowledge of agricultural workers and farmers, the integration of AI into the agri-foods & food-tech arena will bring forth new opportunities and efficiencies as well as the need for training and upskilling.

<sup>57</sup>Canadian agri-food sector intelligence". Agriculture and Agri-Food Canada. July 24, 2019. <http://www.agr.gc.ca/eng/industry-markets-and-trade/canadian-agri-food-sector-intelligence/?id=1361290241756>

<sup>58</sup>AI in Agriculture – Present Applications and Impact". Emerj Artificial Intelligence Research. November 21, 2019. <https://emerj.com/ai-sector-overviews/ai-agriculture-present-applications-impact/>

<sup>59</sup>Daniels, Jeff. "Future of farming: Driverless tractors, ag robots". CNBC. September 16, 2016. <https://www.cnbc.com/2016/09/16/future-of-farming-driverless-tractors-ag-robots.html>



## Health and Biotech

For the purposes of this study, health and biotech refers to healthcare equipment and services, pharmaceuticals, biotechnology and life sciences. The ability of AI to process and analyze vast amounts of data will have a significant impact on the healthcare sectors and medical occupations in the future, with areas like pathology, dermatology and radiology set to see some of the most notable changes.

### New AI-Driven Healthcare Monitoring: Microsoft's InnerEye

Microsoft's InnerEye system is a healthcare application that monitors patients for cancer treatments. The InnerEye research project uses two AI branches, machine learning and computer vision to identify cancerous growths in a human body.

Typically, image contouring (building a model of the organ from imaging) is done manually and is both time-intensive and expensive. AI, however, is able to augment and automate aspects of this process, allowing medical experts to focus on more detailed tasks, such as editing the models and refining results.

Supplementing human expertise, the AI system is trained to identify relevant images and then create a 3D model of a patient's organs for the medical team to examine.

Another example of how AI can supplement or assist existing workers in this field is via simulations of drug interactions and proteins, something that can shorten the time and cost of developing new drugs. AI can assist scientists in the identification and synthesis of new molecules in labs, speeding the drug discovery process. Machine learning and automation can autonomously change parameters of a reaction to achieve optimal results. In this example, a robotic laboratory in the UK was able to identify an optimum manufacturing process after 26 hours. In contrast, a conventional approach would have taken scientists approximately two weeks of experimentation to achieve similar results.<sup>60</sup>

AI software is also likely to impact the administrative aspects of medical jobs. AI software is already augmenting many administrative or information-management roles in the healthcare sector. American-based startup IQVIA uses Natural Language Processing technology and other machine learning analytics to combine unstructured data with electronic medical records, information on clinical trials and other medical documents. This provides insights about compliance with industry and legal standards without reading through each individual record.<sup>61</sup>

Another example is 3M's machine learning algorithm trained to search through medical reports to facilitate better coding and labeling of reports related to diseases, treatments and delivered services. This kind of development aids in the discovery of what is needed for internal classification codes, while higher levels of automation of medical coding can help eliminate backlogs of reports, eventually allowing for quicker and more efficient medical billing.<sup>62</sup>

<sup>60</sup>AI lab-bot enrolled in drug discovery programme". *The Engineer*. Oct 7, 2019. <https://www.theengineer.co.uk/ai-lab-bot-drug-discovery-leeds/>

<sup>61</sup>Rise to the challenge of new engagement and transparency rules." IQVIA. Accessed January, 2020. <https://www.iqvia.com/solutions/integrated-global-compliance/commercial-compliance>

<sup>62</sup>Mejia, Niccolo. "Natural Language Processing in Healthcare - Current Applications." *Emerj Artificial Intelligence Research*. December 13, 2019. <https://emerj.com/ai-sector-overviews/natural-language-processing-in-healthcare-current-applications/>



## Clean Resources

Clean resources refer to the extraction or use of natural resources in a way that is carbon-neutral and environmentally-positive. Canada is an internationally-recognized leader in resource extraction but, in the context of climate change, there are great opportunities for using AI to improve performance and environmental outcomes in this sector.

Examples of companies using AI and machine learning for mineral exploration include Goldspot Discoveries and Kore Geosystems. These businesses utilize technologies to look at global mining trends as well as patterns in geological data to predict the best resource locations.<sup>63</sup> In addition to newer entrants, some of the largest mining companies, such as Newmont Goldcorp, are utilizing AI tools, such as IBM Watson, to sort through vast amounts of geological information to improve their targeting.<sup>64</sup>

### Revamping Canada's Oldest Industries: AI in Forestry

Until recently, conducting forest inventory checks was a labour-intensive process, requiring excursion into forests to sample plots and collect data. With the advent of AI, however, deep neural networks can be used to process massive amounts of satellite data in order to extract insights on forest health and monitor this over time.

Previously, much of the work of forest managers might have involved time spent on site in forests, performing inspections and inventory assessments. Increasingly, however, the day-to-day activities of these roles is likely to be transformed by AI. Drones and satellite information are able to identify forest health indicators, estimate forest cover, monitor illegal activities and rapidly respond to environmental impacts. Machine learning and reinforcement learning techniques are able to incorporate large, diverse data sets for better decision-making. As a result, forestry management positions may become more analytical and knowledge-based, focused on utilizing data-driven insights to make decisions, rather than relying on time spent physically in the field investigating.

In addition to forestry applications, AI is also increasingly used by clean technology companies around the world, particularly in renewable power generation. For example, NextEra Energy in the US relies on machine learning to improve efficiency and boost energy generation productivity. In this case, predictive abilities help identify unusual patterns of equipment operations, reducing downtime and disruption. At the same time, AI is also assisting alternative energy companies optimize their efficiency from solar panels and windfarms,<sup>65</sup> and to balance power grid energy usage to reduce the consumption of fossil fuels.

Another example of AI impacting cleantech is the development of new materials (for example, advanced batteries, solar cells, low-energy semiconductors, and catalysts for CO<sub>2</sub> capture).<sup>66</sup> Here, AI can reduce the need for labour intense trial-and-error experimentation and allow researchers to focus on creative tasks.<sup>67</sup> This can provide faster results and less wasted labour and supply inputs, which can be the costliest aspect of these experiments.

<sup>63</sup>Holmes, Frank. "This AI Company Is The Future Of Gold Exploration". *Forbes*. Feb 11, 2019. <https://www.forbes.com/sites/greatspeculations/2019/02/11/this-ai-company-is-the-future-of-gold-exploration/#65e6e34b2ae3>

<sup>64</sup>IBM and Goldcorp Team to Bring Watson to the Mines." *IBM*. March 3, 2017. [https://www.ibm.com/news/ca/en/2017/03/03/t8\\_17903u78442c90.html](https://www.ibm.com/news/ca/en/2017/03/03/t8_17903u78442c90.html)

<sup>65</sup>Kearns, Jane. "Cleantech needs more AI talent to help save the world". *VentureBeat*. May 23, 2018. <https://venturebeat.com/2018/05/23/cleantech-needs-more-ai-talent-to-help-save-the-world/>

<sup>66</sup>Integration of AI and robotics with materials sciences will lead to new clean energy technology". *Canadian Institute for Advanced Research*. January 25, 2018. [https://www.eurekalert.org/pub\\_releases/2018-01/cifa-ioa012518.php](https://www.eurekalert.org/pub_releases/2018-01/cifa-ioa012518.php)

<sup>67</sup>Chen, Cathy. "How AI is revolutionizing the world of clean energy materials". *World Economic Forum*. January 17, 2019. <https://www.weforum.org/agenda/2019/01/how-ai-is-revolutionising-the-world-of-clean-energy-materials/>



## Advanced Manufacturing

Advanced manufacturing refers to the blend of traditional manufacturing processes and procedures with digital technologies. Increasingly, the use of technology in the manufacturing sector is seen as a method of enhancing productivity, boosting output and generating efficiencies that are essential to remaining competitive in an increasingly global and connected economy.

AI is already impacting the manufacturing sector in many different ways. It can be used to optimize manufacturing supply chains, and help companies anticipate, predict and plan for market changes. The ability to do this is a significant advantage for businesses in manufacturing because it helps them move from a reactionary mindset to truly a strategic one.

AI is also changing this sector with 'generative design software,' which is an algorithm that describes restrictions and parameters in the manufacturing process.<sup>68</sup> This can include material types, available production methods, budget limitations and time constraints. The algorithm helps by exploring all possible configurations and suggests the best solutions.

### Canadian Picking Robot Kickstarts the Retail Supply Chain

Toronto's Kindred AI aims to change retail by vastly improving the supply chain to expedite Amazon-ordered onesies.

The company's picking robot, SORT, combines vision, grasping and manipulation algorithms to deliver fast, accurate picking. SORT integrates with warehouse management software to evaluate items in real time, picking and matching them to individual customer orders. This increases productivity and improves the overall efficiency of a supply chain.

Using "human-in-the-loop data methodology," which leverages both human and machine intelligence to create algorithms and models, Kindred's AI evaluates millions of data points to calculate and execute an optimal pick strategy for each task in real time. SORT is currently best suited for applications in the apparel industry, but Kindred is quickly working to expand this offering to a wider array of general-merchandise items.

Supply chains are expected to benefit significantly from the integration and adoption of AI. The three biggest cost drivers for any supply chain are the following: inventory carrying costs, transportation, and labour. Using predictive analytics and AI-enabled projections could cause a business to reduce its overall inventory levels, cutting the cost of transportation. At the same time, improved sorting and storing techniques driven by AI can help employees work more efficiently when receiving, storing, replenishing and shipping stock.

<sup>68</sup>Kushmaro, Philip. "5 ways industrial AI is revolutionizing manufacturing." CIO. September 27, 2018. <https://www.cio.com/article/3309058/5-ways-industrial-ai-is-revolutionizing-manufacturing.html>



## SECTION IV

# AI ETHICS AND TRANSPARENCY

|| *The irony is that the more we design artificial intelligence technology that successfully mimics humans, the more AI learns in the way that we do—with all of our biases and limitations.* ||

- Suresh Venkatasubramanian Associate professor in the University of Utah's School of Computing

While the possibilities that AI can usher in has created excitement and optimism, there has also been a corresponding growth in the concern over the potential impacts of this technology on the economy and civil society in general.

In many ways, it is tempting to place substantial trust in AI, treating it as a neutral or unbiased intelligence built entirely on logic and facts. However, given that AI is ultimately a human construction—that is, programmed and finely tuned by human beings—these systems reflect human beliefs, biases, social norms and values. For example, if AI is trained using unrepresentative input data (a selection bias accidentally measuring only a specific subset of an audience instead of the whole, making the data sample unrepresentative of the total population), the subsequent perceptions and recommendations could function to reinforce existing inequalities. Unrepresentative data can result in seemingly highly 'accurate' or credible output that is, however, invalid due to biases in the input data.

Further, the current lack of diversity among AI researchers also introduces biases. Globally, it is estimated that women represent about 12% of AI researchers and about 6% of mobile application and software developers.<sup>69</sup> A lack of diversity among these professionals, means that AI outputs reflect narrow views and blind spots.

A common but questionable narrative is that algorithms lead to more informed or accurate decisions, as they are based on data rather than human instinct.<sup>70</sup> People may assign a higher degree of trust to digital or numerical systems versus human-driven systems, however, it can be argued that this trust is flawed due to inherent uncertainties regarding where and how data is generated, who is capturing the data, and even who is deciding what to capture in those datasets. Given that all of these decisions are ultimately made by humans, it is inevitable that biases are captured in those datasets, and they get propagated into the system.<sup>71</sup>

Increasingly, we are seeing examples of how algorithms, automated decision-making, and AI are resulting in biased outcomes. One of the most common examples rests with the analysis of racial disparities in predictions for bond risk scores in the judicial system. By comparing risk scores to actual criminal activity, the analysis concluded that AI software was twice as likely to falsely label black defendants as future criminals than white defendants.<sup>72</sup>

Other similar examples include the profiling of African Americans by face-recognition networks used in law enforcement, due to the disproportionate representation of African Americans in mugshot databases,<sup>73</sup> or Asians being nearly twice as likely to be charged higher prices from SAT preparation services due to geographically-biased pricing.<sup>74</sup>

## AI and Gender Biases: The Case of the Amazon Recruiting Engine

Making global headlines, Amazon's machine learning specialists found that their recruiting engine did not rate candidates for software developer jobs and other technical posts in a gender-neutral way.

Instead, the automated tool was trained to vet applicants by observing patterns found in resumes submitted to the company over the last decade, where the sample of applicants was predominantly male. As a result of the narrow and biased data sample, this system taught itself that male candidates were in fact preferable for these roles, and ended up downgrading graduates from all-women colleges.

Although it was an unintended consequence—and attempts were made to edit the program and correct these logic errors—there was no guarantee that the engine would not devise other forms of discriminatory sorting. As a result, this project was ultimately terminated, and the team disbanded.<sup>75</sup>

<sup>69</sup>First UNESCO recommendations to combat gender bias in applications using artificial intelligence". UNESCO. May 17, 2019. <https://en.unesco.org/news/first-unesco-recommendations-combat-gender-bias-applications-using-artificial-intelligence>

<sup>70</sup>Bousquet, Chris. "Algorithmic Fairness: Tackling Bias in City Algorithms". Ash Center for Democratic Governance and Innovation, Harvard Kennedy School. August 31, 2018. <https://datasmart.ash.harvard.edu/news/article/algorithmic-fairness-tackling-bias-city-algorithms>

<sup>71</sup>Serebrin, Jacob. "E Is For Ethics In AI — And Montreal's Playing A Leading Role". Canada.ai. April 5, 2019. <http://www.canada.ai/posts/e-is-for-ethics-in-ai-and-montreals-playing-a-leading-role>

<sup>72</sup>Bousquet, Chris. "Algorithmic Fairness: Tackling Bias in City Algorithms".

<sup>73</sup>Lohr, Steve. "Facial Recognition Is Accurate, if You're a White Guy". The New York Times. February 9, 2018. <https://www.nytimes.com/2018/02/09/technology/facial-recognition-race-artificial-intelligence.html>

<sup>74</sup>Angwin, Julia, Surya Mattu and Jeff Larson. "The Tiger Mom Tax: Asians Are Nearly Twice as Likely to Get a Higher Price from Princeton Review". ProPublica. September 1, 2015. <https://www.propublica.org/article/asians-nearly-twice-as-likely-to-get-higher-price-from-princeton-review>

<sup>75</sup>Dastin, Jeffrey. "Amazon scraps secret AI recruiting tool that showed bias against women". Reuters. October 9, 2018. <https://www.reuters.com/article/us-amazon-com-jobs-automation-insight/amazon-scrap-secret-ai-recruiting-tool-that-showed-bias-against-women-idUSKCN1MK08G>

## Efforts to Address Ethical AI Issues

More and more, companies are reacting to the ethical challenges and concerns surrounding AI, including a number of notable efforts to address issues like sampling bias caused by oversampling, content moderation, and the development of advisory committees to monitor and validate results.

A well-known example resulted from the criticism of Facebook for its actions in regard to user privacy and dealing with bad actors on the platform. Since identified, Facebook aimed to develop initiatives based on ethical AI use, such as developing an Applied Machine Learning group tasked with removing spam from newsfeeds, searching for fake accounts, and addressing content moderation concerns. Through these mechanisms, Facebook hopes that it will be able to reduce the amount of offensive and damaging content that is sorted by human content moderators.<sup>76</sup>

### AI Ethics Advisory Boards: A Good Idea that Requires Careful Member Selection

Increased scrutiny coupled with the growing possibilities of AI have led to many large tech companies expanding their research operations in the area of the ethical use of AI. Examples of these efforts include funding independent researchers on this topic, creating ethics advisory boards, developing industry-wide collaborations for ethics standards, and collaborating with universities to expand the number of roles related to ethical considerations.

However, some have criticized these efforts as insufficient and ultimately failing to reflect diversity and address existing inequalities in society.<sup>77</sup> For example, Google ultimately ended up disbanding their AI ethics board over controversies and resignations related to its membership, including one member's previous campaigns against anti-discrimination laws for LGBTQ groups and expressed skepticism of climate change.<sup>78</sup>

In addition to these boards requiring a careful selection process, some have pointed to the possibility that AI ethics advisory committees will ultimately act as defences against stronger calls for regulation of the technology. For example, when researchers discover harmful uses of AI, the companies that develop the technology may point at boards and charters as evidence to deflect criticisms and harmful intent. While the development of these boards and committees are important to provide oversight and verification, they must ultimately be carefully selected and framed with clear guidelines and responsibilities.

Some remain skeptical of the intentions of ethics committees, believing that these ethical efforts are mostly symbolic, with ethical AI becoming a popular 'corporate buzz phrase' for internal committees, job titles, and philanthropic initiatives.<sup>79</sup> The rapid development of AI requires the creation of overarching bodies or committees to examine, monitor, track and research the ethical implications of the technology.

<sup>76</sup>Vanian, Jonathan. "Unmasking A.I.'s Bias Problem." *Fortune*. June 25, 2018. <https://fortune.com/longform/ai-bias-problem/> ; Vincent, James. "AI won't relieve the misery of Facebook's human moderators." *The Verge*. February 27, 2019. <https://www.theverge.com/2019/2/27/18242724/facebook-moderation-ai-artificial-intelligence-platforms>

<sup>77</sup>Levin, Sam. "Bias deep inside the code": the problem with AI 'ethics' in Silicon Valley'. *The Guardian*. March 29, 2019. <https://www.theguardian.com/technology/2019/mar/28/big-tech-ai-ethics-boards-prejudice>

<sup>78</sup>Piper, Kelsey. "Exclusive: Google cancels AI ethics board in response to outcry". *Vox*. April 4, 2019. <https://www.vox.com/future-perfect/2019/4/4/18295933/google-cancels-ai-ethics-board>

<sup>79</sup>O'Brien, Matt and Rachel Lerman. "What are tech titans doing about AI ethics concerns?" *CTV News*. April 7, 2019. <https://www.ctvnews.ca/sci-tech/what-are-tech-titans-doing-about-ai-ethics-concerns-1.4369595>



## AI Ethics and Value Judgments

The functional use of AI ethics and values looms over many applications. One of the more prominent examples is the value judgments involved in AI programming for autonomous vehicles. As many have noted, a truly autonomous vehicle would have to make split-second decisions in case of dangerous situations where the car's AI could be forced to make a decision saving one life versus another.

### The MIT Moral Machine: An Example of AI and Ethical Judgements

In a situation where a collision is unavoidable, should the car hit the obstacle and kill its own driver or to swerve into a crowded sidewalk and kill the pedestrians?

Because of these complex issues, M.I.T.'s Media lab invited people from around the world to play a game called 'Moral Machine'. In this game, players were assigned the role of self-driving car and tasked with decision making in relation to the most ethical outcomes to the above question. Two million people from 200 countries logged more than 40 million decisions in this experiment, making it largest study of moral preferences for machine intelligence ever conducted.<sup>80</sup>

The results of the experiment highlighted the fluid and cultural nature of these moral decisions, grouping responses into three geographic clusters: The Western cluster (North America and Western Europe); the Eastern cluster (a mix of East Asian and Islamic countries); and the Southern cluster (composed of Latin-American countries and African countries). The results of the findings were eye-opening:

Players in **Western cluster** were more likely to spare a business executive than a homeless person, and were also more likely to kill jaywalkers rather than lawful pedestrians



Players in the **Eastern cluster** were more likely to kill a young person and spare an older person

Players in **Southern cluster** were more likely to kill an overweight person than an athletic person

Consequently, some research is focussed on the opportunity and the challenges of moral judgments, particularly in the context of an algorithm with life and death implications. Currently, Germany is the only country that has a framework for the ethics of driverless cars, including the prohibition of using personal features or characteristics in the event of unavoidable accident situations.

Given these complexities, it is likely that there will be many years of further debates and discussions over the growing legal, philosophical, moral and ethical implications of AI.

<sup>80</sup>Lester, Caroline. "A Study on Driverless-Car Ethics Offers a Troubling Look into Our Values." *The New Yorker*. January 24, 2019. <https://www.newyorker.com/science/elements/a-study-on-driverless-car-ethics-offers-a-troubling-look-into-our-values>

## Transparency and ‘Explainability’

Given the potential for bias in AI development and use, the increasing interest in transparent AI decision-making is understandable and reasonable. However, releasing the parameters or mechanics of an AI does not necessarily provide insight into how it actually works in practice. Given the widely varying levels of expertise or knowledge in terms of modern digital technologies, it is challenging to have open and transparent discussions on necessary policies and procedures.

With AI's growing power and impact, there have been increasing calls for what is referred to as explainable AI (XAI, Interpretable AI, or Transparent AI).<sup>81</sup> Yet the complexity that gives AI power can also make it difficult or impossible to disentangle—it is not always a simple process to reverse-engineer or to deconstruct an AI decision. Neural networks, named for their similarity to biological neural networks, are mysterious and innately opaque; in deep learning, the system is not guided by explicit knowledge and rules but has effectively taught itself by making internal adjustments. What this means is that the system may not necessarily 'know how it knows what it knows,' nor is it necessarily able to communicate the foundation of its knowledge. Geoffrey Hinton, one of the most influential pioneers in deep learning, explains this phenomenon in the following way:

**||** *A deep-learning system doesn't have any explanatory power... the more powerful the deep-learning system becomes, the more opaque it can become. As more features are extracted, the diagnosis becomes increasingly accurate. Why these features were extracted out of millions of other features, however, remains an unanswerable question.*<sup>82</sup> **||**

Despite these challenges, there have been significant efforts by governments and other stakeholder groups to develop guidelines for civil and political rights protections. This includes guidelines to ensure the responsible use of AI to minimize intentional or unintentional discrimination in the public and private sector. The European Union, for example, is looking to develop guidelines for ethical AI that are transparent, explainable, and understood by humans.<sup>83</sup> While the EU's General Data Protection Regulation (GDPR) does have some explainability requirements, there is still significant uncertainty regarding the level of explainability required, and whether it is enough to be 'explainable' as opposed to 'understandable.'<sup>84</sup>

In the future, there may be a greater need for ethicists and privacy experts to consider the impact and degree of explainability or, at least, transparency of AI in companies adopting new technologies. With such a growing demand, we may see a rise in roles dedicated to ethical AI training, AI auditing, and even remediation when AI solutions inflict harm or damages on people or organizations.

<sup>81</sup>Schmelzer, Ron. "Understanding Explainable AI". *Forbes*. July 23, 2019.

<sup>82</sup>Mukherjee, Siddhartha. "A.I. Versus M.D." *The New Yorker*. March 27, 2017. <https://www.newyorker.com/magazine/2017/04/03/ai-versus-md>

<sup>83</sup>Vincent, James. "AI systems should be accountable, explainable, and unbiased, says EU." *The Verge*. April 8, 2019. <https://www.theverge.com/2019/4/8/18300149/eu-artificial-intelligence-ai-ethical-guidelines-recommendations>

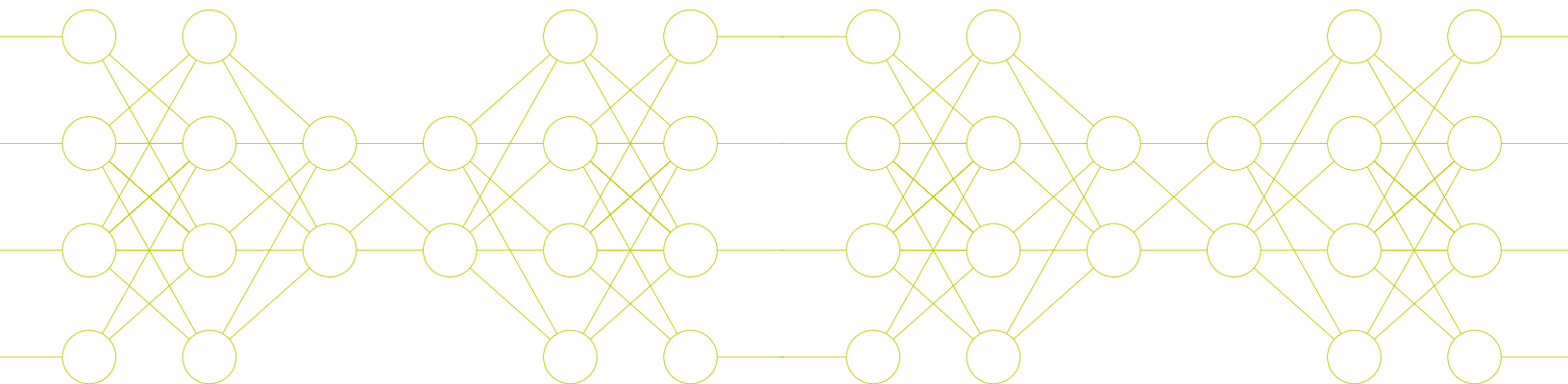
<sup>84</sup>Chowdhury, Rumman. "Is Explainability Enough? Why We Need Understandable AI." *Forbes*. June 4, 2018. <https://www.forbes.com/sites/rummanchowdhury/2018/06/04/is-explainability-enough-why-we-need-understandable-ai/#33e62e1662f4>

## AI and Privacy

Given that the development and use of AI is reliant upon the large-scale usage of data (personal, aggregated, and metadata) obvious questions around the privacy and its implications emerge.

Firstly, the increased presence of smart devices (incorporating AI technologies) represents a vulnerability to exploitation of data, especially since there is limited awareness of how much data software and devices generate and share. Examples include smart speakers and connected home devices like Amazon's Alexa<sup>85</sup>, Microsoft's Cortana<sup>86</sup>, or Google's Home<sup>87</sup>. For these devices, the sharing of audio clips with subcontractors has been integral to the development of Natural Language Processing (NLP) for AI voice recognition, but few customers are aware that this is occurring.

Another potentially negative privacy implication of AI is related to the reduction of anonymity. AI could be utilized to identify, track, and monitor individuals. With growing computational power and access to vast amounts of large datasets, AI can de-anonymize this data. Similarly, voice and facial recognition via AI has rapidly progressed in recent years with the potential to compromise anonymity in public, raising questions regarding the use of these technologies by law enforcement.<sup>88</sup>



<sup>85</sup>O'Flaherty, Kate. "Amazon Staff Are Listening To Alexa Conversations -- Here's What To Do." *Forbes*. April 12, 2019. <https://www.forbes.com/sites/kateoflahertyuk/2019/04/12/amazon-staff-are-listening-to-alexa-conversations-heres-what-to-do/#604658b171a2>

<sup>86</sup>Hachman, Mark. "Microsoft's privacy policy admits contractors listen to Cortana, Skype recordings." *PCWorld*. August 15, 2019. <https://www.pcworld.com/article/3431701/microsofts-privacy-policy-admits-contractors-listen-to-cortana-skype-recordings.html>

<sup>87</sup>Kaser, Rachel. "Google contractors are secretly listening to your Assistant recordings." *TNW*. July 10, 2019. <https://thenextweb.com/google/2019/07/10/google-contractors-are-secretly-listening-to-your-assistant-recordings/>

<sup>88</sup>Deane, Michael. "AI and the Future of Privacy." *Towards Data Science*. September 5, 2018. <https://towardsdatascience.com/ai-and-the-future-of-privacy-3d5f6552a7c4>

## Conclusion

Canada is well positioned as a global leader in AI, particularly when it comes to developing world-class research, skilled talent, and—through leadership on important topics and considerations such as privacy—transparency and ethical use of this technology. Canada is quickly developing outstanding post-secondary research institutions with substantial expertise located in world-renowned AI clusters in Montreal, Toronto and Edmonton. Many leading companies from around the world have recognized these strengths and established research labs and other operations in Canada in order to capitalize on Canadian AI development.

Given the need for highly qualified talent to grow and scale Canada's leadership position in AI, it is important to consider labour market trends and the occupations that are likely to see significant skill shifts and growth in the future as a result of the technology.

ICTC's AI Augmentation model attempts to showcase some of these changes by assessing the likelihood of different occupations being augmented by AI. AI technologies will have uneven impacts on various roles, making it likely that some occupations will be more susceptible to augmentation than others. Economic shocks have led to the increased adoption of maturing, labour-saving technologies such as AI and automation, which has bolstered productivity while impacting labour market outcomes.

Occupations such as auditors, financial analysts, and healthcare information management practitioners are at risk of being augmented by AI. Therefore, it is imperative that these types of occupations are supported by training options that will allow workers to learn new competencies and, ultimately, benefit from AI efficiencies. Planning for these realities today will create an opportunity for those in occupations highly susceptible to AI augmentation to perform value-added work with better compensation.

As with previous technological advances, AI development will deliver net gains and improvements but also create challenges and hurdles that will necessitate a comprehensive and effective strategy of upskilling and, in some cases, retraining. These strategies will be essential in helping Canadians prepare for a future where AI is no longer a "nice to have" option but an accepted standard and cornerstone of future technological, economic and societal development and advancement.

# APPENDIX

## I Research Methodology

The development of this study utilized a variety of secondary and primary research methods to extract findings and generate insights.

The primary research component included 15 key informant interviews (KIIs) with subject-matter experts and industry leaders on AI topics, including machine learning, deep learning, neural networks, data use and privacy, transparency and explainability, and AI research. Findings on the applications and use of AI in Canada—both in the general economy and across sectors—were extracted via KIIs and a survey (providing 112 responses) on digital transformation in the Canadian economy. ICTC also utilized a survey (providing more than 300 responses) to extract key insights on AI jobs, which were then used to identify critical skills for each role through “web scraping” of job boards. Lastly, the study was presented to a project advisory committee made up of AI experts. These experts came from backgrounds including academia, industry, research, and non-profit groups. The advisory group met twice during the course of the project to discuss, refine and validate findings.

The secondary research component of this study included a robust literature review on AI, its applications across the economy, challenges and important considerations of the technology, as well as literature related to skill categorizations or clusters tied to numerous occupations as reflected by international standards. This was complemented with a variety of secondary data, primarily from Statistics Canada and the US Department of Labor (O\*NET).

## II AI Augmentation Methodology

To understand recent and near-future impacts of AI on the labour market, ICTC devised a bottom-up method of rating occupations by their suitability for narrow-AI augmentation. Unlike the potentially unlimited versatility of Artificial General Intelligence (AGI), narrow AI has in recent years nibbled away at a relatively specific set of competencies. Thus, the approach utilized key insights gathered via primary research and secondary-data analysis and literature review to rank the skills, competencies, knowledges, or aptitudes (hereafter referred to as just ‘skills’) by their suitability for augmentation by narrow AI. Utilizing O\*Net data, the relative importance of each 160 different skills corresponds to each occupation code. An AI augmentation score is assigned to each skill depending on its level of sophistication, and the importance of the occupation. Thus, by aggregating the number of skills for each occupation that is augmentable by AI, the degree to which the particular occupation is likely to be impacted by AI can be determined.

For each skill and occupation, a value indicating the level of AI suitability is assigned, depending on the type of skill, skill importance, and skill level. This AI-suitable value is then scaled by the importance of the skill to the occupation, and values are aggregated for each occupation. Sorting occupations by this aggregated value provides an estimate of which occupations are augmentable by AI to a larger or lesser degree.

### III Limitations of Research

While AI research goes back decades, the field has been in a state of constant transformation, making cutting-edge development difficult to measure and quantify. The challenges around the definition of AI can be ameliorated somewhat by discussions with key informants but, ultimately, it remained necessary to group analyses according to the categorizations of “weak (or narrow) AI” and “strong (or general) AI.” Narrow AI was used in this analysis due to availability of data and accuracy of impact measurement. This means that some future AI potential (particularly as it relates to strong or AGI) may be underestimated.

The AI Augmentation model also involved a judgement of skills and work activities based on their likelihood of AI augmentation, according to qualitative primary research extracted in this study and available secondary research. The task of rating skills (and skill levels) for narrow AI suitability necessarily involves qualitative judgement, but this freedom of judgement is constrained by a strict definition of AI under consideration, the understanding of which was derived from a series of Key Informant Interviews with experts, and by taking the average of ratings from several independent research analysts. In such cases, it is possible that O\*NET data may be flawed, or the correspondence between US SOC codes and Canadian NOC codes may have introduced noise and bias. Finally, the model relies on a univariate regression methodology, which guarantees the existence of omitted variables, reverse causality, or other forms of endogeneity in the model. The model does not claim to have identified strictly causal relationships, and instead presents a series of persuasive and statistically significant correlations as evidence of a likely relationship. A more quantitative-style study would attempt to control for covariates such as ‘ease of off-shoring’ and other factors that may be partly driving results, but this level of comprehensiveness is outside the scope of the analysis provided by this paper.

### IV Skills Most Susceptible to AI Augmentation

The AI Augmentation model provides snapshots of both occupations susceptible and less susceptible to AI augmentation, as well as skills. While the report highlights skills less likely to be susceptible to AI augmentation, the following are example of 15 skills likely to be subjected to AI augmentation:

- 1 Basic Number Facility: the ability to add, subtract, multiply, or divide quickly and correctly.
- 2 Memorization
- 3 Physical Strength
- 4 Speed and Flexibility of Closure: the ability to pick out a pattern of information quickly in the presence of distracting information, even without all the information present.
- 5 Perceptual Speed: the ability to examine and compare numbers, letters, and objects quickly.
- 6 Visualization: the ability to imagine how something will look after it is relocated, or when its parts are moved or rearranged.

- 7** Response Orientation: the ability to choose quickly between two or more movements in response to two or more different signals.
- 8** Clerical Skills
- 9** Mathematical Skills
- 10** English and Foreign Language Skills
- 11** Basic Programming Skills
- 12** Operation Monitoring: the ability to monitor gages, dials, or other indicators.
- 13** Basic Judgment and Decision Making: the ability to consider the relative costs and benefits of potential actions to choose the most appropriate ones.
- 14** Processing Information: the ability to compile, code, categorize, calculate, tabulate, audit, or verify information or data.
- 15** Performing Administrative Activities: the ability to perform day-to-day administrative tasks such as maintaining information files and processing paperwork.