The Conference Board of Canada

Lethbridge's Manufacturing Workforce

Composition and Upskilling for the Future

Presented to
Economic Development Lethbridge

Prepared by
The Conference Board of Canada

Contents

Key Findings

- Automation of tasks such as testing and analysis; recording, documentation and reporting; production operations; material handling; machine adjustment and maintenance; quality control; planning and scheduling; weighting and measurement will enhance productivity in manufacturing sector significantly.

- Lethbridge needs to close technology skills with the country in the following task categories to make its manufacturing sector nationally competitive: testing and analysis; quality control, inspection, assurance; recording, documentation and reporting.

- Recent research confirms that manufacturing firms integrating automation technologies and robotic solutions experience accelerated growth rates compared to slow-adopting counterparts. Additional benefits of automation integration include process efficiency, worker productivity, workforce management, and enhanced corporate sustainability.

- Acknowledging a regional lag of 5-10 years, manufacturers stand to benefit from the development of a practitioner roadmap that details industry-level strategies for upskilling as informed by post-second training opportunities in automation technology in similar regions (e.g., Red Deer, Saskatoon, Regina).

- Access to talent was cited as the most frequent barrier that is impeding the integration of automation technologies and robotic solutions in the Lethbridge manufacturing sector. Industry leaders noted that skill specificity for tech onboarding and local workforce composition limit their ability to recruit, retain, and train sufficient skilled labor.

- Estimated training times for addressing some of the top skills gaps in Lethbridge manufacturing sector include computer aided design (1-2 years), analytical software (1-2 years), enterprise resource planning (1-2 years), business intelligence and data analysis (1-2 years).

- Routine, repetitive manual/physical tasks emerged as the most widely automated task type amongst Lethbridge manufacturers. While larger and more advanced organizations indicated the initial stages of automating non-routine manual/physical tasks, automation technologies have not begun to replace non-routine cognitive/interpersonal tasks with any significance.

- Workforce productivity and process efficiency emerged as the top benefits driving manufacturing organizations to invest, deploy, and scale the use of automation technologies and robotic solutions in Lethbridge.

- Similar to other manufacturers located elsewhere, the majority of local manufacturers do not actively measure return on investment (ROI) or payback period as a decision-making criterion for Robotic Process Automation (RPA) and Robotic Solution Integration (RSI).

This remains a central barrier to mobilizing future investments in productivity enhancing technologies.

- There's a noticeable lack of awareness among Lethbridge manufacturers regarding available regional, provincial, or federal financial support and reskilling/upskilling programs. This underscores the urgent need for a local stakeholder (or consortium) to champion the role of aggregating and disseminating this information to the manufacturing companies in the region. This would ensure Lethbridge manufacturing organizations are well-informed and can leverage these supports to boost their competitiveness and productivity.

Introduction

Manufacturing is going through a digital transformation. Technologies such as advanced robotics, the Internet of Things (IoT), cloud computing, artificial intelligence and machine learning result in increased automation, predictive maintenance, and self-optimization of process improvements in production. This leads to a new level of efficiency and responsiveness to production problems and customer demands that was not previously possible.[1]

Smart machines with access to vast amounts of data enhance factory efficiency, productivity, and waste reduction. The power of Industry 4.0 lies in digitally connected machines creating and sharing information. Key opportunities include data-driven optimization of operations, adaptable supply chains, autonomous equipment and vehicles, affordable robotics, advancements in additive manufacturing, and leveraging the Internet of Things and cloud technology for operational improvements and access to shared insights.[2]

Despite its numerous benefits, the adoption of advanced automation technologies can be challenging for several reasons. The availability of information and communication technology (ICT) infrastructure required to deploy digital technologies, the cost of automation technologies, organizational culture, and skill level of the workforce can interfere in the value perception and consequent level of investments in automation technologies. [3] Given the speed with which these technologies emerge, companies are grappling with how to upskill their current workforce to take on new work responsibilities made possible by Industry 4.0 and to recruit new employees with the appropriate skills.

Employing close to 10 percent of the workforce, the manufacturing industry is an important part of Lethbridge's economy. The health of the regional economy is tied to the resilience of the manufacturing industry. We analyze barriers to adopting automation technologies by manufacturing companies in the region. Doing both primary data collection (i.e., interviews and expert consultation) and secondary data analysis, we investigate businesses' perception about the feasibility of adopting automation technologies and whether the region's workforce has the requisite skills to incorporate automation technologies.

---

[1] IBM, *What is Industry 4.0?*
[2] Marr, *What is Industry 4.0?*
[3] Dalenogare, *The Expected Contribution of Industry 4.0 Technologies for Industrial Performance.*

Research Objectives

The purpose of this project is to analyze the current state of Lethbridge’s manufacturing workforce and identify ways to make it more resilient by offering different ways for it to adopt productivity-enhancing technologies such as robotics equipment and automation tools. Specifically, it:

- Identifies the range of manufacturing tasks that can be automated, and skills associated with performing those tasks.

- Identifies the current state of Lethbridge’s manufacturing workforce and recommends ways to make it more resilient and able to make use of productivity-enhancing technologies such as robotics equipment and automation tools.

- Systematically documents what regional employers are doing to address existing talent challenges and other barriers in the adoption of productivity-enhancing technologies.

- Synthesizes practical evidence as to structure, duration, and success of different training programs in upskilling/reskilling. As well as determining time length required to teach a worker using a new equipment, trouble shooting potential problems, and fixing machinery issues.

- Provides recommendations to facilitate the transition of Lethbridge manufacturing workforce for Industry 4.0.

Taken together, this project provides a solid understanding of the composition of region’s manufacturing workforce, manufacturing related tasks that can be automated, and technology skills associated with performing those automatable tasks. Additionally, it identifies specific skills gaps that need to be closed for local manufacturers to adopt automation technologies and the training requirements associated with that upskilling. This research informs economic development policy and programs on Industry 4.0 workforce requirements in the Lethbridge Census Metropolitan Area. Namely, it offers specific ways to design and implement targeted training programs.

See Appendix B for the full methodology.

Literature Review

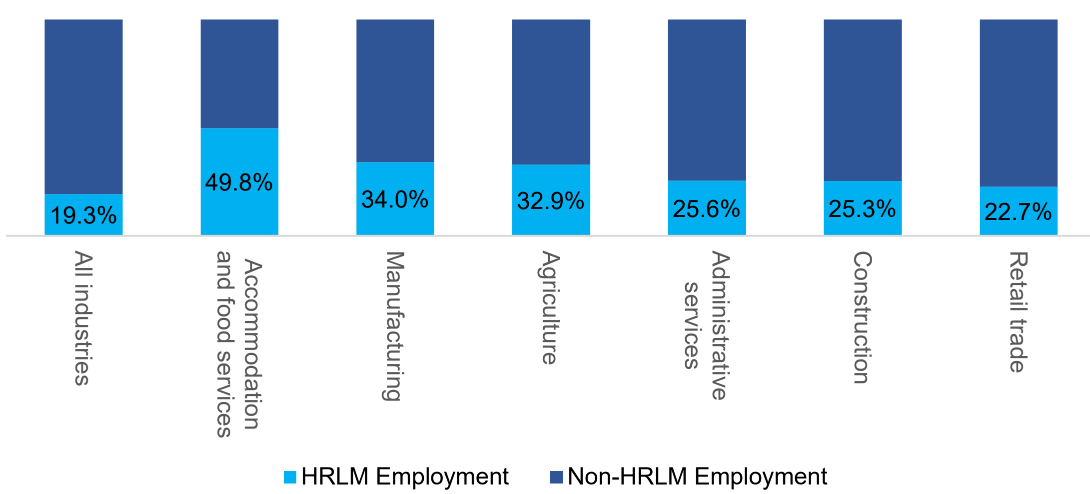
This review synthesizes literature pertinent to the evolution of automation technologies and robotic solutions throughout the global manufacturing sector. With an emphasis on the Canadian context, we examine the impacts, challenges, and benefits of automation technologies on manufacturing occupations, the nature of work, and evolution of workforce upskilling/reskilling efforts in the face of automation, the business case (e.g., return on investment, payback period) of integrating automation technologies. Lastly, we examine major automation trends that are likely to shape to future of Canadian manufacturing.

Automation in Manufacturing

Manufacturing is More Susceptible to Automation Than Other Sectors.

At the task-level, manufacturing remains the second most readily automatable sector across multiple economies. Comparatively, high level of automation potential in manufacturing rests largely on the fact that a significant proportion of work tasks involve physical labour in predictable environments. Because of the prevalence of such predictable physical work, nearly 60 percent of all manufacturing activities could be automated based on existing technologies.[4] Our analysis of 2021 Census data indicates that one in three jobs in manufacturing are at high-risk of being automated within the next decade (Chart 1).

Chart 1
Canada's Manufacturing Sector Has Substantially More Jobs Susceptible to Automation than the Overall Economy



Source: CBOC; Statistics Canada. HRLM (High Risk-Low Mobility).

[4] McKinsey, *Skill Shift.*

However, recent research indicates that past projections of manufacturing automatability mask considerable variance. Frenette and Franks found that automation technologies have yet to have a significant impact on the importance of routine and cognitive tasks in Canadian workers' jobs on a large scale.[5] With marginal declines in routine-intensive manufacturing occupations (e.g., welding, painting, assembling) spanning as far back as the 1980s, automation-related changes in the importance of non-routine cognitive analytical and interpersonal tasks might be best described as marginal.[6]

While the estimated impact of automation on manufacturing tasks and occupations has not materialized completely, we expect automation trends to increase in the future. The vulnerability of manufacturing to automation also varies at the industry-level. Upon further dissecting the manufacturing industry, wages in robotic intensive sub-sectors (e.g., food and beverage processing, aerospace and aviation manufacturing, metalworking and machining, automotives, electronics) surpass the average for manufacturing due to their elevated skill demands. These sectors are poised for further automation in the coming years.

Automation Technologies in Manufacturing Are Evolving.

The rapid development of process automation, robotic technologies, and other types of 'intelligent solutions' have emerged to provide opportunities for the manufacturing sector to reduce costs, enhance productivity growth, and generate new and improved products.

Industrial automation pathways vary in their intensity and pace according to relative economic, industrial, labour, and task compositions. For advanced economies, countries with relatively high labour concentrations in industrial sectors, compared to service sectors, face higher automation potential rates (other things being equal). At the industrial level, the manufacturing sector, after accommodation and food services, faces the highest potential for automation (based on existing occupation composition and proven automation technologies). This is largely attributable to technical feasibility, cost(s) of hardware/software deployment, and labor costs related to supply and demand dynamics within the industrial sector.[7]

Cost of labor is another variable in leading to different rates of automation adoption. The variability of labor costs in manufacturing sub-sectors ranges from 15 percent of production costs in chemical, food-product, and steel manufacturing to upwards of 30 percent in apparel, furniture, fabricated-metals, and electronic-based facilities. With projected automation growth rates expected to climb to approximately 10 percent by the end of the decade, the absolute impact of automated manufacturing may exceed 45 percent by 2030[8].

There are three major forces that are pushing global manufacturing towards its automation inflection point: 1) the increasing cost-effectiveness of Robotic Process Automation (RPA)

---

[5] Frenette and Franks, *Automation and Job Transformation in Canada.*
[6] Acemoglu and Restrepo, *Robots and Jobs.*; Frank and Frenette, *The Changing Nature of Work in Canada amid Recent Advances in Automation Technology.*
[7] Deloitte, *2023 Manufacturing Industry Outlook Report.*
[8] Deloitte, *2023 Manufacturing Industry Outlook Report.*

compared to human labor, 2) advancements in technology and the reduction of integration barriers, and 3) the rise of modular systems for small and medium-sized manufacturing firms.[9] The cost of RPA has been decreasing, while its performance has been improving by approximately 5 percent every year, which means that a US$100,000 investment today can purchase a robotics system that can perform more than twice as much work as a robotics system that cost the same amount a decade ago. With the capacity to now operate in less-structured environments, robotic technologies have advanced to offer manufacturers increased safety, modularity, and programmability - all of which has helped increase the adaptability of manufacturing facilities. It is the continuous improvements in price, performance, and availability that has revolutionized wider adoption by small and medium-sized manufacturers.

In sum, the economics of automation have become increasingly attractive amid rising wages and falling costs of technology. Today, the manufacturing sector faces an accelerating pace of technical change, an ever-broadening scope of technical innovations.

There are Different Aspects of Automation Technologies Used in Manufacturing.

As the global automation installations are expected to surpass 4 million units by 2025, four categories of industrial automation technologies are leading the adoption: 1) computers and electronic products, 2) electrical equipment, appliances, and components, 3) transportation equipment, and 4) machinery. These technologies are estimated to account for approximately 75 percent of all automation technologies and robotic solutions deployed in the next decade. Eighty-five (85) percent of the production tasks associated with the operation of these tech categories are automatable.[10]

Manufacturers are facing the challenge of achieving profitable growth while maintaining quality. Consequently, many of them are turning to technology to solve their production challenges, to gain efficiency while ensuring quality. The top automation technology categories among those who have already adopted some elements of smart manufacturing include production monitoring, quality management systems, and enterprise resource planning (Table 1).[11]

---

[9] Boston Consulting Group, *The Robotics Revolution.*
[10] Boston Consulting Group, *The Robotics Revolution.*
[11] Rockwell Automation, *State of Smart Manufacturing Report.*

Table 1
There is Variation in Automation Technology Adoption by Manufacturing Businesses

Technology Category	Already Adopted (%)	Planning to Adopt (%)
Production Monitoring	54	31
Quality Management System	51	35
Enterprise Resource Planning	49	34
Supply Chain Planning	46	38
Industrial IoT	42	36
Manufacturing Execution Systems	41	38
Advanced Analytics	39	39
Enterprise Asset Management	39	38
Computerized Maintenance Management System	38	39
Asset Performance Management	34	42

Source: Rockwell Automation (2022) 8th Annual State of Smart Manufacturing Report.

The adoption of specific technologies varies throughout the manufacturing sector based on industrial (i.e., sub-sector, regulations and industry standards, technical compatibility, industrial maturity), organizational (i.e., firm size, organizational culture, organizational readiness, leadership support, resource availability, training infrastructure), and workforce (i.e., existing expertise, education, age, gender) level factors.[12] For example, on average manufacturing firms in highly regulated industries (e.g., aerospace, electronics, industrial machinery) invest roughly two times as much of their operating budget in automation technologies (34 percent) compared to their less regulated counterparts (e.g., metal fabrication, packaging, pulp and paper).

The Pace of Technology Adoption is Increasing in Canadian Manufacturing Sector, But Challenges Remain.

When exploring the biggest barriers to automating the manufacturing sector, nearly one half (46 percent) of Canadian manufacturing firms indicate that accessing talent remains their most pressing challenge. Impacting the efficacy and speed of automation technology adoption, manufacturing firms report that the largest workforce challenges include training workers on updated processes, change management (e.g., establishing employee buy-in), rising labor costs, and employee engagement[13]. Alternatively, for those firms who demonstrate the ability to attract, retain, and upskill labour can build sustainable competitive advantage. Beyond the workforce, additional challenges to AT integration include optimizing data utilization, measuring and achieving a return on investment from AT expenditures, supply chain and procurement risks, and cybersecurity[14]

Robots are increasingly being used across various manufacturing sub-sectors to reduce variability, increase speed in repetitive processes, overcome ergonomic restrictions, and

[12] Rockwell Automation, *State of Smart Manufacturing Report.*
[13] Rockwell Automation, *State of Smart Manufacturing Report*.
[14] Rockwell Automation, *State of Smart Manufacturing Report*.

enhance plant utilization and productivity.[15] In addition, robotics help manufacturers adapt to changes in the global labor market, such as the aging of working-age populations and rising labor costs in developed economies.[16] As of 2020, Canada was ranked 18th in terms of industrial robot density (165 units per 10,000 employees) with current levels of deployment well above the global average, but below the G7 average[17].

In a recently completed survey of 1,350 Canadian manufacturing firms, 90 percent of manufacturing firms have adopted some form of automation technologies or robotic solutions.[18] This underscores the degree to which automation technologies have become a mainstream solution for risk management and competitive advantage. Looking towards the future, the same survey shows that asset performance management (i.e., IBM Maximo, UpKeep), computerized maintenance management systems (i.e., SAP Plant Maintenance, Oracle eAM), and advanced analytics software (i.e., SAS Analytics Pro, IBM SPSS) are the top priorities for automation in manufacturing firms moving forward.

Automation technologies are used to address challenges related to cybersecurity, the COVID-19 pandemic, product quality, and organizational growth by Canadian manufacturers (Table 2). Canadian manufacturers have also been turning to automation to address both internal and external risks. The top two internal risks that automation technologies are being used to address include the management of workforce disruptions and supply issues (52 percent). Half of respondents also indicated the digitization of operations, providing cloud-based solutions, increased cybersecurity protection, and business continuity as top reasons for the use of automation technologies.

Table 2
Top Drivers in Canadian Manufacturing Impacting Integration of Automation Technologies

Top Drivers for Automation Adoption	% of Respondents
Cybersecurity risks	29
Impacts of COVID-19 pandemic	28
Product quality/ Balancing quality and growth	27
Shortage of skilled workers	26
Supply chain disruptions	26
Keeping pace with market transformations	26
Deploying and integrating new technology	26
Inflation	25
Adapting to new regulations and standards	22
Lowering carbon emissions	21

Source: Rockwell Automation (2022) 8th Annual State of Smart Manufacturing Report.

Adoption rates of automation will not affect all manufacturers and economies equally.

[15] Autor and Salomons, *Is Automation Labor-Displacing?*
[16] Muro and others, *Automation and Artificial Intelligence.*
[17] International Federation of Industrial Robotics, *World Robotics Report 2020.*
[18] Rockwell Automation, *State of Smart Manufacturing Report.*

The impact on relative cost savings from automation is expected to be higher among those with relatively high labor costs to begin with. According to a recent study, the deployment of industrial robots intensifies when utilization provides 15 percent hourly cost savings compared to human labor.[19] Achieving profitable growth while maintaining quality is one of the most pressing concerns facing manufacturers today. This in part helps explain why many are turning to technology to solve their production challenges to gain efficiency while ensuring quality.[20]

Impact of Automation Technologies on Tasks and Occupations

Impact of Automation on Occupations Varies.

The degree of automation potential throughout indicates that the different ways in which automation impacts the global economy can be traced back to two factors: 1) The sectoral makeup of each economy, 2) the occupational makeup of sectors[21]. For example, to what extent are workers in these sectors with job titles with high automation potential, such as production, and those in job titles with lower automation potential such as management.

According to several studies, a considerable percentage of occupations are at risk of being automated over the next 10 to 20 years (Table 3). For example, Frey and Osborne project that 47 percent of all U.S. occupations are at high-risk of automation.[22] Given the global homogeneity of manufacturing processes, technologies, and nature of work, Frey and Osborne indicate that this projection may be extrapolated to the Canadian context.[23] However, occupation-based approaches have come under scrutiny over the last decade due to the systemic overestimation of automation potential.[24] The criticism rests on the central assumption of those projections that workers within the same occupation have identical task structures. Parallel research has found that workers' task structures differ remarkably, even within the same occupation.[25] Since occupations usually consist of performing a bundle of tasks not all of which may be easily automatable, the potential for automating entire occupations may be much lower than suggested by the approach followed by Frey and Osborne. In a 2016 study of 21 OECD countries led by Arntz et al.,[26] the extent of job automatability may be as low as about 9 percent.

---

19 Frenette and Frank, *Automation and Job Transformation in Canada.*
20 Autor and Salomons, *Is Automation Labor-Displacing?*; Fernandez-Macias and Bisello, *A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work*; Rockwell Automation, *State of Smart Manufacturing Report.*
21 Frey and Osborne, *Technology at Work v 2.0*.
22 Frey and Osborne, "Automation and The Future of Work."
23 Arntz et al., *The Risk of Automation for Jobs in OECD Countries.*
24 Fernandez-Macias and Bisello, *A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work.*
25 Autor and Handel, *Is Automation Labor Displacing?*; Arntz et al., *The Risk of Automation for Jobs in OECD Countries.*
26 Frey and Osborne, *Technology at Work v 2.0*.

Table 3
Background Studies on Automation Potential on Nature of Work

Authors	Date	Unit of Analysis	Scope	Key Findings
Frey and Osborne	2013	Jobs/occupations	US labor market	About 47% of total US occupations are at high risk of automation perhaps over the next decade or two
Citibank, Frey, and Osborne	2016	Jobs/occupations	50+ countries and regions	In the OECD, on average 57% of jobs are susceptible to automation. This number rises to 69% in India and 77% in China
OECD	2016	Tasks	21 OECD countries	On average, 9% of jobs across the 21 OECD countries are automatable
World Economic Forum	2016	N/A	15 major developed and developing economies	Automation and technological advancements could lead to a net employment impact of more than 5.1 million jobs lost to disruptive labor market changes between 2015–20, with a total loss of 7.1 million jobs— two-thirds of which are concentrated in the office and administrative job family
McKinsey Global Institute	2017	Work activities	46 countries representing about 80% of global labour force	Almost half of work activities globally have the potential to be automated using current technology.
Fossen and Zorgner	2019	Jobs/Occupations	US Labor Market	Over 75% of the U.S. workforce face either high transformative or low destructive impact from digitalization (each group ~37-38%). 'Rising starts need creative and social intelligence ensuring these occupations will be transformed not replaced. Collapsing jobs require fewer technical skills and are more prone to being replaced.
Acemolgu et al.	2022	Tasks	300,000 U.S. Firms	In large firms, 12-64% of U.S. workers and 22-72% of manufacturing workers are exposed to automation technologies. These technologies raise labor productivity by 11.4%, explaining 20-30% of the difference between large and median industry firms.

Different Automation Technologies Impact Different Tasks.

In parallel, task-based approaches have been receiving increasing attention under the assumption that automation typically aims to automate specific tasks rather than whole occupations. According to these approaches, the proliferation of automation throughout manufacturing can be categorized into three distinct but partially overlapping waves. These automation waves progressively automate tasks that are harder to automate. The first and already underway is the 'algorithm' wave of automation that involves automating structured data analysis and simple digital tasks.

Second is the 'augmentation' wave that will see the automation of repetitive tasks such as form filling, communication, and information exchange through advanced technological support. These technologies are still in development but are expected to reach full maturity in the 2020s and extend to include statistical analysis of unstructured data in semi-controlled environments like aerial drones and robots in warehouses.

The third wave of automation is defined by the deployment of widescale RPA technologies with the automation of tasks based on physical labour, manual dexterity, and problem solving in dynamic real-world situations that require responsive actions. Also called the autonomy wave, this phase signals a potential inflection point for the manufacturing industry, where a certain maturation of RPA technologies will support sufficient return on investment to warrant widescale integration and shifts in competitiveness. With material impacts expected to be realized by early adopters from 2030-2040, some estimates indicate that task-level automation may exceed 40 percent in some industries.[27]

Return on Investment (ROI) for Automation Technologies in Manufacturing

There is A Strong Business Case for Automation Technologies in Manufacturing.

Automation technologies are only valuable to the extent that they provide a suitable financial return. However, the benefits associated with their adoption are often overestimated and unsubstantiated. With pressures to innovate intensifying, manufacturing firms are looking beyond mere cost reductions in technology adoption. That is necessary if manufacturing organizations are to build deep and rapid competitive advantage through automation investments.

One of the key questions of capital efficiency in manufacturing is whether to invest in more automation, especially as the trade-off between automation and labour continues to shift. Wages are rising in low-cost manufacturing centers and talent is becoming scarce, while automation is becoming more affordable and now capable of better precision and consistency than humans. But the relative inflexibility of most automation solutions, especially in an environment that rewards agility and modularization, is pushing toward more adaptive labor-oriented solutions. Companies that can strike the balance between automation and flexibility needed to build the next generation of products will enjoy significant competitive advantages.

The real costs of automation technologies extend well beyond the initial purchase price with several studies highlighting that more than two thirds of the automation life cycle costs are felt after their installation[28]. Manufacturing firms must then consider ongoing maintenance and support costs, and in particular the ongoing costs of upskilling/reskilling workforce training.[29]

---

[27] Boston Consulting Group, *The Robotics Revolution.*
[28] McKinsey Global Institute, *A Future That Works.*
[29] White et al., *Calculating ROI for Automation Projects.*

Eighty-four (84) percent of Canadian manufacturers are actively engaged in the measurement and evaluation of automation solutions[30]. Compared to the acceleration of technical innovation, the methods driving their cost-benefit analyses have remained relatively slow to change, with the traditional approach of having an annual investment budget limits acting as a limiting factor or core constraint. Based on the robotic process automation lifecycle, organizations seeking to integrate new automation technologies should be evaluating both expected payback period and realized return on investment (ROI) during the initial analysis phase and final evaluation/performance phase.[31] This includes an assessment of both risks (e.g., market, project execution, performance, supplier) and benefits associated with specific technologies.

One of the primary measures used to assess automation-related ROI is "return on invested capital" (ROIC). Providing sound internal measures at the firm-level, ROIC has also been found to be correlated with a firm's long-term stock performance.[32] At a granular level, ROIC is described as "the profit measured as after tax net income (cash adjusted) for the year divided by the invested capital at the start of the year".[33] Typically evaluated over 2–3 year intervals to account for annual fluctuations, manufacturers can boost ROIC by increasing profits or reducing capital expenditures. Technical engineering, procurement costs, purchase pricing, installation/configuration/calibration, and project execution are major areas of automated-related cost savings.[34]

The second measure of automation viability is net present value (NPV). NPV is determined by comparing the present value of the expected future cash flows generated by the project, after adjusting for taxes, to the present value of the required investment. In financial terms, all assets, including stocks, bonds, and manufacturing plants, are valued based on their net present value. If the net present value of a technology is greater than the required investment, it may be considered for integration.[35] NPV of various automation technologies can then be compared and ranked to develop a profitability index that informs an investment strategy.

Finally, there is an expert survey approach. In deciding which tasks to automate, an expert survey indicates that organizations use four common qualitative indicators. This includes execution frequency (i.e., volume of transactions), degree of stability, degree of rule-based procedural rigidity, and degree of standardization. Failure rate, automation ratio, number of intersections, structure of data, and application stability are used in practice to help quantify the impact potential of automation investments.[36]

---

[30] Rockwell Automation, *Annual State of Smart Manufacturing Report.*
[31] Enriquez et al., *Robotic Process Automation*
[32] White et al., *Calculating ROI for automation projects*.
[33] White et al., *Calculating ROI for automation projects.*
[34] White et al., *Calculating ROI for automation projects*.
[35] White et al., *Calculating ROI for Automation Projects.*
[36] Wanner et al., *Process Selection in RPA Projects.*

There is Limited Evidence Regarding the ROI Payback Periods.

More than half of surveyed manufacturing firms in the United States have not estimated payback period associated with existing automation investments.[37] This figure drops to 35 percent for organizations who are actively scaling their automation solutions. The assessment of automation ROI is done at both the technological and organizational levels. Of the few ROI-related studies that have been conducted, one study found that organizations automating their workforce are more successful than non-adopters.[38] Another study found that organizations with "sustainable, automation-driven" innovation strategies grow at a rate of 2.6 times faster compared to firms who fail to prioritize automation technologies.[39]

With respect to costs and revenue benefits of integrated automation technologies, intelligent automation provides an average cost reduction of 22 percent and increase in revenue of 11 percent over the next three years.[40] Manufacturing firms already piloting automation technologies expect an average payback period of 15 months, while those at the scaling phase expect an average payback period of 9 months. It is important to note that accounting for variance across technologies and targeted tasks, ROI may be magnified in cases where automation technologies are complemented with artificial intelligence tools. In cases where organizations combine robotic process automation with AI, manufacturing firms report higher revenues (8.5 percent versus 2.9 percent gains) and improved customer experience.

There is no consensus regarding specific automation technologies and robotic solutions that produce the greatest returns on investment. Several studies report that robotic process automation, compared to other automation technologies, yields significantly higher increases in productivity and faster time to value. In a 2022 survey of Canadian manufacturing firms, Rockwell Automation found that process automation (33 percent), cloud/SAAS (30 percent), and industrial internet of things (IIOT) (25 percent) were identified as the automation technologies that yield the greatest returns on investment.[41]

Major Challenges Remain in Assessing ROI and Payback Period.

Generating and measuring ROI from investments in automation technologies remains a big challenge for manufacturing firms in both Canada, and globally. This is one of the reasons why 30-50 percent of new RPA initiatives fail completely[42] The extent to which organizations can accurately assess ROI and payback period of automation investments is constrained by the lack of comparable and transferable indicators across industries. While specific investment evaluations vary both between and across manufacturing firms, the absence of standardized tools perpetuates a reliance on the use of highly individualized measurement

---

[37] Deloitte, *2023 Manufacturing Industry Outlook Report.*
[38] Koch et al., *Robots and Firms.*
[39] Forester Research, "Automation."
[40] Deloitte, 2023 *Manufacturing Industry Outlook Report.*
[41] Rockwell Automation, *State of Smart Manufacturing Report.*
[42] Kirchmer and Franz, *Value-driven Robotic Process Automation.*

frameworks to inform the identification of automatable tasks and appropriate technology solutions.[43]

There is no universal roadmap for successful deployment of automation technologies in manufacturing. Consequently, manufacturing firms adapt innovation strategies to facility-level realities through trial-and-error experimentation. Beyond technology paralysis (i.e., the inability to decide between automation solutions), there are 5 factors that limit the degree to which firms' actual ROI may fall short of initial expectations:[44]

- redundant automations (on average, 20-30 percent of established automation are deemed as being redundant or wasteful),
- maintenance costs (systemic underestimation of maintenance costs, high break-fix costs, and gradual technical obsolescence),
- application licensing costs (which require access to a wide range of technical systems which come at a price, inflated RPA platforming fees (which rise as RPA platforms acquire new technical capabilities),
- inflating RPA resource costs (from the hiring of additional staff to deliver and maintain evolving technologies), and
- design and compliance time (from the costs associated with hiring expert knowledge and time it takes to develop new technical solutions).

It is through the holistic consideration of these factors that manufacturing firms can begin to optimize technology fit and purpose throughout their operations.

Future Trends in Manufacturing Automation

Emerging Automation Technologies in Manufacturing Are Related to Streamlining Production Processes and Data-Based Decision Making.

Cloud-based technologies have been identified as the top technology categories for manufacturing firms to increase their investments in. This is followed by the adoption of AI and machine learning, IoT, and robotics process automation.[45] Another recent study notes that as manufacturers seek to create new value, they will increase the use of automation technologies in combination with AI, digital twins (i.e., a virtual copy of a real-world physical product, systems or process serving as a digital counterpart), generative design, and design for manufacturing and assembly.[46] This type of software-defined manufacturing will reduce barriers to entry for small and medium sized organizations, increase modularity, reduce lead/processing times, and ultimately, reduce risk associated with their integration.

In Canada, 97 percent of manufacturing firms have plans to use automation technologies moving forward to enable more agile and resilient production processes, empower the

---

[43] Deloitte, "2023 Manufacturing Industry Outlook Report."
[44] Wanner et al., "Process Selection in RPA Projects."
[45] Rockwell Automation, *State of Smart Manufacturing Report.*
[46] Deloitte, "2023 Manufacturing Industry Outlook Report."

workforce, manage risk, drive sustainability, and accelerate business model transformations[47]. As for the future of Canadian manufacturing, 45 percent of manufacturers plan to use the technology within the next year, and another 39 percent plan for the next 1-2 years. Cloud-based technologies have been identified as the top technology categories for manufacturing firms to increase their automation investments in, with an eye towards the future[48]. This is followed by the adoption of AI and machine learning, IoT, and robotics process automation.

Moving forward, manufacturing firms will need to continue to leverage automation technologies to drive better data and analytics usage, increase process automation, adopt cloud technologies, and use automation to improve ESG/sustainability practices to drive improvements. As manufacturers continue to digitize their operations, more firms are using connected devices to enhance operational efficiency and product quality. Industrial hardened devices (e.g., handheld scanners, tablets), consumer devices (e.g., mobile phones), cameras/scanners/drones, sensors, and optical quality scanners are the top technologies expected to shape the future of smart manufacturing.

Complimentary to automation technologies, the use of these digital software technologies is helping to usher in a new era of data-driven decision making in the manufacturing sector. Deepening the sectors capacity for innovation, when used in combination of automation process technologies, manufacturing organizations experience reduced lead/processing times, reduced barriers to entry, and ultimately reduce risks associated with technical investments.[49]

Manufacturing Needs Workforce with Complimentary Non-Routine Cognitive Skills.

Eighty-nine (89) percent of Canadian manufacturers expect to maintain or grow employment while adopting automation technologies.[50] While this helps in part dispel fears of workforce displacement at scale, the continued evolution of automation technologies will lead to an increased importance of complimentary non-routine cognitive and interpersonal tasks.[51]

The top skills being sought include communication and teamwork, flexibility/adaptability, employee (peer) engagement, employee initiative, analytical thinking, and knowledge of smart technologies. That means manufacturers need to place emphasis on accessing talent that can adapt to changing requirements and collaborate in teams. At a macro-economic level, this will translate to a growing share of Canadian manufacturing workers occupying managerial, professional, and technical occupations. [52]

The ability of manufacturing to automate non-routine cognitive and interpersonal tasks has proven to be a challenge for many organizations. This is largely because these tasks require

---

[47] Rockwell Automation, *State of Smart Manufacturing Report.*
[48] Rockwell Automation, *The State of Smart Manufacturing.*
[49] Deloitte, *Automation with Intelligence*.
[50] Rockwell Automation, *The State of Smart Manufacturing.*
[51] Frenette and Frank, *Automation and Job Transformation in Canada.*
[52] Frenette and Frank, *Automation and Job Transformation in Canada.*

a high degree of creativity, critical thinking, and emotional intelligence, which are difficult to replicate through technology[53].

One of the major challenges in automating non-routine cognitive tasks is that they often involve complex decision-making processes that are difficult to codify. For example, tasks like strategic planning or problem-solving require a deep understanding of the business context and a high level of judgment, which are difficult to automate. Similarly, interpersonal tasks like negotiation or conflict resolution require a high degree of emotional intelligence and social skills, which are difficult to replicate through technology[54].

Ultimately, manufacturing firms will need to strike a balance between technology and human capabilities. While technology can certainly help to streamline processes and improve efficiency, it cannot replace the creativity, critical thinking, emotional intelligence that are essential for success in these types of tasks, at least, not with currently existing technologies. There is a need to invest in training and workforce development programs, in parallel to leveraging technology to augment rather than replace human capabilities.

[53] Fernandez-Macias and Bisello, *A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work.*

[54]Fernandez-Macias and Bisello, *A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work.*

Analysis

Composition of Manufacturing Jobs and Skills in Lethbridge

Lethbridge's manufacturing employment is more concentrated by occupations than the nation. While the top ten occupations account for less than 30 percent of manufacturing employment in Canada, the same percentage is nearly 51 percent for Lethbridge (Chart 2 and 3).

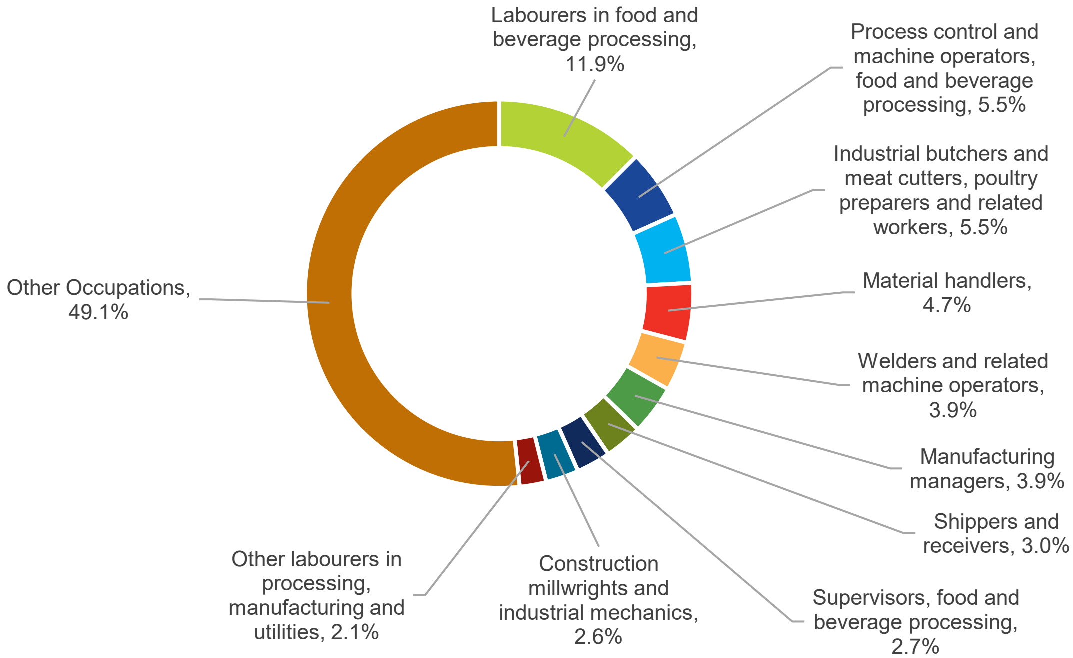
Looking at the occupational level differences, the differential between the region and the nation is mostly attributable to higher concentration of food and beverage processing occupations in Lethbridge (Chart 4). On the other hand, manufacturing managers and occupations relevant to auto manufacturing are underrepresented in Lethbridge.

This pattern can be explained in two ways. First, the region's occupational composition could simply be a function of its industrial composition. The region might be specialized in food and beverage manufacturing (relative to the nation) and therefore a large portion of its manufacturing workforce consists of occupations needed by this industry. Second, the region's manufacturing industries might be employing a slightly different set of occupations than the Canadian average.

We examine the first possibility in Table 4 and find that is indeed the case. To be certain about this, we also compared the share of 124 different occupations in food manufacturing in Lethbridge with that of Canada. There are some differences in terms of the share of occupations, but most of those differences can be explained by the region's specialization in sub-sectors of food manufacturing.

Chart 2

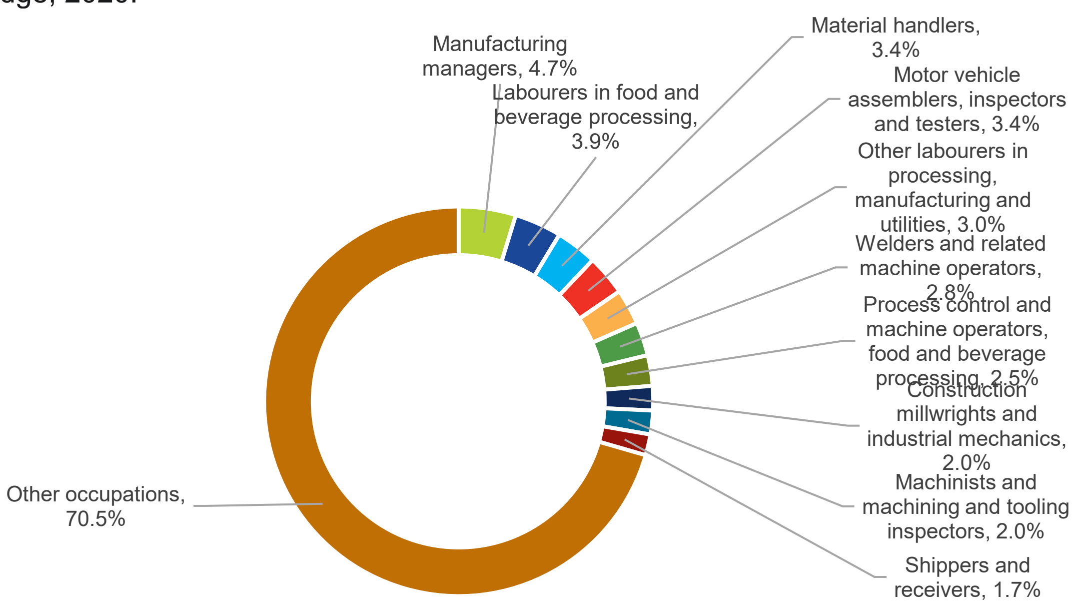
Top 10 Occupations Account for A Larger Share of Employment in Lethbridge Compared to Canada, 2020.



Source: The Conference Board of Canada

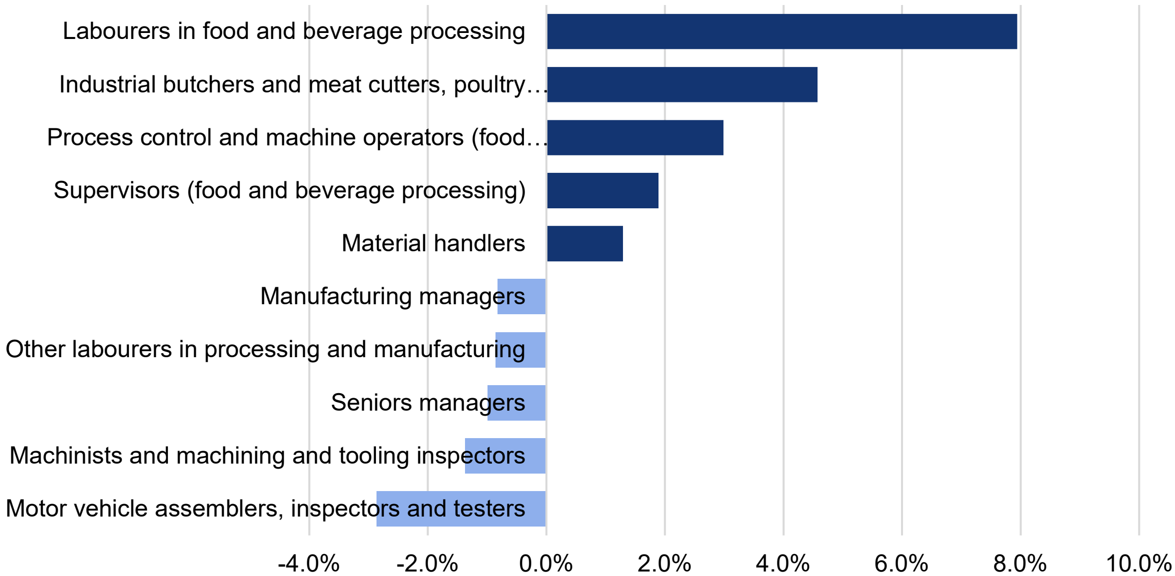
Chart 3

Top 10 Occupations Account for A Smaller Share of Employment in Canada Compared to Lethbridge, 2020.



Source: The Conference Board of Canada

Chart 4
Occupations Related to Food and Beverage Processing are Overrepresented in Lethbridge, 2020 (percentage difference from the national average)



Source: The Conference Board of Canada

Table 4
Manufacturing Employment in Lethbridge is Highly Concentrated in Food Manufacturing, 2020

	Lethbridge		Canada		
NAICS/Industry	**Employment**	**Share (%)**	**Employment**	**Share (%)**	**Difference (%)**
311 Food manufacturing	2,535	51.0	243,305	16.9	34.0
312 Beverage and tobacco product manufacturing	220	4.4	38,550	2.7	1.7
314 Textile product mills	20	0.4	6,825	0.5	-0.1
316 Leather and allied product manufacturing	0	0.0	2,430	0.2	-0.2
327 Non-metallic mineral product manufacturing	130	2.6	42,155	2.9	-0.3
313 Textile mills	0	0.0	5,065	0.4	-0.4
331 Primary metal manufacturing	165	3.3	55,500	3.9	-0.5
324 Petroleum and coal product manufacturing	15	0.3	14,985	1.0	-0.7
332 Fabricated metal product manufacturing	420	8.4	133,140	9.3	-0.8
321 Wood product manufacturing	250	5.0	86,750	6.0	-1.0
315 Clothing manufacturing	0	0.0	20,750	1.4	-1.4
337 Furniture and related product manufacturing	155	3.1	71,390	5.0	-1.9
323 Printing and related support activities	50	1.0	45,310	3.2	-2.1
335 Electrical equipment, appliance and component manufacturing	0	0.0	31,125	2.2	-2.2
339 Miscellaneous manufacturing	125	2.5	75,195	5.2	-2.7
326 Plastics and rubber products manufacturing	165	3.3	87,440	6.1	-2.8
322 Paper manufacturing	15	0.3	49,950	3.5	-3.2
334 Computer and electronic product manufacturing	10	0.2	49,035	3.4	-3.2
333 Machinery manufacturing	215	4.3	109,010	7.6	-3.3
325 Chemical manufacturing	85	1.7	79,325	5.5	-3.8
336 Transportation equipment manufacturing	380	7.6	190,195	13.2	-5.6
31-33 Manufacturing	**4,975**	**100.0**	**1,437,435**	**100%**	**0**

Source: The Conference Board of Canada

Automatability of Manufacturing Tasks

We identified 12 broad task categories in manufacturing and calculated automation potential for each of them (Table 5). As a first step, we identified detailed tasks with high automation potential and relevance for the Lethbridge manufacturing industry (see Appendix).[55] Those tasks meet two criteria: 1) Automation potential of task is greater than 50 percent (proxied by the degree to which it is repetitive). 2) Occupations that are associated with those tasks exist in the region (measured by concentration quotient).[56]

Using the frequency of task performance as a proxy for automation potential is based on the insights from the literature that a task is likely to be automated if it is repetitive, involving manually performed routine functions. Because most core job tasks of manufacturing occupations follow well-defined repetitive procedures, they can easily be codified in computer software and thus performed by computers, robots, and other automation equipment.[57]

Second, we aggregated automation potential from detailed tasks to 12 broad task categories. As shown in Table 5, predictable functions are associated with the tasks with relatively higher automatability score (e.g. testing, recording) while we see tasks that require a certain level of creativity, perception, manipulation, and social intelligence in the bottom of the list (assembly and procurement).

---

[55] The list of 228 specific tasks is provided in the Appendix. The detailed tasks are from Occupational Information Network (O*NET). Using the method of thematic coding, we created 12 broad task categories. For example, data analytics is part of "testing and analysis" category, while predictive maintenance is part of OAM.

[56] See Methodology in Appendix B for details.

[57] Acemouglu and Autor, Skills, Tasks and Technologies; Frey and Osborne, *The Future of Employment.*

Table 5
Manufacturing Task Categories with Corresponding Automation Potential

Task Category	Description	Automation Potential
Testing and Analysis	Work tasks involving the execution of tests, experiments, and analysis to evaluate product performance, reliability, and compliance with standards.	66.6
Recording, Documentation, and Reporting (RDR)	Work tasks involving the creation, recording, and management of documentation related to manufacturing processes.	60.2
Production Operations	Work tasks involving the execution of manufacturing processes and activities to produce goods according to established standards and procedures.	59.4
Material Handling	Work tasks related to the movement, transportation, and organization of materials within a manufacturing facility.	58.6
Machine Operation, Adjustments and Maintenance (OAM)	Work tasks centered around operating, maintaining, and repairing machinery and equipment, and systems used in the manufacturing process to ensure quality and efficiency.	57.6
Quality Control, Inspection, and Assurance (CIA)	Work tasks focused on maintaining, inspecting and verifying/improving the quality of manufactured products at various stages of the production process.	57.4
Planning and Scheduling	Work tasks focused on creating and managing production schedules, coordinating workflow, and optimizing resource allocation.	56.9
Weighing and Measurement	Work tasks involving the accurate measurement and weighing of materials and components used in the manufacturing process.	56.6
Equipment Operation and Setup	Work tasks related to the operation, control, and setup of specialized equipment used in manufacturing processes.	55.5
Cleaning and Maintenance	Work tasks focused on cleaning and maintaining work areas, machinery, and equipment to ensure a safe and hygienic manufacturing environment.	54.5
Assembly and Installation	Work tasks involving the assembly of components and parts to create finished products, as well as the installation and integration of finished products according to specifications.	53.9
Procurement and Customer Service	Work tasks related to procurement activities, such as sourcing materials, negotiating contracts, and managing supplier relationships.	52.3

Source: The Conference Board of Canada's Analysis Based on O*NET Data.

Note: 66.6 means, testing and analysis of products can be automated 66.6 percent of the time.

Adopting a task-based strategy of inquiry, our analysis avoids the shortcomings associated with occupational-based approaches whose assumptions of whole job automation leads to overestimations of susceptibility to automation.[58] Recent research categorizing current automation as a journey focused on the automation of repeatable tasks helps validate our selection of task frequency as a proxy variable.[59] Building off these studies, we evaluate automation potential of manufacturing task-measures according to the frequency of task performance to develop a weighted automatability score of task-time share.

[58] Frey and Osborne, *The Future of Employment.*
[59] PWC, *Will Robots Really Steal Our Jobs?;* Arntz et al., *The Risk of Automation for Jobs in OECD Countries.*

Skills Required for The Deployment of Automation Technologies

Having determined which tasks to focus on, using technology skills data from O*NET and the review of automation technologies in practice, we identified technology and tools associated with performing these tasks in more efficient ways (Table 7). These facility level technologies are mostly used by engineers, technologists, quality control and assurance workers, machine operators, and maintenance workers. Unlike the enterprise level technologies, these are mostly designed for and used in the manufacturing industry.[60]

Facility level technology skills range from automating production processes to maintenance to quality check to inventory management. In addition, we specified whether the given technology is emerging (in the context of manufacturing) or established. This determination informed our estimate of time needed to close technology skill gaps between manufacturing industry in Lethbridge and the nation.

It is important to note that people in different positions in a manufacturing company may use these technologies to some extent and how they use them may vary from company to company. That is because the choice of specific automation tool often depends on the specific needs and requirements of manufacturing operations, as well as the size and complexity of the company. For example, in the case of sensor that detects and counts every time a product is complete passes by it:

- The operator may see the part count on a screen, but they don't need to know how that sensor works.
- Someone from maintenance, or engineering may need to get involved if the sensor is broken or not working as intended.
- The sensors may feed information into an MES system that measures OEE, which may be important to the plant manager.
- That same information may help identify bottlenecks in the process that a controls technician may be able to optimize with some process changes.
- That information may also identify to a shift supervisor a need for more operator training if a specific shift is underperforming.

This example suggests that while different employees may need to know different aspects of technologies used, some employees need to be more knowledgeable about certain aspects of technologies than others. In terms of training, the way technologies are implemented will determine if and how workers in other roles interact with those technologies. Regarding the deployment of new technologies, they all require some level of custom training provided by

---

[60] Besides facility level technologies, there are also enterprise level technologies, which are important too and might be in short supply in the region. However, the focus of this report is on addressing facility level shortages and technical skills gaps.

the employer since most integrations are custom to the client and to the manufacturing process.

Our interviews and expert consultation in Lethbridge suggest that the critical gap in skillset seen in Alberta regarding most of these technologies is how they are implemented. Due to the shortage of highly skilled engineers and maintenance roles (both internal and external), manufacturing companies rely on out of province (or country) support for keeping their systems maintained, which often results in systems not getting optimized. Besides poor optimization, this also leads to a hesitancy among stakeholders who decide on projects, as they may be cautious about introducing a proven technology that might not be adequately implemented or supported in this context. This observation highlights the importance of addressing the shortage of facility level skills in the region.

Table 7

Technology Skills Corresponding to Highly Automatable Manufacturing Tasks

Technology Skill	Example of Technology	Status
Enterprise resource planning (ERM)	Microsoft Dynamics	Established
Facilities management software	InnQuest Software RoomMaster	Established
Inventory management software	Oracle NetSuite	Established
Computer aided design (CAD) software	Autodesk AutoCAD	Established
Computer aided manufacturing (CAM) software	Dassault Systems SolidWorks	Established
Materials requirements planning logistics and supply chain software	LSA Visual Easy Lean	Established
Compliance software	Pilgrim Quality Solutions SmartSolve	Established
Batch processing & batch management	Rockwell FactoryTalk Batch	Emerging
Procurement software	Ariba Spend Management Suite	Established
Process mapping and design software	Microsoft Visio	Emerging
Track and trace	Epicor Traceability	Emerging
Manufacturing execution system (MES)	Wonderware MES	Emerging
Manufacturing operations management (MOM)	Siemens SIMATIC IT	Emerging
Overall equipment effectiveness (OEE)	GE Digital Proficy	Emerging
Computerized maintenance management system (CMMS)	SAP Plant Maintenance	Emerging
Predictive maintenance	GE Digital Predix APM	Emerging
Quality management software (QMS)	SAP Quality Management	Emerging
Warehouse management systems (WMS)	Oracle Warehouse Management (WMS)	Emerging
Automated storage and retrieval system (ASRS)	Honeywell Intelligrated	Emerging
Distributed control system (DCS)	Rockwell Automation - PlantPAx	Emerging
Industrial control software	Supervisory control and data acquisition SCADA software	Emerging
Human machine interface (HMI)	GE Digital iFIX	Emerging
Programmable logical controller (PLC)	Allen-Bradley RSLogix / Studio 5000	Emerging
Programmable automation controller (PAC)	Siemens TIA Portal	Emerging
Measurement and analytics	Rockwell FactoryTalk Analytics	Emerging
Preventative maintenance	eMaint CMMS	Emerging
Simulation and analysis	Digital twin	Emerging
Safety solutions	Environmental, Health, and Safety (EHS) Management Software	Emerging

Source: The Conference Board of Canada's Analysis Based on O*NET Data; Expert Consultation.

Skills Gaps in Lethbridge Manufacturing Workforce

Having determined this, we then matched these technologies and tools to Lethbridge's workforce (i.e., occupations as existed in 2021 Census) to see what extent existing workers have knowledge of these technologies and tools. We repeated the same analysis for the national workforce to be able to say how much improvement Lethbridge's manufacturing workforce needs to make to reach the national average in automating tasks with high automation potential. Finally, we mapped those skills to broad task categories to identify the automation task categories for which Lethbridge has technology skill gaps to close (Table 8). Main task categories with the largest gaps are testing and analysis, quality control, inspection, assurance. These findings hold true when we compare the whole workforce of Lethbridge with that of the nation.

Table 8

Lethbridge Has Technology Skill Gaps to Close for Most of the Automation Task Categories

(% point differences in the share of occupations possessing given technology skills. Sorted by descending order by differential in the manufacturing workforce)

Automation Task Category	Manufacturing Workforce	Total Workforce
Testing and Analysis	1.1	1.8
Quality Control, Inspection, Assurance	1.0	1.2
Recording, Documentation and Reporting	0.6	0.3
Assembly and Installation	0.3	0.6
Weighing and Measurement	0.3	-0.3
Procurement and Customer Service	0.1	0.3
Cleaning and Maintenance	0.1	0.5
Planning and Scheduling	0.0	0.2
Material Handling	-0.1	-1.3
Equipment Operation and Setup	-0.8	-0.4
Machine Operation, Adjustment, Maintenance	-1.2	1.5
Production Operations	-1.4	-4.3

Source: The Conference Board of Canada's Analysis Based on O*NET and Statistics Canada Data.

Note: That Lethbridge has a surplus of workers with Machine Operation & Maintenance, or the Equipment Operation & Setup skills may contradict feedback generated in the interviews. We believe findings from interviews are more accurate because findings in this table assume that an average manufacturing worker in each sub-sector has the same skills composition as their national counterparts. To the extent that regional workers are less skilled than their national counterparts, findings in this table are overestimating skill levels and composition of manufacturing workers in Lethbridge.

Assessment of the Technological Readiness of Local Manufacturers

To complement the quantitative analysis and generate nuanced insights into manufacturing in Lethbridge, we conducted 10 interviews with local key informants. The informant sample included organizations in the following manufacturing sub-sectors: food & consumables (4), industrial & materials (5) construction & real estate (1). Using semi-structured, open-ended questions, the interviews engaged practitioners for perspectives on the following themes:

- Barriers and challenges to integrating, scaling, and operating automation technologies.
- Organizational approaches to automation including current and planned investments in automation technologies, automatability of tasks and work activities, and approaches to assessing return on investment and payback periods.
- Local context affecting capacity for automation.
- Benefits and drivers of automation technologies.
- Workforce upskilling/reskilling approaches and future skill requirements.

Below is what was shared.

Barriers and Challenges to Automation

Accessing high-quality talent emerged as the most prominent barrier impeding manufacturing organizations from integrating new and/or scaling investments in automation technologies and robotic solutions.

Within the manufacturing sector, accessing talent with the technical skills and capabilities required to safely and/or effectively deploy, operate, maintain, adjust, and train other workers on these technologies emerged as the most frequently cited challenge to automating manufacturing facilities.

There is a perceived lack of industry uptake and an inability for employees to develop specialized skills in automation in the Lethbridge manufacturing ecosystem. This could serve as a limiting factor for the development of a quality workforce in this space, including reduced job desirability, attractiveness of worker relocation, limiting access to talent, and further disincentivizes employers to scale AT investments.

Closely related to talent access, interviewees referenced lack of access to adequate training supports (e.g., upskilling, reskilling) as a key challenge to support workforce transitions into digital, automation, and robotic technologies. This barrier is particularly prominent in manufacturing sub-sectors with high levels of (robotic) process automation (e.g., food processing and production, metal fabrication and equipment).

For manufacturers who rely on immigrant labour pools to help address lingering issues of accessing talent, interviewees referenced English as a second language as an impediment to workforce (safety) training. The complexity of technical language and the nuances of

English grammar can make it difficult for non-native speakers to understand and effectively use automation tools. This can lead to misunderstandings, errors, and inefficiencies in the implementation of automation technologies. In addition, language barriers can create communication challenges between team members, further hindering the adoption of automation.

For food processing organizations, the gradual rise in median wages for workers with sufficient technical knowledge and skills continues to hinder their capacity to fill hiring needs for AT-related operations. While interviewees indicated that despite being further along the AT lifecycle (e.g., deployment phase, control and monitoring phase, evaluation, and performance phase), AT’s have not matured to the point where AT are replacing human capital at scale.

Of the manufacturing organizations who self-identified as being earlier along in the AT lifecycle, the ability to articulate a “business case” for AT emerged as a more significant barrier compared to more mature counterparts. These organizations indicated that the variability among ATs negatively impacts their ability to accurately assess return-on-investment and payback period. Particularly due to the lack of transferable metrics, standardized tools, and measurement frameworks. This is a key challenge to scaling AT throughout operations and facilities.

Framed under the lens of change management and organizational culture, interviewees pointed to a lack of organizational ‘readiness’ as being a particularly prominent barrier to integrating ATs at a rate and scale necessary to compete with industry standards.

The degree to which firms reported experiencing a lag in automation adoption was particularly important for large manufacturing organizations in the food processing and production sub-sector. With the role of senior leadership being central to overcoming this barrier, manufacturing organizations often lack agile organizational cultures. This often comes at the expense of trial-and-error learning and creates an environment where decision-making is resistant to AT-related experimentation.

Organizational Approaches to Automation

When asked to compare current levels of automation to their sectoral average, interviewees noted that Lethbridge manufacturing is roughly 5 to 10 years behind leading manufacturing regions.

However, perceived automation levels varied significantly across the five manufacturing sub-sectors. Self-reporting the highest levels of existing automation were food processing and production organizations. These firms indicated that AT has reached sufficient maturity within the sub-sector to enable integration at scale.

Moreover, food processing and production organizations indicated that they were above industry standards while expressing plans to continue to reinvest in AT and robotic solutions moving forward. This trend can be explained in part by existing research which has shown that process automation technologies are among the most widely deployed and are reported to deliver the most significant ROI of manufacturing ATs.

Comparatively speaking, metal fabrication and industrial equipment organizations varied significantly in their self-assessments of current automation levels. Extensive automation was reported by larger organizations, whose customer base extends beyond Lethbridge, while smaller organizations within this sub-sector indicating that they were on par or below industry averages.

The uneven adoption of ATs indicates that they may be inaccessible to small-scale manufacturers and highly specialized firms due to factors such as scale of operations, limited financial capacity, specificity of operations, and the nature of work (i.e., relative composition of work tasks across occupations).

Building human capital is a key to enhancing automation technologies in manufacturing organizations.

During the early and mid-stages (i.e., planning, design, construction, deployment) of the AT lifecycle[61], the role of senior leadership was described as central to helping manufacturing organizations align themselves with current automation trends. Senior leaders were described as having several key functions that support the integration of AT across manufacturing sub-sectors, including:

- setting the vision and strategy for AT adoption
- providing resources,
- budgeting for AT investments,
- aligning departments and teams to increase efficacy of integration,
- reducing workforce friction,
- ensuring operational 'fit'.

Strong top-down communications from senior leaders were also cited as an effective strategy for combatting (frontline) employee resistance to AT integration. Stemming from AT anxiety and fears of job loss, this leverage point was particularly prominent in food processing and production and metal fabrication and industrial equipment organizations.

As organizations progress throughout the AT lifecycle, enabling bottom-up workforce development becomes increasingly important. Beginning at the deployment phase and through the evaluation and performance phase, ensuring sufficient technical 'know-how' and skills throughout the workforce was paramount to ensuring effective AT utilization. Interviewees cited the use of change management tactics, such as employee engagement and automation awareness programs as a key leverage point to deepening buy-in.

When complimented with in-house upskilling/reskilling programs, manufacturing organizations indicated that their experience with AT integration was positive to the extent

[61] Enriquez et al., *Robotic Process Automation*.

that it warranted continued investment plans. Thus, both top-down leadership and bottom-up employee engagement are crucial for organizations to identify, deploy, and operate ATs in a manner that yields sufficient short-term returns to warrant continued investments.

Robotic process automation (RPA) and automation-focused Software as a Solution (SAAS) are among the most widely deployed automation technologies amongst manufacturing firms, however, there is considerable variation at the organizational-level.

In interviews, participants were asked to identify specific automation technologies and robotic solutions which firstly have already been deployed, and secondly, which had further investment plans. The most cited ATs that have been deployed included RPA, SAAS, and enterprise resource planning (ERP).

Referenced across all five manufacturing sub-sectors, process automation and digital software solutions constitute those ATs which have been found to be the most widely used (both within Lethbridge and across Canadian manufacturing[62]), as well as the ATs that have been reported as delivering the highest ROI. This further underscores the extent to which the 'business case' for ATs is shaping investment trends across Lethbridge's manufacturing sector. Beyond these two AT categories, the interviews revealed little consistency in AT deployment with variability occurring at both the sectoral level (across and within manufacturing sub-sectors) and organizational level (across facilities and suppliers).

Of the five sub-sectors examined, food processing and production organizations indicated higher levels of technical maturity, demonstrated by referencing a wider array of existing AT deployment. Specific to this sub-sector, two technologies were cited as being deployed. First, computerized numeric control technologies, used to control the movements and operations of machines across the production line. Second, and reserved for organizations who cited advanced levels of existing automation, was programmable logic controller (PLC) technologies. Serving as an interface between the manufacturing floor and supervisory control and data acquisition (SCADA) and human machine interface systems, PLC technologies are used to control complex production processes while providing real-time data feedback.

For process-oriented sub-sectors organizations referenced the use of enterprise asset management (EAM) technologies. EAM deployment was restricted to larger organizations with multiple facilities who use these ATs for asset tracking, predictive maintenance, and inventory management.

Additionally, interviewees representing larger organizations cited the use of customer relationship management (CRM) (e.g., Salesforce) and human resource information system technologies. Outward and inward facing respectively, these technologies serve a similar role and are being used to support large companies manage and automate core business administration processes. While not communicated directly, this suggests a potential

---

[62] Rockwell Automation, *The State of Smart Manufacturing.*

correlation between organizational size and ROI for CRM and HRIS technologies. Whether or not these technologies are deployed across manufacturing organizations may be determined by the size of the workforce and/or customer base being serviced.

These findings correspond with those produced by our model which highlights that EAM, ERP, SAAS, and RPA technologies are well established within manufacturing occupations. Alternatively, industrial control systems (e.g., SCADA, PLC, HMI) are still emerging and have yet to be deployed at scale.

The diversity of automation technologies is paralleled by a lack of transferable solutions throughout the sector. Specifically, manufacturers indicated little in the way of collaboration when it comes to integrating specific automation technologies. Instead, each organization prioritizes the development of facility-level proprietary solutions and in-house tailored systems. This approach hinders any substantive collective action, sharing of best practices, or transferable technology solutions. This further underscores the need for an industry group to empower manufacturers to work together as a strategy for addressing the regional lag in technology integration.

Repetitive, routine tasks involving manual and physical labour are being automated at scale, but few occupations are being replaced.

Across all manufacturing sub-sectors, routine repetitive tasks that are manual in nature or require physically demanding labour were identified as those tasks most frequently automated. This includes tasks related to welding, assembling, painting, product handling, pouring, grinding, and cutting. Interviewees indicated that tasks of this nature remained central to future automation plans as organizations seek to accelerate post-COVID-19 AT integration and overcome the automation lag in Lethbridge manufacturing.

Interviewees went on to note that based on existing AT and robotic solutions, the automation of routine repetitive tasks was a relatively straightforward process compared to non-routine cognitive tasks. This aligns with existing research as well as our model. Past research indicates that most of the automation taking place from 2020-2030 will focus on the automation of repetitive routine (manual/physical) tasks[63]

As per our discussions, industry experts indicated that the automation of these tasks helped to enhance job desirability (helping firms attract and retain talent), boost processual/worker efficiency, and create safer working conditions. In parallel, the lion share of these tasks might be categorized as part of production operations, which our model shows are the most widely established task category across Lethbridge manufacturing. Logically, this points to a higher automatability potential.

Our discussions also revealed that the automation of routine cognitive tasks has occurred at-scale and across all five focal manufacturing sub-sectors. Citing the continued deployment of software as a solution, manufacturers are using digital technologies to

---

[63] McKinsey Global Institute, *Automation and The Future of The Workforce.*

automate tasks related to data collection, data processing, asset tracking, and inventory management. The automation of these tasks is supported by our model which shows that many SAAS technologies are already well established in the manufacturing sector, thus increasing the automation potential for skills associated with their deployment.

For larger organizations who reported a high degree of AT maturity, there was partial evidence of the automation of non-routine manual/physical tasks as well as the automation of non-routine cognitive analytical and interpersonal tasks. For the former, interviewees referenced that the automation of these tasks (e.g., molding, casting, transportation of materials) was largely a function of improving worker safety. For the latter, only a select few organizations with sufficient human capital (e.g., engineers) reported the initial automation of non-routine cognitive analytical tasks (e.g., data analytics).

This is supported by our model which highlights that non-routine cognitive tasks which may typically be categorized as part of testing and analysis, quality control, inspection, and assurance, and assembly and installation have yet to fully establish themselves in Lethbridge's manufacturing workforce. Compounded by factors including workforce composition and accessibility of ATs, this suggests that the automation of this task type will likely remain fragmented, reserved for the most technically mature organizations moving forward.

Interestingly, none of the priorities for manufacturing automation noted by respondents to the Rockwell Automation survey found in the *State of Smart Manufacturing Report* (asset performance management (i.e., IBM Maximo, UpKeep), computerized maintenance management systems (i.e., SAP Plant Maintenance, Oracle eAM), and advanced analytics software (i.e., SAS Analytics Pro, IBM SPSS)) were mentioned by key informants in the Lethbridge manufacturing sector.

Assessing the return on investment and payback period for automation technologies is fragmented and driven largely on past experiences.

In theory, well established metrics and measurement frameworks guide manufacturing organizations to accurately assess the ROI and payback period of specific automation technologies and robotic solutions integrations. This, in turn, would guide strategic planning and operational budgeting. However, our discussions revealed that this practice continues to elude most of the Lethbridge manufacturing sector.

When probed to speak to the ROI and payback period associated with the integration of ATs, interviewees struggled to quantify the benefits of task-level automation along with the methods, indicators, and measurement frameworks used to do so. With several experts citing an "intuition-based" approach to AT adoption, whether to invest in a specific AT is largely dependent on whether the organization has had a positive experience with automation in the past. Manufacturing firms continue to invest in well-established ATs, but apprehensive to engage in trial-and-error learning with emerging technologies.

Assessing ROI and payback period for ATs and robotic solutions is a challenge that extends beyond Lethbridge manufacturing firms. The prominence of RPA and SAAS in our discussions can in part be attributed to past research which has established the ROI and payback periods for technologies. In the absence of quantifiable benefits, a risk averse culture may continue to impede AT adoption. t\This translates to organizations continuing to report themselves as falling behind their competitors and industry standards on automation.

Across all interviews, only a single interviewee was able to identify an expected ROI and payback period of 30-50 percent and 3 years respectively. However, a shared sentiment was that upfront capital costs of ATs serve as a central metric for assessing technical viability. This highlights a lingering need for standardized metrics and measurement frameworks. As importantly, increased cooperation between suppliers and manufacturers to work collaboratively and share data-driven insights that help quantify the benefits of AT adoption is needed. In turn, this could reduce barriers to scaling their adoption in manufacturing organizations.

In the absence of sufficient external support and programming, manufacturing organizations have begun upskilling and reskilling their workforce in-house.

When probed on workforce training options, interviewees demonstrated little interest and low awareness of regional, provincial, or federal financial supports or upskilling/reskilling programs. The perception amongst Lethbridge manufacturers was that there are few if any relevant programs that are being offered regionally.

Collectively, a general perception amongst interviewees was that while Lethbridge, and Alberta more broadly, has fallen short in the provision of adequate training supports, other provinces (e.g., Ontario) have been successful in their subsidization of workforce upskilling opportunities. This perception often leads to manufacturers disengaging from future external opportunities while creating an uneven competitive landscape that props up manufacturing in specific geographies.

A shared concern across manufacturing organizations is a lack of understanding of who is responsible workforce training (e.g., upskilling, reskilling). As per our discussions manufacturing organizations tend to internalize the responsibility of workforce development, designing and deploying in-house training programs to align themselves with automation trends.

This trend is compounded by two specific factors. First, participants cited that there is a lack of adequate external programming for upskilling and reskilling the manufacturing workforce. This was the case both regionally (Lethbridge) and nationally (Canada). Second, participants indicated that training programs must be highly specialized, referencing that AT adoption and operation requires technical skills and knowledge that often varies at the project-level.

In turn, interviewees perceived that external programming often lacks the specificity required for ground-level implementation. While existing programs nationally may help with targeted training, the general sentiment from interviewees is that further specialization is required internally for proprietary systems to complement more general training on ATs.

When designing training programs internally, manufacturers indicated they rely on two sources of knowledge and expertise. The first sees manufacturing organizations address AT-related skills gaps by sourcing expertise from their suppliers. This strategy was particularly relevant for organizations when a) they are early along the automation technology lifecycle, and b) they are introducing first-of-its-kind automation technologies and seeking to build new technical competencies throughout their workforce. The second involves firms leveraging existing competencies and technical skills within their workforce and facilitating peer-to-peer training systems. This design approach is prevalent in manufacturers further along the AT lifecycle with proven track record of establishing technical skills and operational know-how.

While internal training for employees may seem like a viable option for addressing skills gaps, it is not without its limitations. Companies may have proprietary systems that they train employees on, which limits their exposure to industry best practices and new technologies. Moreover, internal training can be expensive and time-consuming, especially for smaller companies with limited resources. As such, it may not be the most cost-effective means of addressing skills gaps in the long run. To overcome these limitations, companies may need to explore alternative options such as partnering with external training providers or investing in online learning platforms that offer a wider range of courses and resources.

From a training perspective, these insights underscore a stark reality that is hindering Canada's ability to fulfill its 2022 Digital Ambition. There is a clear and urgent need for education and awareness building for existing training programs. Alternatively, there is a need for new financial mechanisms that enable agile deployment of in-house programs and the organizational level. As it stands, our discussions indicate that the current approach to regional workforce development has fallen short and has created a scenario that sees manufacturing falling behind.

While manufacturers are planning to ramp up their adoption of AT, the rate of diffusion is impeded by technical skills gaps and operational capabilities throughout the workforce.

With respect to technical skills, manufacturing organizations consistently referenced a need for the regional workforce to develop competency in computer-aided design. Used to optimize manufacturing processes and as a compliment to other ATs, developing CAD was perceived to help increase efficiency and productivity gains from AT adoption, and enhance product and process quality.

Manufacturing organizations cited project-level variability and technological specificity as two compounding factors that requires workers to be able to onboard quickly and efficiently. While the soft skills needed for this are already well-established within the Lethbridge manufacturing sector, organizations indicated that their importance would persist in the face of growing AT integration.

Relying on immigrant labour pools to fill staffing requirements, manufacturing organizations indicated that communications, particularly English as a Second Language (ESL) plays a key role in organizations' ability to train for safely and efficiently operating ATs. Given that access to talent is a core challenge within this sector, continued reliance on new immigrants should be expected to continue and underscores a need to have ESL programs embedded at the firm-level to successfully train new employees on ATs and other emerging technologies.

Moreover, relying on labour from technology suppliers may be more expensive, less efficient, and introduce legacy costs. Long-term, it would likely be a cheaper solution to ensure local talent and the current workforce is upskilled/reskilled for introducing and operating ATs.

Overall, it appears from our key informant interviews that there appears to be little to no collective training or collaboration to address skills gaps in Lethbridge manufacturing. As emerging technologies, robotics, and ATs become a bigger part of manufacturing globally, it would benefit the Lethbridge manufacturing sector to work together on upskilling and reskilling the workforce in these areas to stay competitive.

One potential option 'Engineering Design Technology' program at Lethbridge College. Delivered as a 2-year diploma, this program may serve as a potential option for manufacturers to upskill their workforce in areas including quality assurance and control, computer-aided design and drafting, mechanics of materials, and electrical fundamentals.

Inventory of Workforce Training Programs

To aid the design of possible workforce training programs in Lethbridge, we scanned economic development practices across the country. Through a comparative assessment of industrial composition across Canadian Metropolitan Areas, 20 CMAs were identified as the most similar to the Lethbridge region based on their industrial structure (Table 9). This helped to ensure that the programs being assessed as well as upskilling/reskilling time estimates were for those skills most relevant to the Lethbridge Manufacturing context. With the aim of identifying programs that can be drawn upon to help address existing technical skills gaps in Lethbridge manufacturing, this inventory is selective rather than exhaustive.

In assessing the pan-Canadian landscape for tech-related upskilling and reskilling programs, our analysis show that the main sponsors that are delivering these programs include polytechnics and colleges. Offering programming that ranges from short-term (< 1 month) certificates to multi-year diplomas, this inventory highlights the potential of establishing public-private partnerships as one potential pathway to efficiently deploy best practices at the organizational-level.

Moreover, this inventory may be used by manufacturers in several ways. First, this list provides multiple entry points to inform program design and strategic planning for tech-related upskilling and reskilling. Second, manufacturers can use this list to identify regional partners that can be engaged in the facilitation of custom programming. Third, manufacturers may gather insights to help them estimate the training time and costs associated with upskilling/reskilling their workforce.

Table 9

Training Length Varies Based on the Technology Skills Targeted by the Programs

City	Program Name	Sponsor	Skills	Time (days)	Context
Red Deer (CMA)	Instrumentation and Automation Engineering Technology Diploma	Red Deer Polytechnic	Computer programming; CAD; professional communications; technology mathematics; microcontrollers; process measurements; PLC programming; electrical machines and drive; process controls; robotics; DCS, SCADA, HMI; hydraulics and pneumatics; network systems; IT Networks; instrumentation systems; analyzers; project management	320	Full-time
	CareerMOVES	Manpower Services Alberta	Supply chain management; inventory management, procurement, business operations; logistics	105	Full-time
Regina (CMA)	Instrumentation Engineering Technology Diploma	Sask Polytechnic	Analytical instruments codes and standards computer programming, data communications and networks digital and linear circuits, digital logic distributed systems drafting electronics instrument measurement machine shop process applications project management relay and instrument controls	532	Full-time
Saskatoon (CMA)	Design and Manufacturing Engineering Technology	Sask Polytechnic	Advanced Manufacturing (CNC machines, robots, industrial 3D printing) Mechatronics (Electronics, Microcontrollers - Arduino/Raspberry Pi, Programming) Computer systems and networking (Computer hardware, Wi-Fi, Networking) CAD and engineering software (2D/3D CAD, CNC simulation, Finite Element Analysis)	560	Full-time
Winnipeg (CMA)	Manufacturing and Skilled Trades Micro-credential Program	RRC Polytechnic	Safety standards and awareness; tool and equipment maintenance and operations; math and measurements	120	Part-time
Guelph (CMA)	Electric Vehicle Up-skilling training program	AIA Canada	Safety State of the art tools and use Diagnostic trouble codes Electric motor controls High Voltage battery introduction, Autonomous Driver Assistance Systems (ADAS)	300	Part-time
Brantford (CMA)	Advanced Automation and Manufacturing Program	Mohawk College	CAD; systems design; machining; welding; robotics; industrial automation processes; process control and monitoring; data analytics; RPA	480	Part-time
	Manufacturing Engineering Technician-Automation Program	Mohawk College	Mechanical maintenance, machining, and fluid power; machine fabrication and repair operations; measurement, metallurgy, automated systems, mathematics, blueprint interpretation, safety and troubleshooting; maintaining, and preventative maintenance on automated systems.; PLC programming, basic electrical circuit theory, and ladder logic development and applications; AutoCAD, rigging and hoisting, power transmission, and welding.	480	Full-time
	QUICKTRAIN Canada	Canadian Colleges for a Resilient Recovery	building information modeling; digital twins; CAD; CAM; GIS; Data systems and visualization; Microsoft Excel, Microsoft Power BI	43	Part-time

St. Catharines - Niagara (CMA)	Industrial Automation Program	Niagara College	PLC programming; HMI Design; Industrial robotics; programming; CAD; motors and variable speed drives; industrial communications and devices; industrial automation; pneumatic and hydraulic systems; material handling; compliance technologies	270	Full-time
Barrie (CMA)	Industrial Automation Program	City of Barrie	PLC programming; machine building and integration; pneumatic controls; industrial control systems; systems design; CAD; production; troubleshooting; machine programming; hardware configuration; quality control systems; industrial robotics programming	19	Part-time
	Robotics Micro-credential	City of Barrie	Integrated systems; robotics programming; mechanical design; simulation software; machine safety and controls; advanced programming; automation process controls; PLC programming; RPA;	19	Part-time
Greater Sudbury (CMA)	Power Engineering Technology Program	Cambrian College	Power plant operations; control systems; boilers and auxiliaries; safety and administration; communications; heating, refrigeration, and gas compression; building systems; machine movers; applied chemistry; math and thermodynamics; electricity and control systems; power plan simulations; energy systems	320	Full-time
	Electrical Engineering Technician - Industrial	Cambrian College	CAD; Data analysis; machine installation; electrical communications; motor controls; digital electronics; instrumentation; technical communications; power electronics; electrical code; PLC programming; AC and DC Machines;	320	Full-time
Kelowna (CMA)	Mechanical Engineering Technology Diploma	Technology Accreditation Canada	Product design, specification, installation and maintenance of equipment, cost estimating, technical sales, quality management, inspection, production planning, automation, CAD/CAM, robotics, and research and development; machine design; instrumentation and control	480	Full-time
Kamloops (CMA)	Architectural and Engineering Technology Diploma	Thomson Rivers University	CAD; graphical communications; building electrical design; technical mathematics; materials and applications; occupational writing; building technologies; civil technologies; fluid mechanics; structural analysis; HVAC Design; Building services; statics and material strengths; regulations and safety	480	Full-time
Abbotsford - Mission (CMA)	Automation and Robotics Technician Program	International Electronics Technician Articulation Committee	Technical drafting and AutoCAD application; Hydraulic and pneumatic control systems; Microprocessors/microcontrollers and data acquisition Project management and occupational organization Programmable logic controllers Wiring, motors, and actuators, Control systems, including hands-on introduction to agricultural and manufacturing control systems; Automation and robotics project	160	Full-time
Chilliwack (CMA)	Automation and Robotics Technician Program	International Electronics Technician Articulation Committee	Technical drafting and AutoCAD applications Hydraulic and pneumatic control systems Microprocessors/ microcontrollers and data acquisition Project management and occupational organization Programmable logic controllers; Wiring, motors, and actuators; Control systems, including hands-on introduction to agricultural and manufacturing control systems; Automation and robotics project	160	Full-time
Drummondville (CMA)	Mechanical Engineering Techniques (Mechanical Manufacturing)	Cegep de Drummondville	CAD; quality control; industrial machine operations; industrial programming; statistics; machining; industrial controls; hydraulic systems; CAM; quality control systems; systems design	560	Full-time

Saguenay (CMA)	Electrical Engineering Technology- Automation and Control Program	Cegep De Chicoutimi	Instrumentation and automation or instrumentation and control; electromechanical; electrodynamics; robotic process automation; electrical maintenance and servicing; troubleshooting and machine maintenance; electrical systems design	480	Full-time
Sherbrooke (CMA)	AEC Industrial Robotics Program	Ecole Nationale D'Aerotechnique	Electrical and pneumatic circuits; industrial automation; industrial robotics; installation, safety and maintenance of robotics; network and operator interface; robot systems; robotic design and simulation; advanced industrial robotics; CAD	480	Full-time
Moncton (CMA)	Manufacturing Fundamentals	Government of New Brunswick	Workplace safety; quality control; welding; metal fabrication; machining; electrical systems; instrumentation;	40	Part-time
	Information Technology- Quality Assurance Testing Program	NBCC	Test Plans, Cases, and Processes; Test Methodologies, Test Design; Technical Writing; Report Writing; Communications; Interpersonal Behavior; Data Presentation; Programming Relational Databases; Data Manipulation Language (SQL)	160	Full-time
Fredericton (CMA)	Manufacturing Fundamentals	Government of New Brunswick	Workplace safety; quality control; welding; metal fabrication; machining; electrical systems; instrumentation;	40	Part-time
Saint John (CMA)	Process Control Technician	NBCC	Electrical circuits and machines; building systems; technical sketching; boiler plant operations and maintenance; heat engine and prime movers, computer system controls; safety controls; technical math foundations	160	Full-time

Our analysis of these manufacturing-centered programs across Canada yields several insights for Lethbridge:

- Program Duration and Format: Programs vary widely in duration, from as short as 19 days to as long as 560 days. While longer programs do not necessarily guarantee a more comprehensive skill set, they often delve deeper into certain specialized areas. Most programs are full-time, although there are part-time options available that focus on specific skills such as CAD and Machining.

- Skills Gap: Our analysis identified certain skills that are less frequently covered in the current educational landscape. Some of these include "Automation and robotics project", "Industrial automation", "Robotics", and "Building systems". These areas might represent niches or potential gaps that Lethbridge can address to differentiate its educational offerings.

- Time vs. Skills Trade-off: The correlation between the number of skills taught and the duration of the program is weak. This means that the breadth or intensity of a program is not necessarily tied to its length. Institutions in Lethbridge could consider offering intensive short-term courses that deliver high value, targeting specific gaps in the market.

- Reference Programs: Certain cities and institutions stand out for their specialized programs. For instance, Brantford's Mohawk College and Barrie's City College offer programs that emphasize automation in manufacturing. These programs could serve as valuable references for Lethbridge institutions looking to design or enhance their curriculum.

- Estimated Training Times: Based on program delivery timelines, estimated timeframes for upskilling workers are as follows:

  - Testing and Analysis (mean: 180 days; range 40-300 days)
  - Quality Control, Inspection, and Assurance (mean: 240 days; range 40-480 days)
  - Recording, Documentation, and Reporting (mean: 240 days; range: 40-480 days)
  - Assembly and Installation (mean: 240 days; range: 40-480 days)
  - Weighing and Measurement (mean: 240 days; range: 40-480 days)
  - Procurement and Customer Service (mean: 72.5 days; range: 40-105 days)
  - Cleaning and Maintenance (mean: 260 days; range: 40-480 days)
  - Planning and Scheduling (mean: 301.5 days; range: 43-560 days)
  - Material Handling (mean: 149.5 days; range: 19-480 days)
  - Equipment Operation and Setup (mean: 119.5 days; range: 19-320 days)
  - Machine Operation, Adjustment, Maintenance (mean: 249.5 days; range: 19-480 days)
  - Production Operations (mean: 300 days; range: 40-560 days)

- In summary, the average timeframes range from approximately 2-8 months for different task categories, with part-time programs generally taking less time compared to full-time options. These estimates reflect a basic understanding of relevant tasks and may vary according to proficiency levels.

To compliment the growing number of potential upskilling programs across Canada, there is a need for additional research to assess the impact of these programs on the manufacturing sector. This includes quantifying the outcomes from programs across other metropolitan jurisdictions. This research can benefit manufacturing by providing insights into the effectiveness of upskilling and reskilling programs in improving productivity, reducing costs, and increasing competitiveness.

To accomplish this research, there is a need for collaboration between industry stakeholders, government agencies, and academic institutions. Data collection and analysis methods should also be standardized to ensure that results are reliable and comparable across different programs and sectors. Overall, additional research on upskilling and reskilling programs can provide valuable information for policymakers, employers, and workers in the manufacturing sector.

Conclusion

The main challenges to integrating automation technologies in the Lethbridge manufacturing sector include accessing talent, organizational readiness (i.e., management culture that resists to change), increasing wage requirements for hiring specialized workers, specialized skill development and technical knowledge, and proving the ROI and payback period for AT integration.

Manufacturing is experiencing digital transformation through advanced robotics, IoT, cloud computing, AI, and machine learning, leading to increased automation and efficiency. Industry 4.0's digitally connected machines offer data-driven optimization, adaptable supply chains, and affordable robotics, but adopting advanced automation can be challenging due to infrastructure, cost, culture, and skill-related issues that require upskilling and targeted recruitment for a successful transition.

Manufacturing automation is categorized into three waves: the algorithm wave, automating structured data analysis; the augmentation wave, automating repetitive tasks with advanced tech support; and the autonomy wave, deploying RPA technologies for physical labor and problem-solving tasks.

The impact of automation on the economy depends on two factors: the sectoral and occupational makeup of each economy. While many studies have shown that a significant percentage of jobs are at risk of automation in the next decade or two, occupation-based approaches to assessing automation potential have been criticized for overestimating it due to variations in workers' task structures within the same occupation. Task-based approaches, which focus on automating specific tasks rather than entire occupations, have gained attention. According to those studies, over 40 percent of manufacturing tasks could be performed by robotic solutions by 2040.

Studies show organizations embracing automation outperform non-adopters and achieve faster growth. For instance, intelligent automation yields cost reductions of 22 percent and revenue increases of 11 percent over three years. While specific technologies with the highest ROI vary, robotic process automation is often more productive. However, ROI assessment faces challenges due to lack of standardized tools and transferable indicators across industries, leading to trial-and-error approaches for successful deployment of automation in manufacturing.

Assessing the return on investment (ROI) for automation involves three primary measures: return on invested capital (ROIC), net present value (NPV), and expert surveys to identify quantitative indicators. ROIC gauges profitability through profit and capital investment, while NPV compares future cash flows to required investment. Expert surveys reveal common indicators used for automation ROI, such as execution frequency, stability, standardization, and failure rate.

As the manufacturing sector increases its adoption of automation technologies, it will require a workforce with non-routine cognitive skills to complement automation technologies. Communication and teamwork are the most sought-after skills, followed by flexibility, employee engagement, initiative, and analytical thinking. Overall, there is greater emphasis on the need for adaptable and collaborative talent.

Despite perceptions that Lethbridge manufacturing has fallen behind on AT deployment trends, our primary research shows that currently a range of ATs such as RPA and SAAS (across all organizations), CRM and HRIS (primarily in larger organizations), ERP and EAM (primarily in process-oriented organizations), and CNC and PLC technologies (in technically advanced organizations) are active in the sector. For manufacturers who are successfully piloting and deploying ATs, labor productivity and process efficiencies are the primary benefits gained from automation.

While it is possible to provide internal training to leverage automated solutions, a broad strategy (involving community stakeholders with knowledge & understanding of this industry) would be a more effective means of dealing with skills shortages and would help introduce solutions that could be used by SMEs that lack expertise in this industry.

Recommendations

For Lethbridge

- Given its specialization in food manufacturing, Lethbridge needs to focus on automation of tasks in that sector. If not automated already, automation of tasks such as testing and analysis; recording, documentation and reporting; production operations; material handling; machine adjustment and maintenance; quality control; planning and scheduling; weighting and measurement will enhance productivity in manufacturing sector significantly.

- In terms of skills required for the deployment of automation technologies, Lethbridge needs to ensure that manufacturing workers know certain facility level tools and technologies. Some of the top facility level technologies include Supervisory control and data acquisition (SCADA) software, Oracle NetSuite, GE Digital Predix APM, Rockwell FactoryTalk Analytics.

- Lethbridge needs to close technology skills with the country in the following task categories to make its manufacturing sector nationally competitive: testing and analysis; quality control, inspection, assurance; recording, documentation and reporting.

- As has been implemented in similar regions such as Red Deer, Regina, and Saskatoon, Lethbridge manufacturers will benefit from a collective approach to workforce training related to deploying and utilizing automation technologies. This approach will ensure that economies of scale are created in working with out-of-region or out-of-country technology providers and the experience/expertise of different firms is leveraged and shared.

- To help address issues of capacity and training, Lethbridge manufacturers should develop an industry-sponsored working group to focus on the design and management of a strategic plan for collective workforce training. Through research and benchmarking, the group can identify best practices and innovative solutions that can be implemented to enhance productivity, efficiency, and competitiveness. By working together, industry players can leverage their collective expertise and resources to create a more vibrant and sustainable manufacturing sector in Lethbridge.

- Interviewees commonly perceived that Alberta, especially Lethbridge, lags behind other provinces like Ontario in offering substantial training supports and subsidization for workforce upskilling. Given the potential for this perception to cause disengagement and an uneven competitive landscape, Alberta's local and provincial authorities are best positioned to review and better promote their training initiatives. Collaborative efforts with industry stakeholders can help bridge this perceived gap, ensuring that manufacturers remain engaged and can compete on a more even footing with those in other provinces.

- Lethbridge could prioritize the development of a comprehensive automation labour force strategy. This strategy should continually assess labour needs, delineate clear targets, and design solutions to meet these targets. A consortium of local authorities, industry groups, and educational institutions stand as the ideal entities to lead this initiative. Furthermore, integrating the newcomer labour force into this strategy can be pivotal, facilitating their seamless integration into the community while concurrently catering to the region's labour demands.

- Lethbridge manufacturers have displayed a significant gap in awareness regarding available regional, provincial, or federal workforce training options and financial supports. Local authorities, industry associations, and educational institutions are best positioned to address this gap. They should collaborate to launch targeted awareness campaigns and information dissemination initiatives. These efforts will ensure manufacturers are well-informed about relevant upskilling and reskilling programs, fostering a culture of continuous learning and adaptation in the region.

For Manufacturing Firms

- Manufacturing firms should seek to establish regional partnerships with polytechnics and colleges. By leveraging their existing knowledge and program design capabilities, manufacturers can reduce the time and costs associated with addressing key skills gaps including computer-aided design, business intelligence and data analysis, analytic software, and enterprise resource planning.

- In terms of measuring the return on investment and payback period associated with automation technology investments, there is a need for greater precision across measurement frameworks and transparency in quantifying benefits associated with AT deployment. Manufacturers can partner with AT suppliers using data sharing agreements and general data protection regulations to enhance ROI/payback period assessments through real-time feedback at the project-level, which in turn, will reduce barriers (particularly for small and medium sized firms) associated with senior leadership buy-in, and up-front capital costs.

- In terms of talent, manufacturers should continue and expand their automation training efforts for proprietary internal systems. This strategy can enhance the efficacy of AT deployment by reducing resistance to change/enhancing employee buy-in, reduce employee turnover, enhance peer-to-peer training, and ensure upskilling training is aligned at the project-level. A local industry association could also work to cultivate goals and benchmarks for internal training required to ensure documentation and goal alignment for local manufacturers, especially those earlier in the adoption curve.

- Manufacturing organizations, especially those early in the AT lifecycle, face challenges in presenting a compelling business case for AT due to variability in technology outcomes and a lack of standard metrics and tools. It's imperative for these firms to collaborate with industry associations, technology providers, and peers to develop and adopt standardized tools, metrics, and measurement frameworks for assessing the return-on-investment and payback period of AT investments. Such standardization will not only facilitate accurate evaluations but also foster confidence in scaling AT across operations and facilities.

Appendix A

References

Acemoglu, Daron, Anderson, Gary., Beede, David., Buffington, Catherine., Childress, Eric., Dinlersoz, Emin., Foster, Lucia., Goldchalg, Nathan., Haltiwanger, J., Kroff, Zachary., Restrepo, P., Zolas, N. 2022. "Automation and the Workforce: A Firm-Level View from the 2019 Annual Business Survey. Massachusetts Institute of Technology Working Paper No. 2049427. 45pp.

Acemoglu, Daron, and Pascual Restrepo. 2017. "Robots and Jobs: Evidence from US Labor Markets." National Bureau of Economic Research. Working Paper No. 23285. March 2017. 91pp.

Arntz, Melanie, Terry Gregory, and Ulrich Zierahn. 2016. "The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis." OECD Social, Employment and Migration Working Papers No. 189. 35pp.

Autor, David, and Anna Salomons. 2018. "Is automation labor-displacing? Productivity, growth, employment, and the labor share." BPEA Conference Drafts, March 2018. 75pp.

Bughin, Jacques, James Manyika, and Jonathan Woetzel. 2017. "A Future That Works: Automation, Employment, and Productivity." McKinsey Global Institute. January 2017. 148pp.

Canadian Manufacturers and Exporters. 2019. "Embracing Change: Industry 4.0 and Canada's Digital Future in Manufacturing." 22pp.

Conference Board of Canada. 2020. "Responding to Automation: How Adaptable is Canada's Labour Market?" Issue Briefing March 2020. 16pp.

Cutean, A., Davidson, R. 2018. Mapping Calgary's Digital Future: Tech Employment Opportunities for Displaced Workers, Information and Communications Technology Council (ICTC), Ottawa, Ontario. 73pp.

Deloitte. 2022. "Automation with intelligence: Reimagining the organization in the 'Age of With'." Deloitte Insights Report. 28pp.

Deloitte. 2023. "2023 Manufacturing Industry Outlook Report." 12pp.

Enriquez, José G., Alberto Jimenez-Ramirez, Francisco J. Dominguez-Mayo, and Juan A. Garcia-Garcia. 2020. "Robotic Process Automation: A Scientific and Industrial Systemic Mapping Study." IEEE Access 8: 39113-39129.

European Commission. 2019. "The Impact of the Digital Transformation on EU Labour Markets." Report of the High-Level Expert Group. April 2019. 52pp.

European Parliamentary Research Service. 2021. "Digital automation and the future of work." EPRS Panel for the Future of Science and Technology. January 2021. 78pp.

Fernandez-Macia, Eva, and Michele Bisello. 2022. "A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work." Social Indicators Research 159: 821-841.

Frank, Kasey, Zhe Yang, and Marc Frenette. 2021. "The changing nature of work in Canada amid recent advances in automation technology." Statistics Canada Economic and Social Reports, vol.1, no.1. 27pp.

Frenette, Marc, and Kasey Frank. 2020. "Automation and Job Transformation in Canada: Who's at Risk?" Analytical Studies Branch Research Paper Series. Paper No. 448. June 29, 2020. 25pp.

Frey, Carl Benedikt, and Michael A. Osborne. 2013. "The Future of Employment: How Susceptible Are Jobs to Computerisation?" Oxford Martin School Working Paper. 79pp.

Frey, Carl Benedikt, Michael A. Osborne, and Citi GPS. 2016. "Technology at Work 2.0: The future is not what is used to be." Global Perspectives and Solutions Report. January 2016. 156pp.

Frohm, Jörgen, Viktor Lindstrom, Magnus Winroth, and Johan Stahre. 2008. "Levels of Automation in Manufacturing." Ergonomia 30(3): 37pp.

IBM. "What is Industry 4.0?" Accessed June 9, 2023. https://www.ibm.com/topics/industry-4-0

Kaur, Ritu, Ashish Awasthi, and Katarzyna Grzybowska. 2020. "Evaluation of Key Skills Supporting Industry 4.0—A Review of Literature and Practice." In Sustainable Logistics and Production in Industry 4.0, edited by Katarzyna Grzybowska, Ashish Awasthi, and Rajeev Sawhney. EcoProduction. Springer, Cham. https://doi.org/10.1007/978-3-030-33369-0_2

Lucas Santos Dalenogare, Guilherme Brittes Benitez, Néstor Fabián Ayala, Alejandro Germán Frank. 2018. "The expected contribution of Industry 4.0 technologies for industrial performance." International Journal of Production Economics 204: 383-394. https://doi.org/10.1016/j.ijpe.2018.08.019.

Marr, Bernard. 2018. "What is Industry 4.0? Here's A Super Easy Explanation for Anyone." https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/?sh=1ebd7a7c9788

McKinsey Global Institute. 2012. "Manufacturing the future: The next era of global growth and innovation." McKinsey Operations Practice Report. November 2012. 184pp.

McKinsey Global Institute. 2018. "Skill Shift: Automation and the Future of the Workforce." Discussion Paper. March 2018. 84pp.

Muro, Mark, Robert Maxim, and Jacob Whiton. 2019. "Automation and Artificial Intelligence: How machines are affecting people and places." Brookings Institute Policy Report. January 2019. 108pp.

Nedelkoska, Ljubica, and Glenda Quintini. 2018. "Automation, skills use and training." OECD Social, Employment and Migration Working Papers No. 202. 125pp.

NTT Data. 2022. "The Road to Industry 4.0." Exford Economic Executive Summary Report. January 2022. 18pp.

PWC. 2018. "Will robots really steal our jobs? An international analysis of the potential long-term impact of automation." PWC Economics Report. 47pp.

Rockwell Automation. 2022. "8th Annual State of Smart Manufacturing Report." 38pp.

Sirkin, Harold L., Michael Zinser, and John R. Rose. 2015. "The Robotics Revolution: The Next Great Leap in Manufacturing." The Boston Consulting Group Report. September 2015. 28pp.

Wanner, Judith, Alexander Hofmann, Melanie Fischer, Frank Imgrund, Christian Janiesch, and Jörg Geyer-Klingberg. 2019. "Process Selection in RPA Projects: Towards a Quantifiable Method of Decision Making." Fortieth International Conference of Information Systems. Munich 2019. 17pp.

Wilson, Mike, and Mathieu Poirier. 2019. "We're Hiring: Manufacturing Workforce Survey Report." Canadian Manufacturers and Exporters Workforce Report. 25pp.

Appendix B

Methodology

Methodology consists of three main components.

Environmental Scan

We conducted literature review to identify the range of manufacturing tasks that can be automated. In the identification of those tasks, we focused on the operation and usage of productivity-enhancing automation technologies (in the manufacturing sector). As part of this review, we tried to identify if there is a consensus as to general return-on-investment (ROI) that highlights the payback time for companies when introducing automated tools into manufacturing process. The third part of this review was related to workforce training programs. We developed an inventory of workforce training programs that have been implemented in other regions of the country to draw lessons for Lethbridge.

Workforce Composition and Upskilling Analysis

Using findings from the environmental scan, we identified the range of manufacturing tasks that can be automated. We then specified main skills sets that are associated with performing the tasks identified above. We then identified specific skills gaps among the local manufacturing workforce that prevent the adoption of productivity-enhancing automation technologies. Lastly, we estimated the proportion of local manufacturing employees who currently have the skills and training required to harness the power of automated machinery in support roles (e.g., materials handling, machinery inspection, machine testing, quality inspection, welding).

As part of manufacturing tasks identification and skills gaps analysis, we examined the occupational and sectoral composition of local economy (in comparison to the national average).

Automatability of Manufacturing Tasks

We applied a 5-step approach to identifying manufacturing with automation potential. First, using detailed manufacturing task descriptions and employee survey data from O*NET, we calculated the "degree" of automatability for 4,181 tasks relevant to manufacturing sector. For this, we estimated the approximate number of times a particular task is performed in a year to determine the degree to which it is repetitive. In this estimation, we assumed that there are 260 workdays in a year and employees work 8 hours a day. The number of times a particular task is performed per hour worked varies from yearly or less to hourly or more.

Table 1
Manufacturing Employment in Lethbridge is Highly Concentrated in Food Manufacturing, 2020 (categories are those that are included in the survey given to employees)

Frequency Category	Frequency	Number of Times Performed
1	Yearly or less	1
2	More than yearly	6
3	More than monthly	18
4	More than weekly	78
5	Daily	260
6	Several times daily	1,040
7	Hourly or more	2,080

Source: The Conference Board of Canada's Analysis Based on O*NET Data.

Second, we calculated the weighted average for each of the 4,181 tasks across survey respondents (Table 2). The value of 61.7 indicates that the task of discarding inferior or defective products or foreign matter, and placing acceptable products in containers for further processing can be automated approximately 62 of the time.

Table 2
Calculation of the Automation Potential for A Particular Task
(i.e., *Discard Inferior or Defective Products or Foreign Matter, and Place Acceptable Products in Containers for Further Processing)*

Frequency Category	Number of Times Performed (A)	% Share of Respondents (B)	Aggregate Number of Times Performed (C=A*B)	Weighting Response by Category (D=C/3,483)	Normalizing Responses by Max Automation (E=36.8/59.7*100)
1	1	0.0	0	0.0	
2	6	0.0	0	0.0	
3	18	2.1	38	<0.1	
4	78	9.2	721	0.2	
5	260	26.5	6,895	2.0	
6	1,040	8.4	8,694	2.5	
7	2,080	53.8	111,862	32.1	
Total	**3,483**	**100.0**	**128,211**	**36.8**	**61.7**

Source: The Conference Board of Canada's Analysis Based on O*NET Data.

Note: Absolute automation value (59.7) is calculated using a hypothetical survey response in which 100 percent of the surveyed employees indicate that they perform the task hourly or more. Benchmarking actual responses by this hypothetical response was a necessary step to be able to talk about automation potential of tasks in more meaningful way.

Third, because we are interested in the automatability of manufacturing tasks that are applicable to the manufacturing processes in Lethbridge, we excluded those tasks that are not associated with the existing manufacturing occupations in Lethbridge. Additionally, we calculated relative concentration scores for manufacturing occupations in Lethbridge by the following formula.[64]

$$CQ = \frac{\text{Occupation's share of regional employment in manufacturing}}{\text{Occupation's share of national employment in manufacturing}}$$

These concentration quotients enabled us to assign heavier weight to those tasks that are associated with occupations that are overrepresented in the region relative to the nation. Lastly, we normalized concentration quotients using minimum-maximum scaling method. The formula for the minimum-maximum scaling method is:

$$X_{scaled} = \frac{X - X_{min}}{X - X_{max}}$$

The resulting values are expressed in percentages and thus addable to automation scores calculated in the previous step.

Fourth, we averaged the automation scores from Step 2 and normalized concentration quotients from Step 3 to arrive at the list of manufacturing tasks with high automation potential (greater than 50 percent) and relevance for the Lethbridge manufacturing industry (at least 10 employees performing the corresponding tasks).

As a final step, we classified tasks into 12 mutually exclusive categories based on the similarities between them (Table 3). These task categories are provided in Table 4. Tasks in Table 3 are sorted in order of higher automatability and high relevance for Lethbridge (fifth column). Tasks with higher probabilities of automation are likely to lead to productivity gains in the sector.

Table 3

Manufacturing Tasks Sorted in Order of High Automation Potential and Relevance to the Manufacturing Industry in Lethbridge

Class	Task Description	Automation Potential	Concentration Quotient (CQ)	Average
9	Grade and sort products according to factors such as color, species, length, width, appearance, feel, smell, and quality to ensure correct processing and usage.	0.66	0.90	0.78
2	Discard inferior or defective products or foreign matter, and place acceptable products in containers for further processing.	0.62	0.90	0.76
3	Weigh products or estimate their weight, visually or by feel.	0.59	0.90	0.74
10	Place products in containers according to grade and mark grades on containers.	0.56	0.90	0.73

[64] The CQ measures the relative importance of any given occupation to regional manufacturing compared to the national manufacturing. Values greater than 1 indicate that a given occupation is more important to the regional manufacturing than the national manufacturing industry. Values less than 1 indicate that a given occupation is less important to the regional manufacturing than the national manufacturing industry. Values equal to 1 indicate that a given occupation is equally important to the regional manufacturing and national manufacturing. In standardized CQ values in Table 3, 0.07 or greater correspond to unstandardized CQs greater than 1.

5	Record or compile test results or prepare graphs, charts, or reports.	0.51	0.90	0.71
9	Conduct standardized tests on food, beverages, additives, or preservatives to ensure compliance with standards and regulations regarding factors such as color, texture, or nutrients.	0.50	0.90	0.70
10	Inspect food products and processing procedures to determine whether products are safe to eat.	0.53	0.53	0.53
6	Remove bones, and cut meat into standard cuts in preparation for marketing.	0.63	0.36	0.50
10	Hold or position spray guns to direct spray onto articles.	0.66	0.21	0.43
11	Manipulate products, by hand or using machines, to separate, spread, knead, spin, cast, cut, pull, or roll products.	0.72	0.14	0.43
4	Take product samples during or after processing for laboratory analyses.	0.69	0.14	0.41
9	Verify conformance of machined work to specifications, using measuring instruments, such as calipers, micrometers, or fixed or telescoping gauges.	0.74	0.09	0.41
3	Record production data, such as weight and amount of product processed, type of product, and time and temperature of processing.	0.69	0.14	0.41
9	Observe, feel, taste, or otherwise examine products during and after processing to ensure conformance to standards.	0.68	0.14	0.41
9	Homogenize or pasteurize material to prevent separation or to obtain prescribed butterfat content, using a homogenizing device.	0.67	0.14	0.41
3	Adjust wheel speeds according to the feel of the clay as pieces enlarge and walls become thinner.	0.73	0.08	0.40
10	Measure and examine extruded products to locate defects and to check for conformance to specifications, adjusting controls as necessary to alter products.	0.71	0.09	0.40
3	Measure dimensions of finished workpieces to ensure conformance to specifications, using precision measuring instruments, templates, and fixtures.	0.71	0.09	0.40
9	Trim excess threads or edges of parts, using scissors or knives.	0.75	0.04	0.40
3	Place products on carts or conveyors to transfer them to the next stage of processing.	0.65	0.14	0.39
4	Position balls of clay in centers of potters' wheels, and start motors or pump treadles with feet to revolve wheels.	0.70	0.08	0.39
3	Stop machines to remove finished workpieces or to change tooling, setup, or workpiece placement, according to required machining sequences.	0.70	0.09	0.39
9	Move machine controls to lower tools to workpieces and to engage automatic feeds.	0.70	0.09	0.39
9	Immerse workpieces in coating solutions or liquid metal or plastic for specified times.	0.69	0.09	0.39
6	Push racks or carts to transfer products to storage, cooling stations, or the next stage of processing.	0.64	0.14	0.39
9	Fill processing or cooking containers, such as kettles, rotating cookers, pressure cookers, or vats, with ingredients, by opening valves, by starting pumps or injectors, or by hand.	0.64	0.14	0.39
3	Inspect or measure finished workpieces to determine conformance to specifications, using measuring instruments, such as gauges or micrometers.	0.68	0.09	0.38
10	Select and measure or weigh ingredients, using English or metric measures and balance scales.	0.63	0.14	0.38
6	Operate refining machines to reduce the particle size of cooked batches.	0.63	0.14	0.38
9	Smooth soldered joints and rough spots, using hand files and emery paper, and polish smoothed areas with polishing wheels or buffing wire.	0.72	0.05	0.38

5	Set up, operate, and tend equipment that cooks, mixes, blends, or processes ingredients in the manufacturing of food products, according to formulas or recipes.	0.63	0.14	0.38
9	Observe gauges and thermometers to determine if the mixing chamber temperature is within specified limits, and turn valves to control the temperature.	0.62	0.14	0.38
6	Expose workpieces to acid to develop etch patterns such as designs, lettering, or figures.	0.71	0.05	0.38
9	Weigh or measure products, using scale hoppers or scale conveyors.	0.62	0.14	0.38
10	Observe temperature, humidity, pressure gauges, and product samples and adjust controls, such as thermostats and valves, to maintain prescribed operating conditions for specific stages.	0.61	0.14	0.37
9	Adjust depths and sizes of cuts by adjusting heights of worktables, or by adjusting machine-arm gauges.	0.70	0.05	0.37
10	Follow recipes to produce food products of specified flavor, texture, clarity, bouquet, or color.	0.61	0.14	0.37
3	Record production and test data for each food product batch, such as the ingredients used, temperature, test results, and time cycle.	0.61	0.14	0.37
4	Test products for moisture content, using moisture meters.	0.61	0.14	0.37
9	Mix or blend ingredients, according to recipes, using a paddle or an agitator, or by controlling vats that heat and mix ingredients.	0.61	0.14	0.37
9	Give directions to other workers who are assisting in the batchmaking process.	0.60	0.14	0.37
9	Operate or tend equipment that roasts, bakes, dries, or cures food items such as cocoa and coffee beans, grains, nuts, and bakery products.	0.60	0.14	0.37
3	Determine machine settings, and move bars or levers to reproduce designs on rollers or plates.	0.69	0.05	0.37
9	Press buttons, pull levers, or depress pedals to start and operate cutting and slicing machines.	0.69	0.04	0.37
10	Monitor machine cycles and mill operation to detect jamming and to ensure that products conform to specifications.	0.67	0.07	0.37
3	Adjust dials to regulate flow of current and voltage supplied to terminals to control plating processes.	0.65	0.09	0.37
6	Trim excess material or cut threads off finished products, such as cutting loose ends of plastic off a manufactured toy for a smoother finish.	0.69	0.04	0.36
9	Grade food products according to government regulations or according to type, color, bouquet, and moisture content.	0.59	0.14	0.36
10	Observe gauges, dials, and product characteristics, and adjust controls to maintain appropriate temperature, pressure, and flow of ingredients.	0.59	0.14	0.36
4	Tend or operate and control equipment, such as kettles, cookers, vats and tanks, and boilers, to cook ingredients or prepare products for further processing.	0.59	0.14	0.36
12	Press switches and turn knobs to start, adjust, and regulate equipment, such as beaters, extruders, discharge pipes, and salt pumps.	0.59	0.14	0.36
6	Inspect and pack the final product.	0.59	0.14	0.36
9	Observe and listen to equipment to detect possible malfunctions, such as leaks or plugging, and report malfunctions or undesirable tastes to supervisors.	0.59	0.14	0.36
3	Remove objects from solutions at periodic intervals and observe objects to verify conformance to specifications.	0.63	0.09	0.36
4	Develop detailed design drawings and specifications for mechanical equipment, dies, tools, and controls, using computer-assisted drafting (CAD) equipment.	0.69	0.03	0.36

7	Set up, operate, or tend plating or coating machines to coat metal or plastic products with chromium, zinc, copper, cadmium, nickel, or other metal to protect or decorate surfaces.	0.63	0.09	0.36
10	Remove completed workpieces and place them in trays.	0.67	0.05	0.36
6	Load parts into containers and place containers on conveyors to be inserted into furnaces, or insert parts into furnaces.	0.65	0.07	0.36
9	Monitor equipment operation, gauges, and panel lights to detect deviations from standards.	0.67	0.04	0.35
3	Inspect materials and products for defects, and to ensure conformance to specifications.	0.62	0.09	0.35
10	Observe flow of materials and listen for machine malfunctions, such as jamming or spillage, and notify supervisors if corrective actions fail.	0.57	0.14	0.35
3	Observe continuous operation of automatic machines to ensure that products meet specifications and to detect jams or malfunctions, making adjustments as necessary.	0.62	0.09	0.35
3	Test food product samples for moisture content, acidity level, specific gravity, or butter-fat content, and continue processing until desired levels are reached.	0.57	0.14	0.35
3	Adjust and correct machine set-ups to reduce thicknesses, reshape products, and eliminate product defects.	0.64	0.07	0.35
3	Fill or remove product from trays, carts, hoppers, or equipment, using scoops, peels, or shovels, or by hand.	0.57	0.14	0.35
9	Mark identification numbers, trademarks, grades, marketing data, sizes, or model numbers on products.	0.65	0.04	0.35
3	Raise and shape clay into wares, such as vases and pitchers, on revolving wheels, using hands, fingers, and thumbs.	0.62	0.08	0.35
9	Operate valves, pumps, engines, or generators to control and adjust biofuels production.	0.65	0.04	0.35
6	Machine parts to specifications, using machine tools, such as lathes, milling machines, shapers, or grinders.	0.67	0.02	0.35
9	Open valves, gates, or chutes or use shovels to load or remove products from ovens or other equipment.	0.56	0.14	0.35
4	Start operation of rolling and milling machines to flatten, temper, form, and reduce sheet metal sections and to produce steel strips.	0.63	0.07	0.35
6	Start engines of hoists or winches and use levers and pedals to wind or unwind cable on drums.	0.65	0.04	0.34
10	Unroll, lay out, attach, or mount materials or items on cutting tables or machines.	0.64	0.04	0.34
4	Remove completed materials or products from cutting or slicing machines, and stack or store them for additional processing.	0.64	0.04	0.34
4	Spray coating in specified patterns according to instructions.	0.60	0.09	0.34
10	Examine, inspect, and measure raw materials and finished products to verify conformance to specifications.	0.62	0.07	0.34
6	Rinse coated objects in cleansing liquids and dry them with cloths, centrifugal driers, or by tumbling in sawdust-filled barrels.	0.59	0.09	0.34
11	Collect biofuels samples and perform routine laboratory tests or analyses to assess biofuels quality.	0.64	0.04	0.34
3	Listen to machines during operation to detect sounds such as those made by dull cutting tools or excessive vibration, and adjust machines to compensate for problems.	0.59	0.09	0.34
3	Examine, feel, and taste product samples during production to evaluate quality, color, texture, flavor, and bouquet, and document the results.	0.54	0.14	0.34
9	Fasten, package, or stack materials and products, using hand tools and fastening equipment.	0.59	0.09	0.34
6	Press thumbs into centers of revolving clay to form hollows, and press on the inside and outside of emerging clay	0.60	0.08	0.34

	cylinders with hands and fingers, gradually raising and shaping clay to desired forms and sizes.			
9	Determine mixing sequences, based on knowledge of temperature effects and of the solubility of specific ingredients.	0.54	0.14	0.34
3	Move controls to drive gasoline- or electric-powered trucks, cars, or tractors and transport materials between loading, processing, and storage areas.	0.64	0.04	0.34
12	Use computer software to design patterns for engraving.	0.63	0.05	0.34
10	Set reduction scales to attain specified sizes of reproduction on workpieces, and set pantograph controls for required heights, depths, and widths of cuts.	0.63	0.05	0.34
10	Set up, operate, or tend presses and forging machines to perform hot or cold forging by flattening, straightening, bending, cutting, piercing, or other operations to taper, shape, or form metal.	0.59	0.09	0.34
4	Start presses and pull proofs to check for ink coverage and density, alignment, and registration.	0.65	0.02	0.34
9	Inspect coated or plated areas for defects, such as air bubbles or uneven coverage.	0.58	0.09	0.34
10	Lift workpieces to machines manually or with hoists or cranes.	0.58	0.09	0.34
12	Measure workpieces and lay out work, using precision measuring devices.	0.58	0.09	0.33
10	Adjust machine controls and change tool settings to keep dimensions within specified tolerances.	0.58	0.09	0.33
3	Monitor batch, continuous flow, or hybrid biofuels production processes.	0.62	0.04	0.33
3	Cool food product batches on slabs or in water-cooled kettles.	0.53	0.14	0.33
2	Set oven temperatures, and place items into hot ovens for baking.	0.60	0.06	0.33
9	Collect and inspect random samples during print runs to identify any necessary adjustments.	0.64	0.02	0.33
5	Feed stock into cutting machines, onto conveyors, or under cutting blades, by threading, guiding, pushing, or turning handwheels.	0.62	0.04	0.33
3	Move levers, pedals, and throttles to stop, start, and regulate speeds of hoist or winch drums in response to hand, bell, buzzer, telephone, loud-speaker, or whistle signals, or by observing dial indicators or cable marks.	0.62	0.04	0.33
3	Sew, join, reinforce, or finish parts of articles, such as garments, books, mattresses, toys, and wigs, using needles and thread or other materials.	0.62	0.04	0.33
10	Inspect workpieces for defects, and measure workpieces to determine accuracy of machine operation, using rules, templates, or other measuring instruments.	0.57	0.09	0.33
9	Immerse objects to be coated or plated into cleaning solutions, or spray objects with conductive solutions to prepare them for plating.	0.57	0.09	0.33
9	Read production schedules and work orders to determine processing sequences, furnace temperatures, and heat cycle requirements for objects to be heat-treated.	0.59	0.07	0.33
10	Thread or feed sheets or rods through rolling mechanisms, or start and control mechanisms that automatically feed steel into rollers.	0.59	0.07	0.33
11	Calculate dimensions or tolerances, using instruments, such as micrometers or vernier calipers.	0.64	0.02	0.33
2	Operate auxiliary machines and equipment, such as grinders, canners, and molding presses, to prepare or further process products.	0.52	0.14	0.33

6	Move levers, depress foot pedals, or turn dials to operate cranes, cherry pickers, electromagnets, or other moving equipment for lifting, moving, or placing loads.	0.59	0.06	0.33
1	Select thread, twine, cord, or yarn to be used, and thread needles.	0.61	0.04	0.33
6	Observe machine operations to detect any problems, making necessary adjustments to correct problems.	0.57	0.09	0.33
10	Inspect sample workpieces to verify conformance with specifications, using instruments such as gauges, micrometers, and dial indicators.	0.57	0.09	0.33
4	Inspect vats after cleaning to ensure that fermentable residue has been removed.	0.52	0.14	0.33
10	Examine, measure, and weigh materials or products to verify conformance to specifications, using measuring devices, such as rulers, micrometers, or scales.	0.61	0.04	0.33
3	Pour and regulate the flow of molten metal into molds and forms to produce ingots or other castings, using ladles or hand-controlled mechanisms.	0.58	0.07	0.33
1	Lift upper mold sections from lower sections, and remove molded patterns.	0.56	0.09	0.32
10	Smooth out products in bins, pans, trays, or conveyors, using rakes or shovels.	0.51	0.14	0.32
9	Move levers or controls that operate lifting devices, such as forklifts, lift beams with swivel-hooks, hoists, or elevating platforms, to load, unload, transport, or stack material.	0.61	0.04	0.32
9	Pull wires through bases of articles and wheels to separate finished pieces.	0.56	0.08	0.32
9	Check to ensure that workpieces are properly lubricated and cooled during machine operation.	0.56	0.09	0.32
3	Smooth seams with heated irons, flat bones, or rubbing sticks.	0.60	0.04	0.32
3	Clear or dislodge blockages in bins, screens, or other equipment, using poles, brushes, or mallets.	0.51	0.14	0.32
3	Turn cranks or press buttons to activate winches that move cars under sawing cables or saw frames.	0.59	0.04	0.32
9	Measure or weigh ingredients, using scales or measuring containers.	0.50	0.14	0.32
9	Move pieces from wheels so that they can dry.	0.56	0.08	0.32
6	Move stock or scrap to and from machines manually, or by using carts, handtrucks, or lift trucks.	0.59	0.04	0.32
9	Weigh or measure materials or products to ensure conformance to specifications.	0.55	0.09	0.32
1	Observe machine operation to detect workpiece defects or machine malfunctions, adjusting machines as necessary.	0.55	0.09	0.32
6	Observe drilling or boring machine operations to detect any problems.	0.55	0.09	0.32
3	Activate machine start-up switches to grind, lap, hone, debar, shear, or cut workpieces, according to specifications.	0.55	0.09	0.32
10	Operate compressed air, diesel, electric, gasoline, or steam-driven hoists or winches to control movement of cableways, cages, derricks, draglines, loaders, railcars, or skips.	0.59	0.04	0.32
4	Observe gauges to ensure that machines are operating properly, making adjustments or stopping machines when problems occur.	0.54	0.09	0.31
4	Record production and operational data, such as amount of materials processed.	0.54	0.09	0.31
3	Reel extruded products into rolls of specified lengths and weights.	0.54	0.09	0.31
9	Make repairs, such as enlarging or reducing ring sizes, soldering pieces of jewelry together, and replacing broken clasps and mountings.	0.58	0.05	0.31
4	Monitor and record biofuels processing data.	0.58	0.04	0.31

10	Inspect etched work for depth of etching, uniformity, and defects, using calibrated microscopes, gauges, fingers, or magnifying lenses.	0.58	0.05	0.31
10	Operate safety equipment and use safe work habits.	0.54	0.09	0.31
3	Operate ovens or furnaces to bake cores or to melt, skim, and flux metal.	0.54	0.09	0.31
6	Remove materials and products from machines and equipment, and place them in boxes, trucks or conveyors, using hand tools and moving devices.	0.53	0.09	0.31
12	Fit and align fabricated parts to be welded or assembled.	0.57	0.04	0.31
3	Adjust controls to maintain temperatures and heating times, using thermal instruments and charts, dials and gauges of furnaces, and color of stock in furnaces to make setting determinations.	0.55	0.07	0.31
6	Load, unload, or adjust materials or products on conveyors by hand, by using lifts, hoists, and scoops, or by opening gates, chutes, or hoppers.	0.53	0.09	0.31
3	Read temperature gauges and observe color changes, adjusting furnace flames, torches, or electrical heating units as necessary to melt metal to specifications.	0.55	0.07	0.31
9	Lay out and mark areas of parts to be shot peened and fill hoppers with shot.	0.53	0.09	0.31
3	Weigh or measure materials, ingredients, or products to ensure conformance to requirements.	0.57	0.04	0.31
4	Press and adjust controls to activate, set, and regulate equipment according to specifications.	0.57	0.04	0.31
6	Measure and inspect machined parts to ensure conformance to product specifications.	0.53	0.09	0.31
9	Suspend objects, such as parts or molds from cathode rods, or negative terminals, and immerse objects in plating solutions.	0.53	0.09	0.31
3	Set up and operate computer-controlled machines or robots to perform one or more machine functions on metal or plastic workpieces.	0.53	0.09	0.31
1	Set up, operate, or tend grinding and related tools that remove excess material or burrs from surfaces, sharpen edges or corners, or buff, hone, or polish metal or plastic workpieces.	0.52	0.09	0.31
10	Measure completed workpieces to verify conformance to specifications, using micrometers, gauges, calipers, templates, or rulers.	0.52	0.09	0.31
10	Examine completed workpieces for defects, such as chipped edges or marred surfaces and sort defective pieces according to types of flaws.	0.52	0.09	0.30
5	Position and feed materials into processing machines, by hand or by using automated equipment.	0.52	0.09	0.30
6	Position and move metal wires or workpieces through a series of dies that compress and shape stock to form die impressions.	0.52	0.09	0.30
9	Guide stylus over template, causing cutting tool to duplicate design or letters on workpiece.	0.56	0.05	0.30
6	Stack or load finished items, or place items on conveyor systems.	0.52	0.09	0.30
1	Prepare workpieces for etching or engraving by cutting, sanding, cleaning, polishing, or treating them with wax, acid resist, lime, etching powder, or light-sensitive enamel.	0.56	0.05	0.30
6	Position lifting devices under, over, or around loaded pallets, skids, or boxes and secure material or products for transport to designated areas.	0.57	0.04	0.30
10	Observe color of products being baked, and adjust oven temperatures, humidity, or conveyor speeds accordingly.	0.55	0.06	0.30

1	Attach identification labels to finished packaged items, or cut stencils and stencil information on containers, such as lot numbers or shipping destinations.	0.56	0.04	0.30
6	Read rolling orders, blueprints, and mill schedules to determine setup specifications, work sequences, product dimensions, and installation procedures.	0.54	0.07	0.30
9	Perform sheet metal work necessary for solar panel installations.	0.51	0.10	0.30
12	Brush or spray mold surfaces with parting agents or insert paper into molds to ensure smoothness and prevent sticking or seepage.	0.52	0.09	0.30
12	Set up, operate, or tend machines that cut or slice materials, such as glass, stone, cork, rubber, tobacco, food, paper, or insulating material.	0.56	0.04	0.30
9	Sprinkle or spray parting agents onto patterns and mold sections to facilitate removal of patterns from molds.	0.52	0.09	0.30
9	Load materials and products into machines and equipment, or onto conveyors, using hand tools and moving devices.	0.52	0.09	0.30
9	Study machining instructions, job orders, or blueprints to determine dimensional or finish specifications, sequences of operations, setups, or tooling requirements.	0.52	0.09	0.30
3	Monitor machine operation and control panel displays, and compare readings to specifications to detect malfunctions.	0.51	0.09	0.30
9	Stack finished packaged items, or wrap protective material around each item, and pack the items in cartons or containers.	0.55	0.04	0.30
6	Record times that parts are removed from furnaces to document that objects have attained specified temperatures for specified times.	0.53	0.07	0.30
3	Monitor automated press operation systems and respond to fault, error, or alert messages.	0.57	0.02	0.30
3	Study blueprints, drawings, and sketches to determine material dimensions, required equipment, and operations sequences.	0.55	0.04	0.30
10	Maintain production records.	0.51	0.09	0.30
3	Operate equipment, such as a centrifuge, to extract biofuels products and secondary by-products or reusable fractions.	0.55	0.04	0.30
12	Push dual control buttons and move controls to start, stop, or adjust machinery and equipment.	0.51	0.09	0.30
1	Establish zero reference points on workpieces, such as at the intersections of two edges or over hole locations.	0.51	0.09	0.30
6	Apply hand or foot brakes and move levers to lock hoists or winches.	0.56	0.04	0.30
4	Draft detail and assembly drawings of design components, circuitry or printed circuit boards, using computer-assisted equipment or standard drafting techniques and devices.	0.56	0.03	0.30
3	Adjust ink fountain flow rates.	0.57	0.02	0.30
5	Monitor and record flow meter performance.	0.55	0.04	0.30
4	Record temperatures, amounts of materials processed, or test results on report forms.	0.52	0.07	0.29
5	Select, install, and adjust alignment of drills, cutters, dies, guides, and holding devices, using templates, measuring instruments, and hand tools.	0.50	0.09	0.29
9	Melt or refine metal before casting, calculating required temperatures, and observe metal color, adjusting controls as necessary to maintain required temperatures.	0.54	0.04	0.29
2	Review work orders, blueprints, specifications, or job samples to determine components, settings, and adjustments for cutting and slicing machines.	0.54	0.04	0.29
10	Examine job orders to determine quantities to be printed, stock specifications, colors, or special printing instructions.	0.56	0.02	0.29

3	Manipulate controls and observe dial indicators to monitor, adjust, and regulate speeds of machine mechanisms.	0.52	0.07	0.29
10	Measure and compute dimensions of lettering, designs, or patterns to be engraved.	0.54	0.05	0.29
7	Remove products from equipment, manually or using hoists, and prepare them for storage, shipment, or additional processing.	0.54	0.04	0.29
8	Observe operation of equipment to ensure continuity of flow, safety, and efficient operation, and to detect malfunctions.	0.52	0.07	0.29
10	Sort, grade, weigh, and inspect products, verifying and adjusting product weight or measurement to meet specifications.	0.54	0.04	0.29
10	Observe production or monitor equipment to ensure safe and efficient operation.	0.54	0.04	0.29
3	Monitor and inspect equipment, computer terminals, switches, valves, gauges, alarms, safety devices, and meters to detect leaks or malfunctions and to ensure that equipment is operating efficiently and safely.	0.52	0.07	0.29
3	Operate or tend machines to mix or blend any of a wide variety of materials, such as spices, dough batter, tobacco, fruit juices, chemicals, livestock feed, food products, color pigments, or explosive ingredients.	0.54	0.04	0.29
10	Measure, examine, or test completed units to check for defects and ensure conformance to specifications, using precision instruments, such as micrometers.	0.56	0.02	0.29
10	Reduce heat when processing is complete to allow parts to cool in furnaces or machinery.	0.52	0.07	0.29
3	Monitor the feed and speed of machines during the machining process.	0.56	0.02	0.29
9	Examine parts to ensure metal shades and colors conform to specifications, using knowledge of metal heat-treating.	0.51	0.07	0.29
6	Dump or pour specified amounts of materials into machinery or equipment.	0.53	0.04	0.29
7	Spray chopped fiberglass, resins, and catalysts onto prepared molds or dies using pneumatic spray guns with chopper attachments.	0.53	0.04	0.29
3	Examine sketches, diagrams, samples, blueprints, or photographs to decide how designs are to be etched, cut, or engraved onto workpieces.	0.53	0.05	0.29
1	Fold or shape materials before or after cutting them.	0.53	0.04	0.29
3	Observe actions of cutting tools through microscopes and adjust stylus movement to ensure accurate reproduction.	0.52	0.05	0.29
9	Maintain production records, such as quantities, types, and dimensions of materials produced.	0.53	0.04	0.28
8	Mark curves, lines, holes, dimensions, and welding symbols onto workpieces, using scribes, soapstones, punches, and hand drills.	0.52	0.04	0.28
2	Observe machine operations to ensure quality and conformity of filled or packaged products to standards.	0.52	0.04	0.28
10	Examine materials, ingredients, or products, visually or with hands, to ensure conformance to established standards.	0.50	0.07	0.28
6	Monitor operation of cutting or slicing machines to detect malfunctions or to determine whether supplies need replenishment.	0.52	0.04	0.28
10	Remove defective or substandard materials from machines, and readjust machine components so that products meet standards.	0.52	0.04	0.28
9	Set up and operate machine tools, such as milling machines, lathes, drill presses, and grinders, to machine castings or patterns.	0.51	0.04	0.28
3	Sandblast exposed areas of glass to cut designs in surfaces, using spray guns.	0.51	0.05	0.28

9	Produce three-dimensional models, using computer-aided design (CAD) software.	0.53	0.03	0.28
3	Inspect and test products to verify conformance to specifications, using precision measuring instruments or circuit testers.	0.51	0.04	0.28
1	Position stones and metal pieces, and set, mount, and secure items in place, using setting and hand tools.	0.51	0.05	0.28
3	Feed paper through press cylinders and adjust feed and tension controls.	0.53	0.02	0.28
2	Record production information such as fabric yardage processed, temperature readings, fabric tensions, and machine speeds.	0.51	0.04	0.28
3	Mix or blend ingredients by starting machines and mixing for specified times.	0.51	0.04	0.28
2	Clean and polish metal items and jewelry pieces, using jewelers' tools, polishing wheels, and chemical baths.	0.50	0.05	0.27
3	Tend spinning frames that draw out and twist roving or sliver into yarn.	0.50	0.04	0.27
3	Observe machine operations, control boards, and gauges to detect malfunctions such as clogged bushings and defective binder applicators.	0.50	0.04	0.27
3	Manually or mechanically load or unload materials from pallets, skids, platforms, cars, lifting devices, or other transport vehicles.	0.51	0.04	0.27
3	Record operational or production data on specified forms.	0.50	0.04	0.27
10	Position or align components for assembly, manually or using hoists.	0.53	0.01	0.27
10	Observe equipment gauges and indicators and hand signals of other workers to verify load positions or depths.	0.50	0.04	0.27
1	Select loads or materials according to weight and size specifications.	0.50	0.04	0.27
1	Purchase, for further processing or for resale, farm products, such as milk, grains, or Christmas trees.	0.51	0.03	0.27
9	Obtain customers' names, addresses, and billing information, product numbers, and specifications of items to be purchased, and enter this information on order forms.	0.50	0.03	0.27
3	Load presses with paper and make necessary adjustments, according to paper size.	0.51	0.02	0.27
3	Fasten or install piping, fixtures, or wiring and electrical components to form assemblies or subassemblies, using hand tools, rivet guns, or welding equipment.	0.52	0.01	0.27
10	Prepare purchase orders, solicit bid proposals, and review requisitions for goods and services.	0.50	0.03	0.26

Source: The Conference Board of Canada's Analysis Based on O*NET and Statistics Canada Data.

Note: Automation potential is given in decimal format for the calculation of average value.

Table 4
Task Categories Provided in Table 3

Task Category	Category Description
1	Assembly and Installation
2	Cleaning and Maintenance
3	Machine Operation, Adjustment, Maintenance
4	Recording, Documentation and Reporting
5	Equipment Operation and Setup
6	Material Handling
7	Planning and Scheduling
8	Procurement and Customer Service
9	Production Operations
10	Quality Control, Inspection, Assurance
11	Testing and Analysis
12	Weighing and Measurement

Source: The Conference Board of Canada's Analysis Based on O*NET Data.

Table 5
Estimated Training Length for Technology Skills Corresponding to Highly Automatable Manufacturing Tasks Vary

Technology Skill	Example of Technology	Status
Enterprise resource planning (ERM)	Microsoft Dynamics	Established
Facilities management software	InnQuest Software roomMaster	Established
Inventory management software	Oracle NetSuite	Established
Computer aided design (CAD) software	Autodesk AutoCAD	Established
Computer aided manufacturing (CAM) software	Dassault Systems SolidWorks	Established
Materials requirements planning logistics and supply chain software	LSA Visual Easy Lean	Established
Compliance software	Pilgrim Quality Solutions SmartSolve	Established
Batch processing & batch management	Rockwell FactoryTalk Batch	Emerging
Procurement software	Ariba Spend Management Suite	Established
Process mapping and design software	Microsoft Visio	Emerging
Track and trace	Epicor Traceability	Emerging
Manufacturing execution system (MES)	Wonderware MES	Emerging
Manufacturing operations management (MOM)	Siemens SIMATIC IT	Emerging
Overall equipment effectiveness (OEE)	GE Digital Proficy	Emerging
Computerized maintenance management system (CMMS)	SAP Plant Maintenance	Emerging
Predictive maintenance	GE Digital Predix APM	Emerging
Quality management software (QMS)	SAP Quality Management	Emerging
Warehouse management systems (WMS)	Oracle Warehouse Management (WMS)	Emerging
Automated storage and retrieval system (ASRS)	Honeywell Intelligrated	Emerging
Distributed control system (DCS)	Rockwell Automation - PlantPAx	Emerging

Industrial control software	Supervisory control and data acquisition SCADA software	Emerging
Human machine interface (HMI)	GE Digital iFIX	Emerging
Programmable logical controller (PLC)	Allen-Bradley RSLogix / Studio 5000	Emerging
Programmable automation controller (PAC)	Siemens TIA Portal	Emerging
Measurement and analytics	Rockwell FactoryTalk Analytics	Emerging
Preventative maintenance	eMaint CMMS	Emerging
Simulation and analysis	Digital twin	Emerging
Safety solutions	Environmental, Health, and Safety (EHS) Management Software	Emerging

Source: The Conference Board of Canada's Analysis Based on O*NET Data; Expert Consultation.

Focused Interviews

We conducted 10 interviews to develop a basic, but rich assessment of the state of the local manufacturing sector in terms of its deployment of robotics equipment and automation tools in support roles (material handling, machine tending, quality inspection, welding, etc.).

Through this primary data collection, we collected information related to three topics in particular: 1) Local manufacturers' assessment of the extent of usage of automation technologies in their plants (relative to other manufacturing firms in Canada and abroad), 2) The identification of barriers local firms face in terms of introducing automated machinery into their operations, 3) Their approach to retraining their workers on the use of robotics equipment and automation tools. As part of #2, we probed why Lethbridge manufacturers are not taking steps to introduce additional automation to their facility (if that is identified so during the interview).

The Interview Guide

The Conference Board of Canada
The Conference Board of Canada is the country's leading independent, not-for-profit applied research institute. We provide governments, businesses, and other organizations with highly relevant, balanced, and independent analyses of emerging policy and management issues. The Conference Board researches innovative practices, designs new strategies, and provides leaders with the most up-to-date information, analysis, and expertise to help them excel in Canada and around the world.

About This Project
This research will inform economic development policy and programs on Industry 4.0 workforce requirements in the Lethbridge Census Metropolitan Area. Specifically, it will:

- Identify the range of manufacturing tasks that can be automated, and skills associated with performing those tasks.

- Synthesize practical evidence as to structure, duration, and success of different training programs in upskilling/reskilling.

- Identify the current state of Lethbridge’s manufacturing workforce and identify ways to make it more resilient and able to make use of productivity-enhancing technologies such as robotics equipment and automation tools.

- Systematically document what regional employers are doing to address existing talent challenges and other barriers in the adoption of productivity-enhancing technologies.

- Determine time length required to teach a worker using a new equipment, trouble shooting potential problems, and fixing machinery issues.

- Provide recommendations to facilitate the transition of Lethbridge manufacturing workforce for Industry 4.0.

About the Consultation
We are conducting 8-10 interviews with large manufacturing companies in the Lethbridge area to develop a basic, but rich assessment of the state of the local manufacturing sector in terms of its deployment of robotics equipment and automation tools in support roles (material handling, machine tending, quality inspection, welding, etc.). We are focusing on uncovering information related to four topics in particular:

1. Local manufacturers’ assessment of the extent of usage of automation technologies in their plants (relative to industry competitors and other manufacturing firms in Canada and abroad)
2. The identification of barriers local firms face when introducing automated machinery into their operations.
3. Their approach to retraining their workers on the use of robotics equipment and automation tools.
4. Local manufacturers perspectives about how robotics equipment and automation tools can help overcome challenges related to job vacancies and employee turnover.

The consultation will take approximately 30 – 60 minutes to complete over Microsoft Teams. With your permission, we will record, transcribe, and use the interview data with qualitative data analysis software to increase the robustness of the results. We will not use any direct quotes from participants unless we get their explicit permission.

Questions
Context

1. Could you briefly describe the work carried out by your organization and your role within it?

2. Are there any unique challenges or advantages related to operating in Lethbridge that may affect your approach to deploying automation technologies or robotics equipment in your facility?

3. Have you had challenges in maintaining staffing levels or hiring suitable workers? If so, has this disrupted your business or caused challenges that have had a material impact on your bottom line?

Tasks and Technology

4. Can you briefly describe the current level of automation and robotics deployment in your manufacturing facility?

5. Are there specific operational tasks your firm is seeking to automate through the usage of robotic automation technologies? If so, what are they?

6. How does your facility's usage of automation technologies compare to other manufacturing firms in your industry in Canada and abroad, in your opinion?

7. Are there any specific automation technologies or robotics solutions that you are considering implementing in the near future? If so, which ones

8. How is your facility using automation technologies and robotic solutions to enhance productivity throughout operational manufacturing tasks?

9. What do you believe are the key factors for successfully integrating automation technologies and robotics equipment into a manufacturing facility?

10. When considering automation technologies or robotics equipment, how do you evaluate the return on investment (ROI) and expected payback time?

Barriers to Automation

11. What barriers do you face in introducing automated machinery into your operations?

Workforce Training

12. Have you encountered any workforce challenges when trying to introduce new automation solutions or robotics equipment? If so, can you provide examples?

13. How do you currently approach worker training for using robotics equipment and automation tools in your facility? For example, do you have systematic in-house training?

14. What specific skills or qualifications are necessary for your employees to effectively operate and maintain the automation technologies and robotics equipment in your facility?

15. What type of support, if any, do you receive from external partners or government programs for automation adoption and workforce training?

16. Are there local external training options you are aware of that can be of assistance when training staff?

Wrap-up

17. Are there any other topics we may have missed?

18. Could you recommend other individuals we should interview for this research?

Thank you very much for sharing your time and perspectives.

Where insights meet impact