Journal of Rural and Community Development

Understanding Advanced Manufacturing in Rural Places: A Proposed Spectrum And Assessment Tool

Authors: Jonnah Ronquillo, Sarah-Patricia Breen, Tracey Harvey, Melanie Fontaine, & Kathleen Ayre

Citation:
Ronquillo, J., Breen, S. – P., Harvey, T., Fontaine, M., & Ayre, K. (2024). Understanding advanced manufacturing in rural places: A proposed spectrum and assessment tool. *The Journal of Rural and Community Development*, *19*(1), 87–112.

Publisher:
Rural Development Institute, Brandon University.

Editor:
Dr. Doug Ramsey

ISSN: 1712-8277 © Authors
www.jrcd.ca

Understanding Advanced Manufacturing In Rural Places: A Proposed Spectrum and Assessment Tool

Jonnah Ronquillo
Selkirk College
Castlegar, British Columbia, Canada
jronquillo@selkirk.ca

Sarah-Patricia Breen
University of Saskatchewan
Saskatoon, Saskatchewan, Canada
sbreen@selkirk.ca

Tracey Harvey
Selkirk College
Castlegar, British Columbia, Canada
tharvey@selkirk.ca

Melanie Fontaine
Selkirk College
Castlegar, British Columbia, Canada
melanie@kast.com

Kathleen Ayre
Kootenay Association for Science and Technology
Nelson, British Columbia, Canada
kathleen@kast.com

Abstract

Advanced manufacturing—a range of innovative, integrated, and controlled technological processes aimed at enhancing efficiency and optimizing outcomes—offers opportunities for rural economic development. However, the presence of advanced manufacturing and its related opportunities are not well understood in rural Canada, particularly at the local level. As part of a project exploring advanced manufacturing in the rural Kootenay region of British Columbia, researchers identified the need for a nuanced and rurally inclusive definition of advanced manufacturing and an accompanying assessment to assist in better understanding needs and opportunities. This article summarizes the case study and proposes the 'advanced manufacturing spectrum', a model illustrating and defining advanced manufacturing, with an accompanying assessment tool that aims to assist users to identify themselves within the advanced manufacturing sector and to better understand the current state of advanced manufacturing and potential for advancement. The application of the assessment tool to the case study demonstrates the potential of the spectrum as a diagnostic and planning tool, able to reveal place-based challenges and opportunities and to enable targeted action. However, given the range of rural contexts, we acknowledge potential limitations in the transferability of the spectrum and assessment tool. The purpose of this article is to share the proposed advanced manufacturing spectrum model for further discussion,

testing, and refinement based on its application in other rural regions. We invite further testing of the proposed spectrum and assessment tool to better understand the size and scope of current advanced manufacturing activities across rural places, and to share observations and lessons around the transferability of the spectrum. This article highlights the complex dynamics between government policies, local capacities, and entrepreneurial initiatives in the context of rural development, offering valuable considerations for policymakers and researchers interested in advancing manufacturing.

Keywords: manufacturing; advanced manufacturing; innovation; technology; rural economic development; economic diversification

Comprendre la fabrication de pointe dans les zones rurales : une proposition d'outil d'évaluation et de spectre

Résumé

La fabrication de pointe – une gamme de processus technologiques innovants, intégrés et contrôlés visant à améliorer l'efficacité et à optimiser les résultats – offre des opportunités pour le développement économique rural. Cependant, la présence du secteur manufacturier de pointe et les opportunités qui en découlent ne sont pas bien comprises dans les régions rurales du Canada, en particulier au niveau local. Dans le cadre d'un projet explorant la fabrication de pointe dans la région rurale de Kootenay en Colombie-Britannique, les chercheurs ont identifié la nécessité d'une définition nuancée et inclusive de la fabrication de pointe et d'une évaluation connexe pour aider à mieux comprendre les besoins et les opportunités. Cet article résume l'étude de cas et propose le « spectre de la fabrication de pointe », un modèle illustrant et définissant la fabrication de pointe, accompagné d'un outil d'évaluation visant à aider les utilisateurs à s'identifier au sein du secteur de la fabrication de pointe et à mieux comprendre l'état actuel de la fabrication de pointe. L'application de l'outil d'évaluation à l'étude de cas démontre le potentiel du spectre en tant qu'outil de diagnostic et de planification, capable de révéler les défis et les opportunités locaux et de permettre une action ciblée. Cependant, compte tenu de la diversité des contextes ruraux, nous reconnaissons les limites potentielles de la transférabilité du spectre et de l'outil d'évaluation. Le but de cet article est de partager le modèle de spectre de fabrication de pointe proposé pour des discussions, des tests et un perfectionnement plus approfondis en fonction de son application dans d'autres régions rurales. Nous invitons à tester davantage le spectre proposé et l'outil d'évaluation afin de mieux comprendre la taille et la portée des activités actuelles de fabrication de pointe dans les zones rurales, et de partager des observations et des enseignements sur la transférabilité du spectre. Cet article met en évidence la dynamique complexe entre les politiques gouvernementales, les capacités locales et les initiatives entrepreneuriales dans le contexte du développement rural, offrant des considérations précieuses aux décideurs politiques et aux chercheurs intéressés par le progrès de l'industrie manufacturière.

Mots-clés : fabrication ; fabrication de pointe; innovation; technologie; développement économique rural; diversification économique

1.0 Introduction

Manufacturing is an important sector in rural Canada. Currently, an estimated 11% of rural (population <1,000) and small town (population 1,000–10,000) employment is in manufacturing, higher than the national average of 9% (Statistics Canada, 2023b). Historically, much of Canada's manufacturing sector has related to natural resources (Beshiri, 2010). Particularly in rural places, manufacturing—where it exists—has often been primary manufacturing, an extension of natural resource extraction (e.g., forestry, mining, fishing), dominated by a small number of firms (Barnes et al., 2001; Hayter & Barnes, 1990; Innis, 1930). In the province of British Columbia (BC), natural resources have been the historic engine of economic growth (Hayter & Barnes, 1990). The importance of natural resources to manufacturing in BC continues today. While BC has seen an increase in the range of manufacturing sub-sectors, the top five manufacturing sub-sectors as measured by contributions to Gross Domestic Product and employment remain linked to natural resources: (a) wood products, (b) food, (c) primary metal, (d) paper, and (e) machinery (Government of British Columbia, 2018).

Traditional manufacturing is defined as the process of transforming raw materials into new or finished products using manual or mechanical techniques (Columbia Basin Rural Development Institute, 2017; Katina et al., 2023). Traditional manufacturing is in contrast to advanced manufacturing, where there is growing attention and discourse (NGen, 2022). While there is no single definition of advanced manufacturing, or indeed consensus on the term (advanced, high-tech, etc.), advanced manufacturing encompasses a wide range of innovative, integrated, efficient, and controlled technological processes aimed at enhancing efficiency and optimizing outcomes (Gunawardana, 2006; Katina et al., 2023). Examples of advanced manufacturing can include robotic process automation, the use of 3D printing for rapid prototyping, and the application of machine learning—a field of artificial intelligence that focuses on predictive analytics for the purposes of process optimization. Advanced manufacturing emphasizes continuous improvement and the rapid integration of scientific, engineering, and technological advancements aimed at enabling development of sustainable and environmentally responsible designs and manufacturing capabilities (Katina et al., 2023; NGen, 2022). Advanced manufacturing also encompasses various recent advancements in manufacturing, including (a) additive manufacturing, (b) biomanufacturing, (c) cyber manufacturing, (d) green manufacturing, and (e) space manufacturing (Katina et al., 2023; Pereira et al., 2019).

While advanced manufacturing offers potential for economic growth and diversification, both rural and urban, it has been acknowledged that Canadian manufacturing has lagged in technology adoption, commercialization of technological solutions, and other aspects of advanced manufacturing (NGen, 2022). Strategies and investments into Canada's advanced manufacturing sector are in progress (e.g., NGen's industry led innovation cluster for advanced manufacturing; NGen, 2023). However, the advanced manufacturing sector and its related opportunities and risks are not well understood in rural Canada, particularly at the local level.

In 2023, the Kootenay Association for Science and Technology (KAST), in collaboration with Selkirk Innovates, the applied research department of Selkirk College, developed a project exploring the advanced manufacturing sector within the rural Kootenay region of BC. The project goal was to inform regional understanding of the advanced manufacturing sector and to develop targeted

strategies to support worker recruitment, business retention, and sector expansion—with a particular focus on youth as required by the project funder. During the project an additional opportunity emerged, when we observed that many manufacturing businesses in the case study region did not initially perceive their operations as advanced, nor did they initially view themselves as part of the advanced manufacturing sector, despite their reflection of its characteristics. As a result, we identified the need for a nuanced explanation and rurally inclusive definition of advanced manufacturing and an accompanying assessment to help better understand challenges and opportunities. Using the results of a targeted literature review and sector survey, we developed an 'advanced manufacturing spectrum'—a model illustrating and defining different facets of advanced manufacturing and an accompanying assessment tool, aimed at assisting rural businesses and economic development practitioners to better understand the current state of advanced manufacturing and the opportunities and potential for advancement. We then applied the spectrum as a diagnostic and planning tool within the case study region.

The purpose of this article is to share the proposed advanced manufacturing spectrum model for further discussion, testing, and refinement in other rural regions in Canada. We present this work within the framework of a case study, acknowledging that the variation across rural places may limit the potential transferability of this work. The article starts with an overview of the literature, followed by a description of our methods and the case study region, including the advanced manufacturing survey results, a presentation and discussion of the spectrum, the application of the spectrum to the case study, and ending with discussion and call for action.

2.0 Literature Summary

We conducted a targeted review of the literature, focused on identifying and clarifying how advanced manufacturing is defined, including key criteria and characteristics that are indicative of a business belonging to the sector. As observed in the introduction, there are differing definitions of advanced manufacturing and the literature related to this field is evolving. However, there are common themes across these definitions that help to group criteria and characteristics critical to businesses within the advanced manufacturing sector. These themes are summarized below. Additional context is provided specific to rural considerations related to the themes. However, these rural considerations as discussed within the literature are generalized. This is important to acknowledge as rural is not a single homogenous unit, but rather rural is comprised of a wide range of places with differing contexts that share some similar characteristics, particularly related to size (small) and distance (long) (Agyepong et al., 2020; Nelson et al., 2021).

Research and development, as well as innovation, are critical to advanced manufacturing (Katina et al., 2023). Innovation is identified as playing a crucial role, necessitating the ability for businesses to generate and implement new ideas, and fostering creative environments (Narasimha, 2016). Innovation itself is a broad and evolving field, with variations across disciplines. For the purposes of this article, innovation is understood to include new or improved products and processes (OECD & Eurostat, 2018). It is important for innovation to be considered within the rural context, as it has been recognized that rural innovation can be overlooked, in part because it can look different than in urban locations

(Hall & Vodden, 2019). For example, the literature has observed rural innovation generally to be more incremental in nature, focused on the doing, using, interacting mode of innovation rather than the science, technology, innovation mode (Isaken & Karlsen, 2010; Hall & Vodden, 2019).

Another theme of advanced manufacturing is that of a skilled workforce (Katina et al., 2023). Included within this theme is not only the presence of, or access to a skilled workforce, but accessible and effective education and skills programs to train the new manufacturing workforce (Narasimha, 2016). The availability of postsecondary institutions and training programs for current and prospective employees is closely linked to innovation capacity (Hall & Vodden, 2019). Continuous training was identified as critical to address the loss of traditional career pathways and to align diverse sectors (e.g., aligning engineering with sectors like health, medicine, and agriculture; Evans, 2017). Beyond technical skills, the importance of soft skills (e.g., communication, problem-solving) for managers and workers are highlighted among the skills increasingly in demand within the advanced manufacturing sector (Javdekar et al., 2016; Katina et al., 2023). Related to workforce is the importance of the social aspects, the human networking component that is critical to innovation (Hall & Vodden, 2019; Katina et al., 2023). Within rural settings it is important to acknowledge that there can be additional challenges in attracting and retaining skilled workers (Agyepong et al., 2020).

Technology is a key theme of advanced manufacturing—both hardware and software (Katina et al., 2023). This includes efforts to refine a range of technologies, understanding the associated physical phenomena during part creation, expanding the range of usable materials, and exploring the fabrication of complex integrated systems (Calignano et al., 2017). Technology also includes information and communication technologies (ICTs). As with workforce training and education, access to information technology and communications infrastructure is closely linked with innovation capacity (Hall & Vodden, 2019). Advanced manufacturing businesses should leverage and integrate ICT systems across various areas of manufacturing and its subfunctions (Narasimha, 2016). Here the rural context is again important as connectivity in the form of high-speed internet access continues to be a challenge in rural Canada (Salemink et al., 2017; Weeden & Kelly, 2021).

Alongside the above, is the funding for technology, research and development, and innovation labs (NGen, 2022). Funding plays a crucial role, enabling early-stage innovations to be evaluated at minimal cost, reducing risks associated with substantial investments (Evans, 2017). Supported assets like innovation labs also provide researchers and companies with an opportunity to solidify concepts before seeking additional investment or raising capital. Furthermore, innovation labs facilitate the certification and accreditation of products prior to market release (Evans, 2017).

Sustainability is also a cross cutting theme of Advanced Manufacturing, encompassing the adoption of clean and green manufacturing technologies to address environmental and societal concerns (Narasimha, 2016). This involves considering the entire product lifecycle, from design and manufacturing to including recycling aligned with environmental policies, as well as striving for energy efficiency with renewable energy sources and reducing processing time (Katina et al., 2023; Narasimha, 2016).

The above themes work together, contributing to nurturing innovation, refining technologies, and mitigating risks, while also developing a skilled workforce capable of meeting evolving demands (Calignano et al., 2017; Evans, 2017; Javdekar et al., 2016).

3.0 Methods

The following section provides an overview of the methodological approach taken.

3.1 Data Collection

The overarching research approach consisted of a targeted review of literature and secondary data and the design and implementation of a survey.

To begin, we conducted a targeted literature review of advanced manufacturing literature to enhance our knowledge and understanding of the subject. Our review primarily aimed to provide insights into defining advanced manufacturing and into what criteria indicate that a business is part of this sector. It should be noted that this targeted review was limited by the parameters of the project and should not be considered as rigorous as a scoping or systemic review. We searched for articles through the Selkirk College library database, Research Gate, and Google Scholar, using keywords to identify documents. We began with keywords focused on defining advanced manufacturing (e.g., advanced manufacturing definition, advanced manufacturing rural communities, traditional versus advanced manufacturing) and added additional modifying keywords as we built our knowledge base (e.g., advanced manufacturing and technologies, and management, and innovation, and sustainability). A review of abstracts by two team members working in collaboration determined what literature was included. The literature identified included peer-reviewed journal articles, grey literature, and websites.

We also reviewed existing secondary statistical data sources (e.g., census data, labour market survey data, business count data) to better understand the scope and scale of manufacturing within the region. As ‘advanced manufacturing’ does not have an agreed upon definition, there is no simple way to separate traditional from advanced manufacturing within this secondary data. However, the generalized manufacturing data provided a useful point of comparison of the size of advanced manufacturing versus the manufacturing sector as a whole.

We compiled a regional database of businesses belonging or potentially belonging to the advanced manufacturing sector. To populate the regional database, we identified businesses through web searches for manufacturing operations within the case study region, reviews of business websites, and recommendations from sector experts within our regional networks. Business inclusion was determined on whether there was evidence the businesses are in the manufacturing sector, use technology known to be associated with advanced manufacturing, or have products, services, and processes in place that could be described as advanced. A total of 197 businesses were identified.

The survey was collaboratively designed, building on past regional business retention and expansion surveys, as well as other regional sector surveys (e.g., “The Kootenay Technology Sector Assessment,” by Smillie & Schrottenbaum, 2020). While the 29 questions were primarily quantitative, the survey included 10 open-ended questions, allowing for collection of qualitative data. The survey was approved by the Selkirk College Research Ethics Board (#2022-016). The survey was administered through an online platform and completion of the survey via one-

on-one interviews or small group discussion. This combination of methods was chosen to be wide reaching and accessible (online survey), while trying to ensure representation across the region and across manufacturing sub-sectors (interviews)[1]. We sent invitations to select businesses to complete the survey via one-on-one interviews. These businesses provided a geographic cross section as well as a cross section of sub-sectors and were selected based on the most obvious demonstration of advanced manufacturing activities identified through our web searches (20/197). Email invitations were also sent to all other identified businesses within the database that had a publicly accessible email address (160/197) to complete the online survey. We attempted to reach businesses in the database without public email addresses, as well as other unidentified businesses through posting an invitation to participate in the survey on social media.

We also held a small group discussion with a cohort of Selkirk College's Digital Fabrication (DFAB) students, responding to the survey from the perspective of future employees. DFAB is a new program at the Selkirk Technology Access Centre, a key regional resource for the advanced manufacturing sector. These students were selected based on their relevance as the next generation of skilled workers within the sector, and better understanding their impressions of challenges and opportunities related to future employment with local manufacturing businesses was deemed an important aspect related to skilled workforce.

3.2 Data Analysis

Survey data were compiled into a single Microsoft Excel file. Quantitative data were analyzed using descriptive statistics (e.g., counts, averages, modes). Qualitative data were grouped and categorized based on identified common themes using a combination of deductive coding and a pattern matching technique, categorizing results by key themes identified within the literature. These themes were organized and presented based on the number of times they occurred. This organization enabled the identification of key areas of focus and facilitated the exploration of identified challenges, suggested solutions, and necessary supports.

3.3 Limitations

It is important to acknowledge the limitations of this research, in terms of the case study specifically and the broader development of the spectrum and assessment tool.

Specific to the case study, we were limited in is the inability to determine the precise size of the advanced manufacturing sector in the Kootenay Region. As such, it is uncertain to what degree the survey results are representative of the population as a whole. Next, the number of one-on-one interviews conducted was relatively small (n = 2), limiting the deeper qualitative information obtained. Additionally, within those who completed the survey, there was a difference in the number of participants who completed the survey in part (n = 70), versus those who fully answered all the questions (39/70). The limited response rate may have affected how accurately the

[1]The North American Industry Classification System was used to identify manufacturing sub-Sectors. The sub-sectors include: (a) food; (b) beverage and tobacco; (c) textile; (d) clothing; (e) leather and allied; (f) wood; (g) paper; (h) printing and related support activities; (i) petroleum and coal; (j) chemical; (k) plastics and rubber; (l) non-metallic mineral; (m) primary metal; (n) fabricated metal; (o) machinery; (p) computer and electronic; (q) electrical equipment, appliance and component; (r) transportation equipment; (s) furniture and related; (t) miscellaneous.

findings represent the broader situation. Participation may have been impacted by the timing of the research as invitations were sent during the end of tax filing season, coinciding with a busy period for businesses. The smaller presence of KAST in the eastern portion of the region compared to the west potentially contributing to lower response rates from the eastern portion of the region.

Specific to the broader development of the spectrum and assessment tool, we acknowledge the limitations of the targeted literature review. Future iterations of the spectrum would benefit from a broader review of related literature (e.g., Smart Specialization, Industry 4.0) to better situate this work within the larger body of scholarly work.

4.0 Case Study Region

4.1 Regional Overview and Sector Data

The overarching project focused on a case study region (the Kootenay region) in south-eastern BC (see Figure 1). For the purpose of this research, the region included the entire Kootenay Development Region, comprised of the three Kootenay Regional Districts[2] (Central Kootenay, East Kootenay, Kootenay Boundary). Additionally, owing to the jurisdiction of the Kootenay Association for Science and Technology, a portion of the Thomson-Okanagan Development Region was included—Golden, Revelstoke, and Columbia-Shuswap Electoral Areas A and B. The case study region is home to approximately 176,000 people (Selkirk Innovates, 2022). Using BC's Provincial definition of rural as communities less than 25,000 (Government of British Columbia, 2022), the entire case study region is rural, with no major urban influence. The largest population centre is Cranbrook, at just over 20,000 people (Selkirk Innovates, 2022).

From a manufacturing perspective, the region has a long history of traditional manufacturing related to natural resources (e.g., sawmills; Vodden et al., 2019). Using the North American Industry Classification System Codes 31–33 (Manufacturing), data from Statistics Canada estimates 785 manufacturing businesses in the Kootenay Development Region plus an additional 31 manufacturing businesses in Golden, Revelstoke, and Columbia-Shuswap Electoral Areas A and B (Statistics Canada, 2023a). Of these, an estimated 272 businesses have employees, with the majority of those (217) having fewer than 20 employees (Statistics Canada, 2023a). This aligns with the expectation that the estimates for the manufacturing sector as a whole (272) would be larger than that of the advanced manufacturing sector as identified by the development of the regional database (197).

From an employment perspective, 7,100 people are employed in manufacturing in the Kootenay Development Region, about 8% of the regional labour force (Selkirk Innovates, 2023). An examination of the same employment numbers over time indicates a negative change of -2.7% in the size of the manufacturing labour force between 2017–2022 (Selkirk Innovates, 2023).

The region demonstrates both typical and atypical trends when compared to other rural regions. For example, while the demographics of some communities are

[2]Regional Districts are a form of local government, providing local government and services to unincorporated rural communities, as well as providing a framework for collaboration with and between the incorporated municipalities within their boundaries (Bish & Clemens, 2008).

shrinking and aging, others are the opposite (Selkirk Innovates, 2022). Past research within the region has noted unique physical and cultural characteristics within the region that may impact transferability of results (Breen, 2016).

Figure 1. Case study region.

Source: Ronquillo et al., 2023

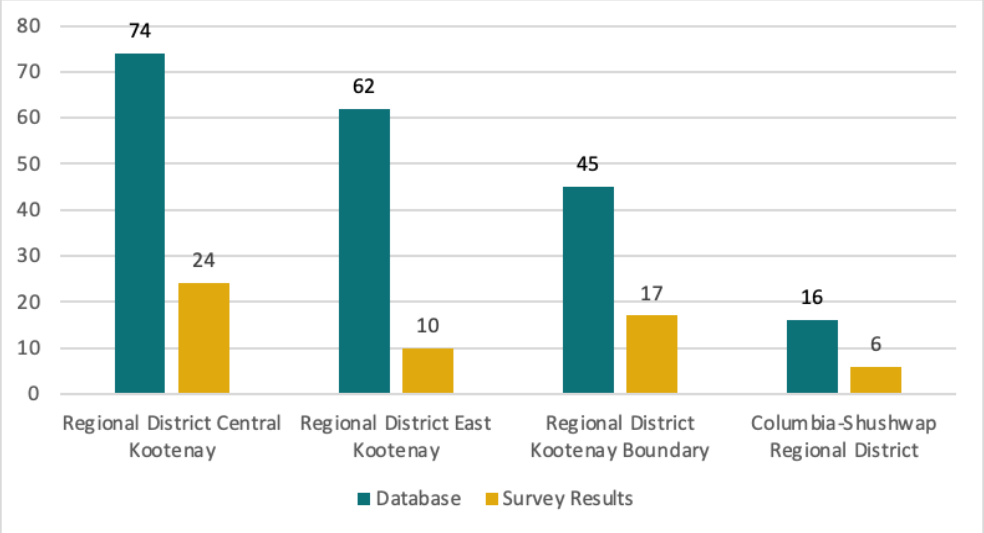
4.2 Survey Results

Businesses identified within the regional database that had a public email address (n = 160) were invited via email to participate in the survey and the survey link was also distributed through regional networks. At this point there were businesses who self-eliminated themselves from the survey. We cannot be certain of the exact number, however, we received emails from some businesses indicating they did not see themselves as part of the advanced manufacturing sector, despite our perception of their businesses having matched the criteria detailed in Section 3. As noted in the introduction, this became a factor for the development of the assessment.

A total of 72 businesses participated in the survey (2 via interview, 70 via online survey). Responses were received from all regional districts in the case study region. By comparing the survey results to the database by regional district, we were able to confirm that survey representation from across the region was proportionate to regional distribution seen in the database, with the exception of the Regional District of East Kootenay (see Figure 2).

In terms of manufacturing sub-sectors, responses were received from businesses in all sub-sectors except for non-metallic mineral product manufacturing and petroleum and coal product manufacturing. Among the respondents, the wood product manufacturing industry accounted for the highest percentage (18%), followed by the beverage and tobacco product manufacturing sector (14%), all of which were beverage manufacturers. The survey also captured responses from businesses that did not fall within the defined manufacturing sub-sectors, but who self-identified as part of the sector. The resulting miscellaneous manufacturing represented 10% of the respondents. These miscellaneous manufacturing businesses encompass a diverse range of activities, including natural resource management, cosmetics, public relations/consultations, and certain types of food processing facilities, among others.

Figure 2. Respondents by regional district.



Source: Ronquillo et al., 2023, p. 14.

Many (47%) of the respondents have been operating for over 20 years, indicating that a portion of the sector is established. The majority of these businesses are associated with the wood product manufacturing sub-sector, aligning with the natural resource history of the region. The other respondents demonstrated a range in business maturity across multiple manufacturing sub-sectors: 5–9 years (19%); 10–19 years (19%); 1–4 years (11%); and less than 1 year (5%).

Respondents were asked questions related to needs, challenges, solutions, and supports. Their responses reflected the idea of a spectrum of advanced manufacturing, with business at different points, each with areas for improvement. For example, the primary barrier identified by survey participants pertains to funding, particularly insufficient working capital to facilitate business expansion and procure necessary funds for capital expenditure, including expenses related to the acquisition and evaluation of new machinery and equipment. This corresponds to what we saw within the advanced manufacturing literature (Pereira et al., 2019). Another set of challenges was workforce, where three primary obstacles were identified: (a) limited availability of local candidates, (b) inadequate skills and educational qualifications, and (c) a scarcity of industry-specific knowledge and experience. Again, we also saw these topics reflected in the literature (Javdekar et al., 2016). The survey also revealed that respondents felt that the case study region offers lower costs of living, including potentially more affordable rent and property tax reductions for new manufacturers, particularly when compared to the Thompson–Okanagan and Lower Mainland–Southwest Development Regions. Collaboration and support were identified as additional strengths, with a strong network of rural individuals and organizations facilitating effective networking. Sector-specific clusters, such as outdoor rec-tech, food processors, and battery recycling, were also recognized as contributing to the region's economic strength.

4.3 Case Study Summary

The findings presented above highlight several points. Within the case study region there is a continued link between natural resources and manufacturing. The region’s manufacturing sector generally shares a characteristic seen in the region's natural resource sectors, where there are small number of large employers (Columbia Basin Rural Development Institute, 2017). In the survey data this connection between natural resources and manufacturing can be seen in the most mature advanced manufacturing businesses coming from the wood product sub-sector. It is also reflected in the decline of manufacturing sector employment within the region since 2017. This decline may be attributed to the closure and curtailment of mills, a trend that has been unfolding across the province's forest sector (Lirette, 2019).

However, a new narrative is emerging as well. Despite the ongoing prevalence of a small number of natural resources based large employers, the majority of businesses within the manufacturing sector generally and advanced manufacturing sector specifically are small-scale operations. These businesses, often operated by single owners or with a small workforce, reflect a range of manufacturing sub-sectors present an opportunity for growth and economic diversification.

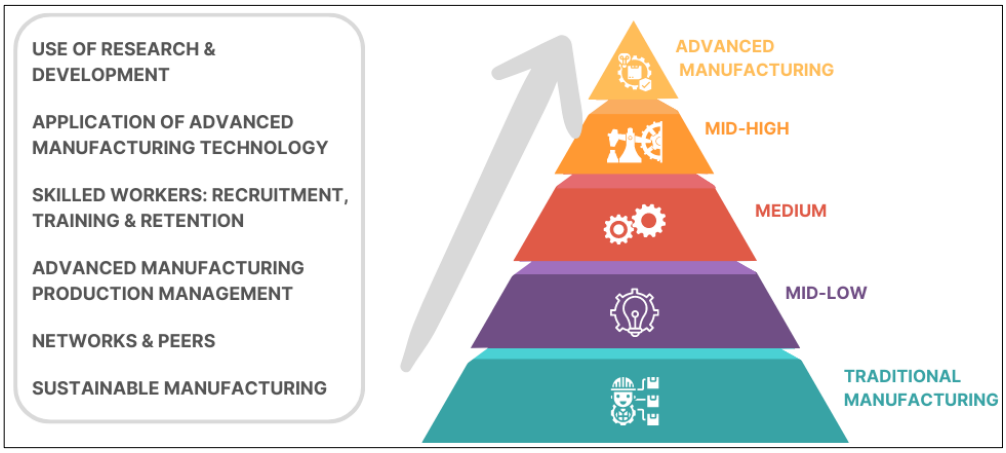
5.0 Development of the Advanced Manufacturing Spectrum and Assessment

The ambiguity in how advanced manufacturing is understood was clear to us from the beginning. This was re-enforced as we conducted our targeted literature review, created the regional database and invited businesses to participate, and analyzed the case study data. We discovered that some businesses that appeared to demonstrate characteristics of advanced manufacturing did not consider themselves to be part of the sector, while other businesses that did not appear to fit neatly into specific manufacturing sub-sectors considered themselves part of the sector, necessitating further investigation through the survey. These observations raised questions within our research team about how we as researchers, but also businesses and economic development practitioners could first understand if a business falls within the advanced manufacturing sector, and second, could identify opportunities and risks and implement related actions.

During our discussions, we began to envision a spectrum from traditional to advanced manufacturing. A spectrum acknowledges that the difference between traditional and advanced is not binary, but rather a wide range of businesses may be included, varying in terms of their attention to the themes of advanced manufacturing identified in Section 2: (a) research and development—including innovation, (b) application of technology, (c) skilled workforce, (d) networks, (e) sustainability, and (f) funding. A spectrum also recognizes the opportunity for continuous improvement and allows for distinctions between businesses at the forefront of technological innovation and others that demonstrate moderate levels of advancement. Through the creation of the spectrum, we aimed to develop a more comprehensive, inclusive, and easy to understand approach to the advanced manufacturing sector. We feel this approach to be particularly important for rural regions, in order to be inclusive when identifying the broad range of businesses and innovations, highlighting multiple opportunities and pathways for improvement, and including economic transitions. A spectrum also highlights the dynamic nature of the sector, with the continuous adoption of new technologies and approaches within different aspects of operations.

Our proposed advanced manufacturing spectrum encapsulates different levels of sophistication and technological advancement, ranging from traditional manufacturing to mid-low, medium, mid-high, and advanced manufacturing, visualized by the pyramid on the right side of Figure 3. Beginning with the themes identified in the literature, and incorporating the initial results from our survey we identified distinct pathways through which businesses could advance up the advanced manufacturing pyramid. These pathways are listed in the box on the left of Figure 3. Five pathways directly match the themes from the literature, (a) engaging in research and development activities to foster innovation; (b) the application of advanced manufacturing technologies; (c) the recruitment, training, and retention of skilled workers; (d) fostering collaboration with sector networks and peers; and (e) incorporating sustainable manufacturing practices. The sixth pathway—advanced manufacturing production management—relates to the themes of workforce and technology, but evidence from the survey suggested it is sufficiently different in practice to require a separate pathway. The sixth theme from the literature—funding—was excluded as a pathway given the influence of funding on all pathways.

Figure 3. Proposed Advanced Manufacturing Spectrum.



Source: Ronquillo et al., 2023, p. 12.

For each of the six pathways identified in Figure 3 we developed the following short, accessible description:

- *Research and development*: Innovation through research and development enables companies to stay at the forefront of technological advancements and gain a competitive edge in the market. Research and development allows for the development of new techniques and products, and can enhance operational efficiency, optimize supply chain management, reduce production costs, and boost profitability.
- *Application of advanced manufacturing technology*: Businesses operating in this sector should actively leverage and integrate technology across various areas of manufacturing and its subfunctions. This enables seamless data exchange, real-time monitoring, and enhanced automation, resulting in improved operational efficiency and productivity. Furthermore, technology integration enables businesses to embrace emerging technologies such as artificial intelligence, robotics, and the Internet of Things, which are poised to shape the future of advanced manufacturing.
- *Skilled workers*: To keep pace with the rapid evolution of the sector, businesses must prioritize investments in training and education programs to enhance the capabilities of their workforce. This necessitates providing ongoing opportunities for professional development to ensure that employees possess the latest knowledge and skills required. In addition to technical expertise, the demand for soft skills such as problem-solving, communication, and writing proficiency is evident. While technology can help address labour shortages, progressing along the advanced manufacturing spectrum requires the creation of stable jobs for highly skilled workers. Achieving this involves implementing strategic recruitment processes to attract skilled talent, offering cutting-edge training programs to enhance skills, and providing attractive benefits to promote employee retention.
- *Advanced manufacturing production management*: advanced manufacturing management assumes a crucial role in optimizing operations and bolstering the overall viability and performance of systems.

Through effective management and integration of process efficiencies within the manufacturing process, advanced manufacturing management enables businesses to adapt and thrive in a rapidly changing environment. This includes (a) the adoption of advanced computer software, (b) streamlining production processes, (c) fostering collaboration among stakeholders, (d) optimizing resource utilization, and (e) responding to evolving market demands.

- *Networks and peers*: Networking and collaboration are key success factors in the advanced manufacturing industry. Given the complex and fast-paced nature of advanced manufacturing, businesses need to actively work together and build strong connections to stay competitive and drive innovation. Collaborating with other organizations and establishing networks allows businesses to overcome challenges such as accessing funding, finding grant opportunities, and sharing knowledge and resources. This also helps businesses stay updated on industry trends and emerging technologies. Collaborative efforts not only benefit individual businesses but also strengthen the overall advanced manufacturing ecosystem.
- *Sustainable manufacturing*: Sustainability is a fundamental consideration in advanced manufacturing. Businesses are expected to adopt clean and green manufacturing technologies that minimize environmental impact. This involves considering the entire product lifecycle, from sourcing raw materials and design to the disposal or recycling of products. Implementing sustainable practices aligned with environmental policies, such as energy efficiency measures and the use of renewable energy sources, is crucial for reducing carbon footprints and promoting a more environmentally friendly manufacturing process. By applying sustainable manufacturing practices, conducting research and development towards sustainability, and implementing solutions that limit their environmental impact, businesses can both advance along the advanced manufacturing spectrum and create a more sustainable environment.

Each of the six pathways combine collectively to shift manufacturing businesses along the spectrum from traditional to advanced manufacturing. Equally important is that each of the six is not binary (present / absent), but its own continuum. Further refining the spectrum to this level of detail enabled the creation of an assessment, allowing researchers, economic development practitioners, and businesses to review the descriptions in detail for a single business or collection of businesses within a target area, identifying where the business or area sits on each scale, and using the results to situate the business or area on the spectrum (see Table 1).

Table 1: *Detailed Advanced Manufacturing Spectrum and Assessment*

Advanced Manufacturing		**Level of Manufacturing**				
Pathways	***Themes***	**Low –Traditional Manufacturing**	**Mid-Low**	**Medium**	**Mid-High**	**Advanced Manufacturing**
Research and Development (R&D)	***Application of R&D***	Relies primarily on traditional manufacturing methods with minimal exploration of emerging technologies.	Basic R&D activities focused on incremental improvements, cost reduction, and optimization of existing products or processes	Innovating for competitive edge, identifying and responding to industry needs and improving efficiency.	Engages in advanced research projects to develop new products, technologies, or processes.	Maintains state-of-the-art research facilities, hires top-notch researchers and scientists.
	Investment in R&D	Primarily relies on external sources, such as industry trends, for technological advancements and innovations.	Limited investment in R&D resources, such as personnel, equipment, and facilities.	Invests in dedicated R&D activities, personnel and facilities to drive innovation	Established infrastructure for R&D, specialized equipment and skilled research team.	Significant investment in R&D activities and a commitment to innovation.
Application of Advanced Manufacturing Technology	***Adoption of Technology in Production & Development***	Relies primarily on traditional manufacturing methods, standard production techniques, and conventional product development practices.	Some adoption of emerging technologies and tools related to Advanced Manufacturing, such as automation, robotics, additive manufacturing, or digital manufacturing, in both production and product development processes.	Active implementation of Advanced Manufacturing techniques, including automation, robotics, additive manufacturing, or digital manufacturing.	Adoption of Advanced Manufacturing techniques, leveraging cutting-edge technologies like artificial intelligence (AI), Internet of Things (IoT), or advanced robotics.	Leading-edge technologies in manufacturing, such as autonomous systems, advanced data analytics, adaptive manufacturing, or advanced supply chain management.
	Investment in Technology for Production & Development	Minimal investment in exploring or adopting emerging technologies or innovative product development approaches	Incorporation of improved product development practices, such as computer-aided design (CAD) or simulation tools, to enhance the development process.	Investment in advanced product development tools and methodologies, such as virtual prototyping, rapid iteration, concurrent engineering, or design for manufacturability (DFM), to accelerate the product development process.	Utilization of state-of-the-art production techniques and product development practices, such as digital twin simulations, advanced data analytics, agile manufacturing, or cross-functional collaboration, to achieve operational excellence and innovation.	Continuous exploration of emerging technologies and methodologies to push the boundaries of manufacturing and product development.

Advanced Manufacturing		**Level of Manufacturing**				
Pathways	***Themes***	**Low –Traditional Manufacturing**	**Mid-Low**	**Medium**	**Mid-High**	**Advanced Manufacturing**
Skilled Workers	***Recruitment***	Relatively passive recruitment process with minimal efforts to attract highly skilled individuals.	Proactive recruitment efforts targeting individuals with relevant skills and experience.	Strategic recruitment initiatives targeting top talent, both internally and externally.	Proactive recruitment strategies, including partnerships with educational institutions, industry networks, and targeted talent sourcing.	Highly strategic recruitment practices, including talent scouting, employer branding, and leveraging innovative sourcing channels.
	Training		Basic training programs provided to new hires, with some investment in upskilling and professional development.	Well-developed training programs to onboard new hires and provide continuous upskilling opportunities.	Comprehensive training and development programs tailored to Advanced Manufacturing skills and technologies.	Cutting-edge training programs, including collaborations with educational institutions and internal centers of excellence.
	Retention	Low focus on employee retention strategies, resulting in higher turnover rates.	Initial retention efforts, such as competitive compensation and benefits, but limited focus on long-term retention strategies.	Efforts to enhance employee retention through career development pathways, performance-based incentives, and a positive work environment.	Robust employee retention initiatives, such as competitive compensation packages, mentorship programs, work-life balance initiatives, and opportunities for advancement.	Strong focus on employee retention, offering attractive benefits, comprehensive career development opportunities, and a supportive company culture.
Management	***Investment in Process Efficiency***	Minimal investment in process optimization, automation, or data-driven decision-making.	Some investment in process optimization, automation, or data-driven decision-making tools.	Significant investment in process optimization, automation, and data-driven decision-making technologies.	Extensive investment in cutting-edge process optimization, automation, and data analytics technologies.	Pioneering the use of revolutionary technologies and methodologies to optimize processes and achieve operational excellence.
	Implementation of Process Efficiency	Relatively basic production planning and control systems with limited integration of advanced technologies.	Introduction of basic production planning and control systems with limited integration of advanced technologies, such as machine monitoring or quality control systems.	Implementation of advanced production planning and control systems, leveraging real-time data integration, advanced analytics, and optimization algorithms.	integration of advanced production planning and control systems with the use of artificial intelligence (AI), machine learning, or predictive analytics.	Implementation of advanced systems, such as smart factories or cyber-physical systems, to enable seamless integration, automation, and optimization across the entire value chain.
	Quality Control of Process Efficiency	Reactive approach to addressing process inefficiencies, with limited use of performance metrics and continuous improvement initiatives.	Initiatives for identifying and addressing process inefficiencies, with periodic performance monitoring and improvement projects.	Proactive approach to identifying and resolving process inefficiencies through continuous improvement methodologies, such as Lean or Six Sigma.	Continuous monitoring of key performance indicators, real-time process optimization, and proactive identification of inefficiencies using advanced analytics and digital twins.	Continuous improvement culture with real-time monitoring, predictive maintenance, and advanced analytics driving continuous optimization and innovation.

Advanced Manufacturing		**Level of Manufacturing**				
Pathways	***Themes***	**Low –Traditional Manufacturing**	**Mid-Low**	**Medium**	**Mid-High**	**Advanced Manufacturing**
Networks & Peers	***Access to Expertise***	Limited access to external expertise, cutting-edge technologies, or collaborative research opportunities.	Limited engagement with external experts, research institutions, or technology providers for specific projects or knowledge exchange.	Engaging in joint projects, partnerships, or technology exchanges with external experts, research institutions, or technology providers.	Actively establishing strategic partnerships, joint ventures, or research collaborations with external experts, research institutions, or technology providers.	Strategic alliances, joint ventures, or research partnerships with leading experts, research institutions, or technology providers to co-create Advanced Manufacturing solutions and drive industry advancements.
	Funding & Grants	Limited exploration of external funding sources for research, development, or expansion.	Limited utilization of external funding sources for specific initiatives, such as research projects or technology adoption.	Pursuit of external funding sources for various initiatives, such as R&D projects, technology acquisitions, or facility expansions.	Actively seeking external funding sources, such as government grants, venture capital, or private equity, to support R&D, innovation, and expansion efforts.	Proactively seeking and leveraging various funding sources, including government grants, strategic partnerships, venture capital, or public offerings.
	Investors or Financial Institutions	Minimal efforts to establish relationships with investors or seek venture capital.	Occasional networking with investors but with minimal strategic relationship-building efforts.	Building relationships with investors through targeted networking, pitching, and regular communication.	Establishing strategic relationships with investors, fostering long-term partnerships, and engaging in ongoing dialogue for mutual growth.	Cultivating strong relationships with investors, strategic partners, and industry stakeholders to foster innovation, drive growth, and attract significant investment.

Advanced Manufacturing		**Level of Manufacturing**				
Pathways	***Themes***	**Low –Traditional Manufacturing**	**Mid-Low**	**Medium**	**Mid-High**	**Advanced Manufacturing**
Sustainability	***Environmental Impact***	Minimal consideration of environmental impact or resource efficiency in manufacturing processes.	Some consideration of environmental impact and resource efficiency in manufacturing processes.	Significant consideration of environmental impact and resource efficiency in manufacturing processes.	Proactive consideration of environmental impact and resource efficiency throughout the manufacturing processes and supply chain.	Holistic approach to environmental impact and resource efficiency across all aspects of manufacturing operations.
	Adoption of Sustainable Technology	Limited adoption of technologies or practices that promote sustainability, such as energy-efficient systems or waste reduction initiatives.	Partial adoption of technologies or practices that promote sustainability, such as energy-efficient systems or recycling programs.	Adoption of advanced technologies or practices that promote sustainability, such as renewable energy sources, closed-loop systems, or life cycle assessments.	Implementation of advanced technologies and innovative practices that promote sustainability, such as carbon footprint reduction strategies, circular economy principles, or sustainable material sourcing.	Implementation of cutting-edge technologies and best practices that drive sustainability, such as smart energy management, zero-waste manufacturing, or eco-design principles.
	Research & Development for Sustainability	Minimal investment in research or development of sustainable manufacturing solutions.	Moderate investment in research or development of sustainable manufacturing solutions.	Active investment in research or development of sustainable manufacturing solutions and continuous improvement of sustainable practices.	Substantial investment in research or development of sustainable manufacturing solutions and active collaboration with external partners, industry groups, or sustainability experts.	Continuous investment in research or development of sustainable manufacturing solutions, active engagement with sustainability thought leaders, and leadership in driving industry-wide sustainable manufacturing initiatives.

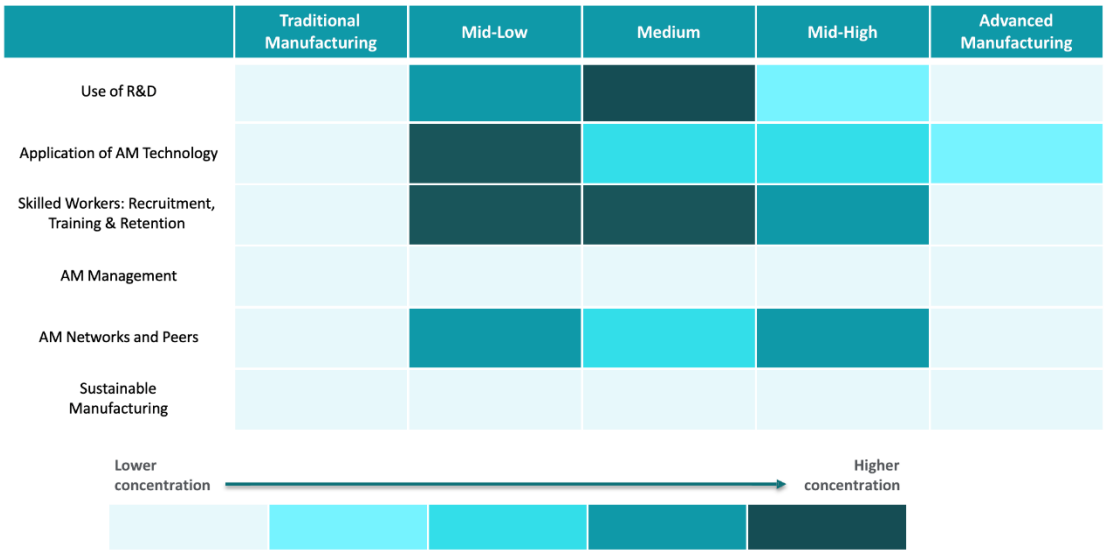
Adapted from Ronquillo et al., 2023.

6.0 Spectrum Application to Case Study

We reviewed the results of the Kootenay Region Advanced Manufacturing Survey relative to the advanced manufacturing spectrum and assessment in order to identify if there were pathways with lower or higher concentration within the case study region. It is important to note that the survey was not designed with this purpose in mind, resulting in more data collected relevant to select pathways. As such these results should be considered preliminary.

Initial survey results indicated that a considerable portion of the responding Kootenay case study businesses would on average fall between the medium and mid-high level of the advanced manufacturing spectrum (see Figure 3). However, the range of business positioning across the region widens to include mid-low to advanced when each advanced manufacturing pathway is analyzed separately, visualized by the darker squares in Figure 4. Analysis of survey data pertaining specifically to research and development indicate a concentration at medium, while data pertaining to the innovation and the application of advanced manufacturing technology indicate a wide range from a concentration at mid-low as well as groupings at medium, mid-high, and advanced. Analysis of survey data pertaining to workforce, particularly challenges with availability of skilled workers, indicate concentration at mid-low and medium. Data related to networks and peers revealed a strong network among select businesses, with the potential to expand, illustrated with the two concentrations at mid-low and mid-high.

Figure 4. Application of detailed advanced manufacturing spectrum to Kootenay survey results.



Source: Ronquillo et al., 2023, p. 24.

This preliminary analysis suggests that within the case study region, certain factors may be limiting the progress of the advanced manufacturing sector as a whole. Workforce is one example. The recruitment, training, and retention of skilled workers play a pivotal role in advancing businesses along the spectrum. The creation of stable jobs for highly skilled workers is instrumental in moving the sector forward, something which could be supported through wage subsidies and similar

programs. Identifying and communicating these challenges enables specific targeting of programs and activities to address these issues.

The above analysis also provided additional insights into where further information (e.g., information related to management practices) may be helpful, as well as into immediate opportunities to support the advanced manufacturing sector in the case study region. For example, the development of networks and peers emerged as an opportunity to grow the sector regionally. Such networks serve as valuable platforms for establishing connections and accessing collaborative opportunities for securing necessary investments, grants, and other forms of funding support.

Overall, the application of the assessment tool revealed specific regional challenges and opportunities, enabling targeted assistance of the advanced manufacturing sector that is informed by place-specific needs and the local, rural context of the case study region, and thus is more likely to result in positive outcomes. Based on the results, KAST developed an openly accessible resource package designed to target some of the regional challenges identified, including the development and provision of the assessment tool to assist businesses to understand if and how they are included within the advanced manufacturing sector. The resource package also included list of key resources and funding opportunities, as well as other tools (Kootenay Association for Science and Technology, 2023). A webinar was also held and recorded, communicating the results of the survey and introducing the spectrum to an audience that included all levels of government—funding and policy—as well as economic development practitioners and industry representatives (Kootenay Association for Science and Technology, 2023). Further investigation within the region may help reveal additional concrete actions for implementation to support moving communities along the spectrum.

7.0 Conclusion

Manufacturing is an important sector across rural Canada. As a sector it contributes to direct employment, as well as having important economic linkages (e.g., indirect employment) to other sectors, including natural resource extraction, and the businesses that provide technical and supporting services. Through the application of innovation and technology, advanced manufacturing offers a range of opportunities (e.g., decreased environmental footprint) and risks (e.g., changes to level and type of employment). The overarching support provided by the spectrum is the opportunity for rural manufacturing businesses to identify with the advanced manufacturing sector, and to communicate the range of pathways through which businesses can be considered ‘advanced’. How the potential, opportunities, and risks manifest will differ by community and region according to place-based factors, necessitating local assessment and planning. A range of targeted actions could be required, including access to information and human capacity, strengthening networks and partnerships, and changes to programs and policy, both internal to businesses, as well as within supporting organizations and across levels of government. This article may provide insights into areas that need targeted policy interventions to support the growth of advanced manufacturing in rural communities. Overall, the article highlights the complex dynamics between government policies, local capacities, and entrepreneurial initiatives in the context of rural development, offering valuable considerations for policymakers and researchers interested in advancing manufacturing in such areas.

The advanced manufacturing spectrum and assessment presented in this article was generated in response to an identified gap in the rural specific understanding and guidance related to advanced manufacturing that emerged from research project exploring the advanced manufacturing sector within the rural Kootenay region of BC. Rural inclusivity was a key driving factor for the creation of the spectrum and assessment, helping rural economic development practitioners and businesses to have greater awareness of the sector, as well as related risks and potential.

As demonstrated through the results of the application of the spectrum to the case study data, we feel the spectrum offers value as a diagnostic and planning tool to not only better understand the advanced manufacturing sector, but to critically reflect on rural challenges and opportunities and to take action accordingly. This is particularly important as while advanced manufacturing literature continues to emerge, the literature reviewed in Section 2 suggests there are differences between rural and urban, and likely across rural, particularly where manufacturing is dominated by a small number of natural resource-based firms, and where businesses may not see themselves as part of the advanced manufacturing sector.

Innovative opportunities for rural economic diversification from advanced manufacturing exist related to natural resource related manufacturing, as well as in other, non-natural resource fields. The spectrum and assessment tool were developed based on the general rural observations from the literature reviewed combined with the results of the case study, with the intent of assisting in identifying a baseline and in informing actions and programs. By understanding and embracing the spectrum of advanced manufacturing, rural businesses and regions can position themselves strategically and discover new, place-specific pathways to economic development. The spectrum enables recognition of different levels of technological advancement and identification of place-specific activities that foster innovation, improve efficiency, and promote collaboration within the advanced manufacturing sector. Through application of the spectrum and assessment, businesses may be empowered to make valuable contributions to the ongoing development of advanced manufacturing practices and drive positive outcomes for the sector. By supporting businesses and their employees in adopting advanced manufacturing practices, rural regions can harness the advantages offered by technological advancements, leading to industry growth and economic development. For example, use of the spectrum and assessment to determine the size and scope of advanced manufacturing in a community could also identify previously unnoticed potential, such as an emergent cluster. Identification of opportunities for diversification is particularly important in rural Canada, often characterized by its overreliance on natural resource extraction, and the resulting boom and bust cycles (Drache, 2020).

According to the secondary data, industries associated with advanced manufacturing are projected to experience growth in the coming years, primarily driven by accelerated digitalization and increased automation. However, the survey results reveal that many businesses in the advanced manufacturing sector face challenges related to staff shortages and the recruitment of qualified individuals to fill vacant positions. These businesses encounter difficulties in finding skilled workers who possess the necessary expertise and industry-specific experience. Additionally, bridging the knowledge gap is identified as a significant concern for businesses operating in the advanced manufacturing sector. As noted in Section 2, challenges in attracting and retaining skilled workforce is an additional challenge in rural areas. One example of the application of the spectrum and assessment is the identification

of the specific skills required to support the local advanced manufacturing and development of targeted workforce solutions.

The advanced manufacturing sector encompasses a spectrum of different levels of technological sophistication and advancement, ranging from traditional to advanced manufacturing. Our research identified various pathways for businesses and regions to advance through the adoption of advanced manufacturing technology, investing in research and development, prioritizing skilled workforce recruitment and training, implementing efficient production management techniques, collaborating with industry networks and peers, and incorporating sustainable manufacturing practices. By pursuing these approaches, businesses can progress and succeed within the dynamic and evolving field of advanced manufacturing.

We end this article with a call to action. The value of the proposed spectrum and assessment tool is currently limited both by the incorporated literature, as well as its creation and testing on a single case study. We invite others to test and further refine the proposed spectrum, incorporating ideas from across other bodies of literature, as well as lessons from other rural areas, and perhaps developing a comparable urban version. In doing so we hope this will support and enable the advancement of advanced manufacturing across rural Canada.

Acknowledgement

This research was funded by the Discovery Foundation's Advanced Manufacturing Program and by Mitacs.

References

Agyepong, V., Gibson, R., & Bollman, R. (2020). *Rural employment and workforce development: Impacts and opportunities* (1.16; Rural Insights Series: COVID-19). Canadian Rural Revitalization Foundation. https://doi.org/10.13140/RG.2.2.15646.87360

Barnes, T. J., Hayter, R., & Hay, E. (2001). Stormy weather: Cyclones, Harold Innis, and Port Alberni, BC. *Environment and Planning A: Economy and Space*, *33*(12), 2127–2147. https://doi.org/10.1068/a34187

Beshiri, R. (2010, August 31). Manufacturing employment in resource value chains: A rural–urban comparison from 2001 to 2008. *Rural and Small Town Canada Analysis Bulletin, 8*. https://www150.statcan.gc.ca/n1/en/catalogue/21-006-X2008005

Bish, R. L., & Clemens, E. G. (2008). *Local government in British Columbia* (4th ed.). Union of British Columbia Municipalities.

Breen, S.-P. W. (2016). *From staples theory to new regionalism: Managing drinking water for regional resilience in rural British Columbia* [Doctoral dissertation, Simon Fraser University]. Summit Research Repository. https://summit.sfu.ca/item/17161

Calignano, F., Manfredi, D., Ambrosio, E. P., Biamino, S., Lombardi, M., Atzeni, E., Salmi, A., Minetola, P., Iuliano, L., & Fino, P. (2017, April). Overview on Additive Manufacturing Technologies. *Proceedings of the IEEE, 105*(4), 593–612. https://doi.org/10.1109/JPROC.2016.2625098

Columbia Basin Rural Development Institute. (2017). *Labour market profile: Manufacturing*. https://sc.arcabc.ca/islandora/object/sc%3A5470

Drache, D. (2020). "Rowing and steering" our way out of the modern staples trap. In J. Stanford (Ed.), *The staple theory @ 50: Reflections on the lasting significance of Mel Watkins' "A staple theory of economic growth"* (pp. 58–64). Report. Canadian Centre for Policy Alternatives.

Evans, D. (2017, May 10). Budget 2017: A glimmer of support for innovation and advanced manufacturing. *The Conversation*. https://theconversation.com/budget-2017-a-glimmer-of-support-for-innovation-and-advanced-manufacturing-77478

Government of British Columbia. (2018, October 24). *Manufacturing in British Columbia*. https://news.gov.bc.ca/factsheets/manufacturing-in-british-columbia

Government of British Columbia. (2022). *Rural Economic Diversification and Infrastructure Program (REDIP)*. https://www2.gov.bc.ca/gov/content/employment-business/economic-development/support-organizations-community-partners/rural-economic-development/redip

Gunawardana, K. D. (2006). Introduction of advanced manufacturing technology: A literature review. *Sabaragamuwa University Journal*, *6*(1), 116–134. https://doi.org/10.4038/suslj.v6i1.1694

Hall, H. M., & Vodden, K. (2019). Learning, knowledge flows, and innovation in Canadian regions. In K. Vodden, D. J. A. Douglas, S. Markey, S., Minnes, & B. Reimer (Eds.), *The theory, practice, and potential of regional development: The case of Canada* (pp. 183–211). Routledge.

Hayter, R., & Barnes, T. (1990). Innis' staple theory, exports, and recession: British Columbia, 1981-86. *Economic Geography*, *66*(2), 156–173. https://doi.org/10.2307/143744

Innis, H. A. (1970). *The fur trade in Canada*. University of Toronto Press (Revised and reprinted from "The fur trade in Canada" 1930, Yale University Press)

Isaken, A., & Karlsen, J. (2010). Different modes of innovation and the challenge of connecting universities and industry: Case studies of two regional industries in Norway. *European Planning Studies*, *18*(12), 1993–2008. https://doi.org/10.1080/09654313.2010.516523

Javdekar, C., Watson, E., Kapilow, V., Bogard, M., Boyer, P., Zeid, I., & Duggan, C. (2016). Closing the advanced manufacturing talent gap. *Procedia Manufacturing*, *5*, 1197–1207. https://doi.org/10.1016/j.promfg.2016.08.094

Katina, P. F., Cash, C. T., Caldwell, L. R., Beck, C. M., & Katina, J. J. (2023). Advanced manufacturing management: A systematic literature review. *Sustainability*, *15*(6), Article 4702. https://doi.org/10.3390/su15064702

Kootenay Association for Science and Technology. (2023). *Kootenay Advanced Manufacturing Resource Package*. https://kast.com/wp-content/uploads/Advanced-Manufacturing-Resource-Package.pdf

Lirette, D. (2019, July 8). 'We've been here before': The fight to survive B.C.'s rising mill closures. *CBC News*. https://www.cbc.ca/news/canada/british-columbia/we-ve-been-here-before-the-fight-to-survive-b-c-s-rising-mill-closures-1.5195016

Narasimha, M. (2016). Advanced manufacturing process. *International Journal of Scientific Engineering and Applied Science, 2*(3), 266–277. https://ijseas.com/volume2/v2i3/ijseas20160329.pdf

Nelson, K. S., Nguyen, T. D., Brownstein, N. A., Garcia, D., Walker, H. C., Watson, J. T., & Xin, A. (2021). Definitions, measures, and uses of rurality: A systematic review of the empirical and quantitative literature. *Journal of Rural Studies, 82*, 351–365. https://doi.org/10.1016/j.jrurstud.2021.01.035

NGen. (2022, August). *Next Generation Manufacturing Canada: Annual Report 2022*. https://www.ngen.ca/hubfs/21-22(AnnualReport)/NGEN_(Annual-Report-22)EN.pdf

Ngen. (2023, April). *Five-year strategic plan*. https://www.ngen.ca/hubfs/Document and Reports/NGen-5YearStrat-2023-EN.pdf

OECD, & Eurostat. (2018, October). *Oslo Manual 2018: Guidelines for collecting, reporting and using data on innovation* (4th ed.). The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing. https://doi.org/10.1787/9789264304604-en

Pereira, T., Kennedy, J. V., & Potgieter, J. (2019). A comparison of traditional manufacturing vs additive manufacturing, the best method for the job. *Procedia Manufacturing, 30*, 11–18. https://doi.org/10.1016/j.promfg.2019.02.003

Ronquillo, J., Ayre, K., Fontaine, M., Breen, S.-P., & Harvey, T. (2023). *The Kootenay advanced manufacturing sector assessment: Identifying top skills in demand, challenges and opportunities* (technical report). Selkirk College. https://sc.arcabc.ca/islandora/object/sc%3A6112

Salemink, K., Strijker, D., & Bosworth, G. (2017). The community reclaims control? Learning experiences from rural broadband initiatives in the Netherlands. *Sociologia Ruralis, 57*(S1), 555–575. https://doi.org/10.1111/soru.12150

Selkirk Innovates. (2022). *Population*. State of the Basin. https://stateofthebasin.ca/society/demographics/population

Selkirk Innovates. (2023). *Employment.* State of the Basin. https://stateofthebasin.ca/economy/business-climate/employment

Smillie, S., & Schrottenbaum, I. (2020). *The Kootenay technology sector assessment 2020*. https://kast.com/reports/the-kootenay-technology-sector-assessment-2020/

Statistics Canada. (2023a). *Canadian Business Counts, with employees, census metropolitan areas and census subdivisions, December 2022* (Table: 33-10-0663-01). https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3310066301

Statistics Canada. (2023b). *Employment by class of worker and industry, annual*. Table: 14-10-0377-01. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410037701

Vodden, K., Douglas, D. J. A., Markey, S., Minnes, S., & Reimer, B. (Eds.). (2019). *The theory, practice, and potential of regional development: The case of Canada*. Routledge.

Weeden, A., & Kelly, W. (2021). Canada's (dis)connected rural broadband policies: Dealing with the digital divide and building 'Digital Capitals' to address the impacts of COVID-19 in rural Canada. *Journal of Rural and Community Development, 16*(4), 208–224.