Twenty-First Century Digital Transformation of Work and Jobs in Northern Saskatchewan

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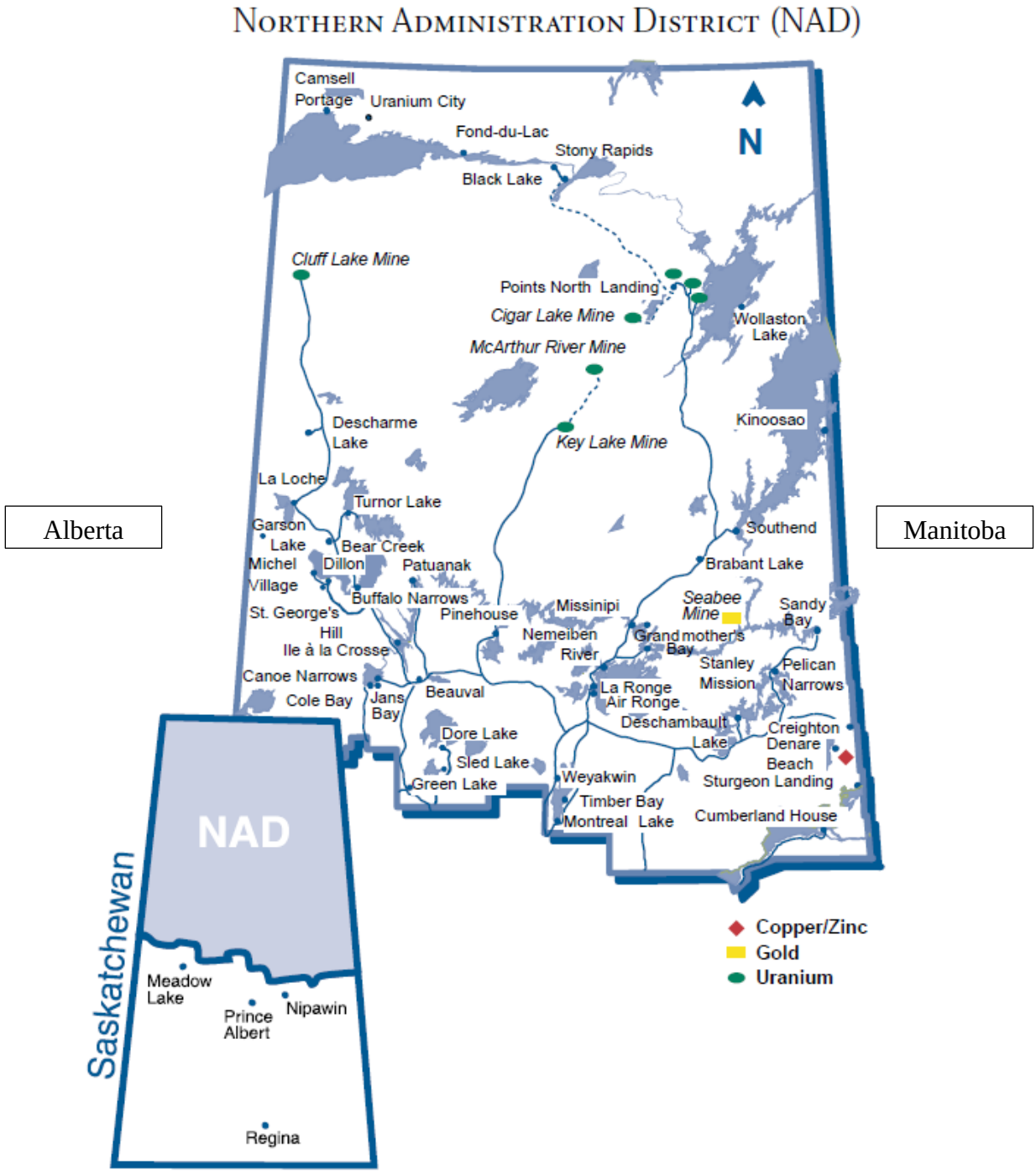
Abstract

The proliferation of digital technologies that replicate human abilities, behaviors and intelligence throughout the second decade of the twenty-first century are transforming work and jobs in many different sectors in the international economy. Human workers are competing against smarter and more capable digital machines for an increasing number of tasks and jobs. The emergence of advanced digital machines challenges policy makers and governments to rethink traditional education and workforce training models and consider new innovative responses for work and jobs in the digital age. Mining operations in northern Saskatchewan use digital technologies to increase productivity, enhance worker safety and lower production costs. New and emerging digital technologies are present in the northern Saskatchewan minerals sector, like exploration drones, advanced computer systems and automated machines are helping mining companies to regain or sustain competitiveness in difficult economic conditions marked by low commodity prices and uncertainty. Digital technologies have also contributed to the job displacement of Aboriginal workers in jobs requiring ordinary skills and education. Northern Saskatchewan's remoteness and poor internet connectivity have not prevented the digital transformation of work or jobs in the region. This thesis examines the potential impact of fewer jobs caused by the digitization of work in the northern Saskatchewan resource economy by structuring the policy problem, assessing the impact on Aboriginal workers and evaluating the preparedness of provincial institutions and programs for education and training. An extensive literature review informed the research questions and methods. Primary data was collected through surveys and key informant interviews with senior officials in the Saskatchewan Government, post-secondary institutions, provincially funded institutions and northern mining companies.

Map of Saskatchewan Northern Administration District



Source: Map Adapted from James D. Winkel, *Northern Saskatchewan: A Transformation*, Saskatchewan Northern Affairs, 2002.

Introduction: Digital Transformation of Work in Northern Saskatchewan

In recent years, digital technologies have become more sophisticated and capable of doing many complex routine and non-routine human tasks.[1] These new and emerging digital technologies are undermining traditional notions of what it means to work and causing a larger global work revolution. New and emerging digital technologies are becoming more powerful and capable of replicating human abilities, such as thinking and moving. Companies are now more able to substitute or compliment human labour with digital machines or software, which is increasing the number of tasks and occupations at risk of digitization. Previous technological changes in work, such as the muscular to mechanical transition in production activity of the first Industrial Revolution in Western Europe in the 1800s, were based on disruptive mechanical technologies that made possible massive change in jobs and work. In the twenty-first century, technological change is premised on digital power, which is causing global disruption in work and jobs. Recent studies have demonstrated that the jobs and tasks at greatest risk of digitization are those requiring little education and the lowest skill level.[2] Workers with the least education and fewest skills have been among the first casualties of the new digital economy.

New and emerging digital technologies are rapidly demonstrating their ability to perform an expanding number of tasks and jobs. Digital technologies are intensifying workforce vulnerability among workers who that lack the financial and social resources necessary for retraining or advanced education. This is especially true for Aboriginal workers in northern Saskatchewan who represent the segment of the workforce that is most vulnerable to the digitization of work and joblessness. Despite evidence of an ongoing digital transformation in the northern mining sector, the public sector institutions responsible for labour market development and post-secondary education and the northern mining sector, have not yet examined the impacts of the digitization of work in a systematic manner. As a result, the policy problem

[1] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton & Company, 2014).
[2] Melanie Arntz, Terry Gregory and Urich Zierahn, *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis*, Paris: Organization for Economic Cooperation and Development, Social, Employment and Migration Working Papers, No 189, 2016.

concerning the future of Aboriginal work in the northern Saskatchewan economy is poorly defined and unstructured.

This thesis discovered that there has been no systematic attempt to understand the link between digital technologies and their contribution to Aboriginal workforce vulnerability in northern Saskatchewan.[3] The northern Saskatchewan economy of the twenty-first century is separate and underdeveloped compared to southern Saskatchewan, despite there being great potential for emerging digital industries.[4] From a public policy perspective, addressing the current and future Aboriginal workforce is challenged by several complex and interrelated realities, including: the availability of few jobs, high unemployment rates, chronic poverty and the legacy of colonialism. Low education attainment among Aboriginals in the region remains a significant barrier to employment. Many students do not graduate from high-school and only small number continue on to post-secondary study. Historically, uranium mining has been the main source of economic development and direct and indirect employment. Large numbers of Aboriginal peoples found work in mines, primarily in operations and processing jobs that require little training, education and skills. However, finding a mining job has become difficult in large part due to a protracted economic downturn for northern Saskatchewan uranium. One contributor to fewer jobs and economic uncertainty in northern Saskatchewan is greater presence of new and emerging digital technologies in mining activity. It is becoming clear that the digital technologies of the twenty-first century lead to enhanced productivity and lower production in northern Saskatchewan mines. The digitization of work substitutes or complements certain tasks or jobs formerly done by human labour. Greater use of digital machines and systems throughout the mining cycle, for instance, has reduced the number of jobs available to Aboriginal workers. The future of work in the northern economy because of digital technologies is likely to be less-labour intensive than in the past.

[3] Northern Saskatchewan, for the purposes of this study, refers to Northern Administration District (NAD), established in 1948 by the Saskatchewan Legislature for administrative purposes and to promote natural resources development of the provincial north. Covering nearly half of Saskatchewan's landmass, the NAD is sparsely populated and isolated due to poor infrastructure, such as roads, bridges, and Internet connectivity, and the vast distances separating communities from urban centres.

[4] Brittany Witham, *Attracting Foreign Investment to Northern Saskatchewan: Two Approaches for the 21st Century* (2016), 3.

Fewer jobs in the northern Saskatchewan region is problematic for the fast growing and young Aboriginal population. An employment gap created by rapid population increase and fewer jobs is likely affect Aboriginal employment in the coming decades. Quite simply, there will plenty more people ready to work and not enough jobs. As work and jobs in northern Saskatchewan become are digitized, Aboriginal workers may have trouble finding jobs in the same quantity as in previous years, in large part because of labour saving technologies.[5]

Problem Definition: From Unstructured to Structured and on the Public Policy Agenda

The question of technological change in the northern mining sector presents a formidable challenge for Saskatchewan Government decision-makers, one that will be pursued through the standard policy cycles and processes. Policy-making is usually described as a process that unfolds in several discrete stages. Harold Lasswell formalized the policy cycle and policy stages in the 1950s, and provided future theorists and practitioners with an explanation for understanding and ordering of the work of policy makers and governments. Lasswell's contribution to understanding policy-making is present in more recent models.

Today, at least in the Canadian context, policy-making involves five stages. Policy makers and academics are quick to point out the complexity of policy development, which is often defined as a forwards-backwards progression. The first stage is agenda-setting where the mix of ideas, debates, coalitions and discussions influence the trajectory and nature of policy making. In the first stage of the policy cycle, involvement includes the 'policy universe', which refers to the many political actors who claim to have a stake in the policy outcomes.

The policy universe will attempt to define the problem and organize resources by raising public awareness and applying pressure on elected officials and civil servants. Defining the policy problem is not

[5] Ken Coates, Greg S. Finnegan, Craig J. Hall and Kelly J. Lendsay, *Unearthing Human Resources: Aboriginal Skills Development and Employment in the Natural Resources Sector* (Ottawa, ON: MacDonald Laurier Institute, 2016), 26-28.

an easy task, since purpose, resources and activities have to be linked to solving the problem (Table 1). Defining the problem determines how the story is structured and told.[6] Policy formulation narrows participation to a subset of the policy universe, referred to as the policy subsystem with membership based on having sufficient knowledge and with resources at stake. The actors in the policy subsystem have direct say in establishing the problem and recommending policy instruments. Decision-making by government officials is the third stage. It reduces the number of actors to authoritative government decision-makers, such as elected representatives, judges and bureaucrats. The whole sub-system reappears in policy implementation, where it can influence the operationalization of policy instruments. Policy evaluation is the final stage of the policy cycle within the policy universe.[7]

Table 1. The Policy Making Cycle

Stages in Policy Cycle	Key Actors Involved
1. Agenda-Setting	1. Policy Ecosystem
2. Policy Formulation	2. Policy Subsystem
3. Decision-Making	3. Government Decision-Makers
4. Policy Implementation	4. Policy Subsystem
5. Policy Evaluation	5. Policy Universe

Source: Michael Howlett, M. Ramesh and Antony Perl, *Studying Public Policy: Policy Cycles and Policy Subsystems*, 2009, 12-13.

Defining the policy problem

Public policies are developed in episodes, tend to be resistant to change, and remain in place for a long time. Periods of rapid change and upheaval greatly increase the probability of 'policy windows,' which allow for the emergence of new policies to replace outdated or ineffective policies.[8] Scholars have sought to understand how undesirable events become problems and emerge onto the public policy agenda.

[6] Eugene Bardach, *A Practical Guide For Policy Analysis: The Eightfold Path to More Effective Program Solving* (Los Angeles: SAGE, 1991), 1.
[7] Michael Howlett, M. Ramesh and Anthony Perl, *Studying Public Policy: Policy Cycles & Policy Subsystems* (London, UK: Oxford University Press, 2009), 12-13.
[8] Frank Baumgartner and Bryan D. Jones, "Agenda Dynamics and Policy Subsystems," *The Journal of Politics* 53, no. 4 (1991): 1044.

This question has been the topic of considerable debate among the leading public policy theorists since Harold Lasswell (1956) named the work done by policy makers as the "policy sciences."

The process of problem definition (i.e. how a real world problem is identified and becomes "structured") is not well understood by academics or policymakers. Hisschemoller and Hoppe (1995) performed an extensive review of the policy and social science literature and defined a policy problem as "usually defined as a gap between the existing and a normatively valued situation that is to be bridged by government action."[9] The degree of structure in a policy problem can vary a great deal (Figure 1). Policymakers and governments typically focus on structured problems and avoid intractable, messy and wicked problems. Problems that are deemed too controversial or poorly understood, remain in the policy wilderness, until the will is mustered, the resources are gathered and coordinated around a central purpose.

Figure 1. Four Types of Policy Problems

		Consensus on relevant norms and values	
		No	**Yes**
Certainty about relevant knowledge	**No**	Unstructured Problem	Moderately Structured Problem (Ends)
	Yes	Moderately Structured Problem (Means)	Structured Problem

Source: Data from Matthijs Hisschemoller and Rob Hoppe, "Copping with Intractable Controversies: The Case for Problem Structuring in Policy Design and Analysis." *Knowledge and Policy* 8 no. 4, 1995: 44.

Certainty (or lack of) is a key determinant of whether a policy problem is unstructured or structured. Knowledge is ambiguous and consensus is absent in unstructured problems. Structured

[9] Matthijs Hisschemoller and Robert Hoppe, "Coping with Intractable Controversies: The case for Problem Structuring in Policy Design and Analysis," *Knowledge and Policy* 8, no. 4 (1995): 43.

problems are the opposite. Problems of this type demonstrate a high degree of knowledge certainty and consensus about desired outcome. A moderately structured problem (means), in contrast, is marked by a dispute or dissent about what knowledge is relevant. Insufficient or disputed knowledge with agreement on consensus is considered a moderately structured problem (ends). Acceptance of new knowledge or a positive breakthrough on consensus can add structure to a problem and shift it to a more favorable direction.[10] Structured problems have a more clearly articulated story of causality and outcome, making it more likely that government will address the problem through policy-making.

Deborah Stone (1989) has written extensively about problem definition and theorized that problems only become known and workable when either stumbled upon or deliberately identified by policymakers, governments or political actors. Stone believes causal ideas are the narrative used by political actors to craft the public policy agenda. They point to the cause, assign blame and select preferred policy instruments. The presence of causal ideas (or story) influences agenda setting and problem definition. Stone contends "difficult conditions become problems only when people come to see them as amenable to human action."[11] Difficult conditions are in the realm of the natural world, which is accidental and uncontrollable. Entry into the social world, where circumstances or issues are perceived to be causally linked, mitigated and/or influenced by a known force, policymakers, governments and political actors appraise the policy problem and contest the causal ideas. Defining the policy problem is typically a highly political process, occurring post-hoc. The affected stakeholders may have a difficult time convincing government that there is a problem, in which case partnerships can be forged and resources marshaled to gain influence over the causal story. The hotly contested nature of problem definition is due to the political nature of the transformation of difficulties into political problems. Stone's description of causal ideas is helpful:

[10] Ibid., 43-44.
[11] Deborah Stone, "Causal Stories and the Formation of Policy Agendas." *Political Science Quarterly* 104, no 2 (1989): 281.

> Problem definition is a process of image making, where the images have to do fundamentally with attributing cause, blame, and responsibility. Conditions, difficulties, or issues thus do not have inherent properties that make them more or less likely to be seen as problems or to be expanded. Rather, political actors *deliberately portray* them in ways calculated to gain support for their side. And political actors, in turn, do not simply accept causal models that are given from science or popular culture or any other source. They compose stories that describe harms and difficulties, attribute them to actions of other individuals or organizations, and thereby claim the right to invoke government power to stop the harm. Government action might include prohibition of an activity, regulation, taxation, economic redistribution, criminal sanctions, education campaigns, direct compensation to victims (through social assistance or special funds), and mandated compensation of victims (through litigation).[12]

At present, the public policy agenda related to Aboriginal employment in northern Saskatchewan is an unstructured policy problem. It is fragmented and fails to address the challenges and opportunities associated with new digital technologies. The Government of Saskatchewan and its post-secondary and training institutions are not guided by a uniform agenda for mitigating the impacts of digital technology. The digital transformation of work is displacing northern Saskatchewan Aboriginal workers. They are finding themselves in direct competition with new digital machines and/or more highly skilled and experienced workers that are capable of doing more advanced tasks. At the same time, job creation in the natural resources field is decreasing, while the population of work ready Aboriginal (workers between 18-29) is at an all-time high and expected to grow rapidly in the near to medium term. The prospect that there will be fewer jobs that require basic skills in northern Saskatchewan threatens to undermine the gains in Aboriginal employment, education and training over the past several decades. Fewer employment opportunities for Aboriginal workers will disrupt families, communities and the entire northern region as Aboriginal peoples struggle to find jobs and earn an income to support their needs.

The first step in agenda setting is for the policy universe and relevant policy sub-system to acknowledge the cause of the transformations occurring in the workplace and its wider effects on the workforce. Stone's work on causal stories informs the policy problem and narrative in this thesis. The causal story about Aboriginal job displacement is rooted in the emergence of digital technologies capable of performing complex and simple social and physical tasks. In setting the policy agenda, politicians,

[12] Ibid., 282.

educators and leaders of the north must recognize what is happening and understand what is at stake. This thesis attempts to define and share the policy problem by developing the causal story for how the digitization of work affects northern Aboriginal employment. The provincial government, its policy makers and educational institutions are not prepared for the new digital economy, digital work or jobs and the disruptive impact of digital technologies on Aboriginal workers in the northern Saskatchewan resource industry. Following Stone's causal story theory is step towards clarity and consensus.

Overview of Research Design

Research Problem

Problems may originate from a variety of places, including as Creswell explains, "a void in the literature, and conflict in research results in the literature, topics that have been neglected in the literature, a need to lift up the voice of marginalized participants and "real-life" problems found in the workplace, the home, the community and so forth."[13] The identification of the problem that the researcher believes needs to addressed is the starting point for research design. This thesis's problem is multi-faceted and matches Creswell's description of the origins of problems. It is also unstructured and not on the public policy agenda. The research question for this thesis is twofold: how are digital technologies contributing to Aboriginal workforce vulnerability in the mining sector in northern Saskatchewan and how are the relevant provincial stakeholders responding. These questions were inspired by a lack of literature on the matter and the potentially disruptive impacts on Aboriginal workers in northern Saskatchewan.

This thesis found that the Saskatchewan Government is not ready for the digital economy in the north and does not appear to be preparing the northern workforce for the widespread introduction of new digital technologies. New and emerging digital technologies have the potential to make the future of work more digital and less physical. In the northern Saskatchewan region, the provincial government and its public policy response needs to assist Aboriginal youth and workers in preparing for the future jobs in northern economy more reliant on digital technologies. Avoiding this important issue will jeopardize the

[13] John W. Creswell, *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (Los Angeles: Sage Publications, 2014), 20.

collective future of Aboriginal youth and their ability to find jobs in or near their community, in the same numbers as in the past.

One of the key findings of this thesis is the poorly defined policy agenda for digital work and economy in the northern Saskatchewan region. The provincial government appears to be focused on traditional and reactive models of employment training designed for 20th century skills training and work, even though there is already evidence that the digital technologies are changing the nature of work and increasing the demand for digitally-skilled knowledge workers. This thesis focuses on the digitization of work in northern Saskatchewan and the probable implications for northern economic development, education and job training. It recognizes the significant potential of digital technologies in the northern Saskatchewan minerals sector (such as autonomous driverless vehicles, unnamed remotely operated drones, advanced computers, the Internet of Things and next generation robots.). The study examines the disruptive impact of new and emerging digital technologies on the Aboriginal workforce in northern Saskatchewan. It also considers the degree to which the Government of Saskatchewan and its teaching institutions are ready to reduce the Aboriginal workforce vulnerability caused by digital technologies.

Methods 1: Literature Review

A literature review helps to "determine if a topic is researchable, to report the results of closely related studies, and to establish the importance of the current study in relationship to previous studies."[14] It is important to situate the research questions within the existing literature, concepts and trends. A literature review shows that the topic of this thesis is timely, has serious implications for the society and is of importance to researchers in several fields. As Boote and Beile argue: "To advance our collective understanding, a research or scholar needs to understand what has been done before, the strengths and

[14] Tonette S. Rocco and Maria S. Plakhotnik, "Conceptual Frameworks, and Theoretical Frameworks: Terms, Functions and Distinction," *Human Resource Development Review* 8, no. 1 (2009): 120-130.

weaknesses of existing studies, and what they might mean." [15] They argue that research is about learning from previous works and building on them in order to make a unique contribution to the field of study.

A review of literature in academia, government and industry was conducted to determine the state of current understanding about the impact of digital technological change on work and to identify the gaps or conflicts in the scholarship. The digitization of work is clearly an emerging field of study. Many authors believe that digital technologies are having a disruptive impact on work and the economy. They suggest that the digitization of work is happening at a rapid pace across the whole economy, and that is causing a disruption in jobs as many are eliminated, relocated or adapted by the new and emerging technologies. The scholarship is uncertain and repetitive. Scholars are busying themselves with trying to establish better theory and methods to reduce uncertainty about the future and allow time to prepare mitigating policies and programs.

Method 2: Surveys

A core element in this project was a combination of survey with key senior government and industry professionals involved in the employment, recruitment and training of people for work in the Saskatchewan mining sector. Surveys are commonly used in qualitative research to gather and understand the ideas, beliefs and perceptions of specific target population. A survey is defined as "a systematic method for gathering information from (a sample of) entities for the purposes of constructing quantitative descriptors of the attributes of the larger population of which the entities are members.[16] The literature review informed the development of survey questions. The survey assessed current knowledge of key concepts in this thesis (ex. digitization of work, digital economy and disruption) and provided an early understanding of participants' institutional perspective. Participants occupied senior or middle positions in their organization and considered to be the subject matter expert. By completing the survey, the

[15] David N. Boote and Penny Beile, "Scholars before Researchers: On the Centrality of Dissertation Literature Review in Research Preparation," *Educational Researcher* 34, no. 6 (2005): 3.
[16] Robert M. Groves et al., *Survey Methodology* (Hoboken, New Jersey: John Wiley & Sons, Inc., 2009), 2.

participants become familiar with this thesis and had time to prepare their responses to key informant interviews.

Many of the individuals contacted declined to participate. The typical reason for refusal to participate was a lack of knowledge about mining, innovation or employment issues or they believed someone else would be a more appropriate. Some individuals did not respond to participation invitations, even after repeated requests were made by email and telephone. This was most common among the potential mining industry participants.

Method 3: Key Informant Interviews

As a complement to the surveys described above, key informant interviews were conducted using a convenience sub-sample of the survey participants. Recruiting key informants began with an initial list of names provided by known Saskatchewan minerals experts, particularly the International Minerals Innovation Institute located in Saskatoon. The list of names grew as more individuals learned of the project and suggested other people who were suitable candidates. Key informants were selected using the snowball technique and preference was given to public policy specialists working on labour market and economic development in the northern Saskatchewan mining industry.

Key informants participated in in-depth face-to-face or telephone interviews. This type of qualitative research interview is common when the goal is to let the interviewee share their experiences and perspectives. Influenced by the research questions, literature review and survey results, the semi-structured interviews allowed participants to the opportunity to "share as much information as possible, unselfconsciously and in his or her own words."[17] The interview questions served only as a roadmap and starting point for deeper discussion; it was anticipated that the pre-determined questions would encourage follow-up and new questions.

[17] Barbara DiCicco-Bloom, "The Qualitative Research Interview," *Medical Education* 40, no. 4 (2006): 317.

Chapter 1: Literature Review

This literature review drew on traditional sources (e.g., books and journal articles), government documents, relevant reports and sector news articles. An appreciation of specific theories in the literature, such as creative destruction, technological unemployment and digitization of work, influenced the research questions and the underlying narrative.

There is an ongoing debate among academics and labour force analysts about the nature of the technological change that is happening in the global economy, particularly as it relates to emerging digital technologies. Brynjolfsson and MacAfee (2014); Frey and Osborne (2013); Manyika et al. of the McKinsey Global Institute (2013), Ford (2015), the Brookfield Institute at Ryerson University (Canada) (2016) and the World Economic Forum (2016) claim that digital technologies are contributing to economic and social change that is different from previous experiences with technological change. They contend that in the twenty-first century technological change is happening more rapidly and broadly, affecting nearly all types of productive activity.[18]

Much of the academic analysis has been based on previous examples of past technological impacting employment. Many scholars cite the Industrial Revolution as the starting point for the analysis of the impact of technology on economic change. New technologies during the first industrial age greatly increased the productive capability of workers and actually created more jobs than were lost to machines. The mechanization of work resulted in the elimination of jobs that required muscle power and manual labour, but even more jobs were created in the factories and industrial cities. Fears of technological unemployment dissipated as it become apparent that unemployed workers were able to find new jobs created by the new mechanized technologies and industrial production processes.

As early as 1930 John Meynard Keynes, the highly regarded British economist, wrote about economic pessimism and deteriorating prosperity in Great Britain in *Economic Possibilities for our*

[18] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton & Company, 2014).

Grandchildren (1930). Keynes began his essay with an assessment of the British nation in the early 1930s:

> We are suffering, not from the rheumatics of old age, but from the growing-pains of over-rapid changes, from the painfulness of readjustment between one economic period and another. The increase of technical efficiency has been taking place faster than we can deal with the problem of labour absorption; the improvement in the standard of life has been a little quick…[19]

He was worried that technological change was happening too fast and that workers were losing their jobs faster than they could find new ones. The gloomy state of affairs in Britain caused Keynes to consider two questions:

> (1) What can we reasonability expect the level of economic life to be a hundred years hence?
>
> And:
>
> (2) What are the economic possibilities for our grandchildren?

Keynes had a pessimistic view of rapid change caused by new powerful mechanical technologies: "For the moment the very rapidity of these changes is hurting us and bringing difficult problems to solve" and the emergence of technological unemployment, which he described as "unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new use for labour."[20] Keynes expected mechanical technologies to replace human workers, reduce the number of jobs available for humans and result in long-term unemployment.

Alois Schumpeter's theory of creative destruction and innovation have factored prominently into the debate on technological change. Schumpeter argued that ongoing creative and destructive forces cause economic change. He theorised that creative destruction was "the essential fact about capitalism."[21] According to Schumpeter, creative destruction is the force of destruction and creation: "the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumer's good, the new

[19] John Maynard Keynes, *Economic Possibilities for Our Children* (New York: W.W. Norton and Company, 1963), 358.
[20] John Maynard Keynes, *Economic Possibilities for Our Children*, 361.
[21] Joseph A. Schumpeter, *Capitalism, Socialism & Democracy* (London, UK: Routledge, 2003), 83.

methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprises creates." Schumpeter believed that creative destruction was the process of change that "incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one."[22] Schumpeter's theory of creative destruction provided an explanation of how economies and societies throughout human history have produced and been changed by new technologies that eventually lead to enhanced production processes and systems. In Schumpeter's mind, creative destruction was the cause of great transformations in social life and the economic order.

In the 1995 book *End of Work*, author Jeremy Rifkin painted a bleak picture of ordinary workers in the future, although he does so with a caveat: if our leaders make smart decisions that do not leave ordinary workers worse off and attempts to reduce the harmful effects of rapid change on ordinary people, they will not be left behind. Rifkin framed his thesis around the unemployment of workers around the world, declaring in the first sentence of his book that "global unemployment has now reached its highest level since the great depression of the 1930s."[23] The cause of high levels of unemployment was a "technology revolution," which he thought was eliminating jobs and forcing large portions of the global workforce into unemployment. Rifkin suggested the world was in the midst of a "third great industrial revolution." In every sector and industry of the economy, technological advancement resulted in new smart machines and products, such as computers and communications technologies, that substituted human workers. Rifkin believed the world had entered the "Information Age" premised on the amazing abilities and potentials of new technologies, many of which were based on digital power.

Rifkin was writing at a time of great turbulence and change in the global economy, but also of significant wealth generation, concentrated in large multi-national corporations. He pointed to the dire state of labour and its increasing vulnerability, citing reports of worker layoffs from profitable companies in the United States. Rifkin believed labour was under siege and things could get worse, noting: "Already,

[22] Ibid., 83.
[23] Jeremy Rifkin, *The End of Work: The Decline of the Global Labor Force and the Dawn of the Post-Market Era* (New York: Putman Books, 1995), xv.

millions of workers have been permanently eliminated from economic process, and whole job categories have shrunk, been restructured, or disappeared." Rifkin observed that the reduction of employment was the preferred method to lower costs, increase productivity and profits. Large firms knew that the new digital technologies offered an efficient method for wealth generation. Labour was forced into competition with powerful new technologies that could outperform humans in certain tasks. The demand for and the value of human labour was undercut and subordinated to computers and software. Business executives cared about making bigger profits and increasing economic value for their shareholders. Profit maximization and indifference to human labour harmed workers since many lost their jobs permanently and ended up filling the growing ranks of the unemployed and underemployed.

By proclaiming that the end of work was underway and soon to be realized, Rifkin challenged traditional notions of work and human identity. As he explained, work has been a central human activity and indispensable fact of life that can be traced back to at least Paleolithic times (the era of the earliest hunter/gatherers) through every major civilization right up to modern times. But this trend may not hold true for much longer if Rifkin is correct. He observes that "for the first time, human labour is being systematically eliminated from the production process."[24] The drive force of this seismic change are sophisticated information and communication technologies or, in short form, "intelligent machines".

One can reasonably speculate that Rifkin interpreted the end of work as the logical outcome of rising unemployment caused by the continued machine substitution for human workers. He frequently returned to the underlying assumption of his argument: that humans are losing their jobs to machines, and as technologies replicate and outperform workers in an increasing number of human tasks, the need for human labour will decrease until it is eventually irrelevant. Rifkin's theory argues that "The introduction of more sophisticated technologies, with the accompanying gains in productivity, means that the global economy can produce more and more goods and services employing an ever smaller percentage of the

[24] Jeremy Rifkin, *The End of Work: The Decline of the Global Labor Force and the Dawn of the Post-Market Era* (New York: Putman Books, 1995), 3.

available workforce."[25] So as technology improves, the situation worsens for human workers, a causal link that is reflected in the unemployment and underemployment statistics, both categories had been increasing steadily prior to and at the time the *End of Work* was published.

Rifkin blames conventional economic wisdom for technological adoption and rising levels of unemployment. The prevailing belief among economic thinkers and businesses is that "new technologies boost productivity, lower the costs of production, and increase the supply of cheap goods, which, in turn, stimulates purchasing power, expands markets, and generates more jobs."[26] Underlying this economic model is the acceptance of technology adoption as representing progress and a positive development. The problem with the accepted economic wisdom of the late twentieth century is that it led to "unprecedented levels of technological unemployment, a precipitous decline in consumer purchasing power, and the specter of a worldwide depression of incalculable magnitude and duration."[27] This sort of economic thinking is based on the idea that "the dramatic benefits brought on by advances in technology and improvements in productivity eventually filter down to the mass of workers in the form of cheaper goods, greater purchasing power, and more jobs is essentially a theory of trickle-down technology."[28] Rifkin noted that labour eventually received a portion of the economic benefits, but not typically without significant labour displacement.

The rapid improvement of digital technologies in the twenty-first century and their potential substitution for humans has increased technological anxiety and concerns about the future of work. Joel Moykr et al. argue that "these worries are not new to the modern era and that understanding the history provides perspective on whether this time is truly different."[29] Generation after generation has had serious concerns and anxiety about new technologies, usually during times of economic hardship. The literature has portrayed technology as "…as alien, incomprehensible, increasingly powerful and threatening, and

[25] Ibid., 11.
[26] Ibid., 15.
[27] Ibid., 15.
[28] Ibid., 15.
[29] Joel Mokyr, Chris Vickers and Nicolas L. Ziebarth, "The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?" *Journal of Economic Perspectives* 29, no. 3 (2015): 32.

possibly uncontrollable."[30] Mokyr et al. provide a comprehensive overview of the literature on technology anxiety through history, arguing worries about technological change can be divided into three categories, including: concern about massive substitution of machines for labour, anxiety about the moral implications of technological progress for human welfare and worries that technological progress has stalled for good. They find that current technology anxiety and speculation about the future have occurred before and twenty-first century technological change does closely resemble past iterations.

Mokyr et al. suggests that the first radical technological revolution, the Industrial Revolution in Western Europe, serves an excellent starting point for a discussion about the potential impacts of technological change on labour. Scholars from the 18th century on debated "how technological progress affected workers and how these effects might differ between the short run and the long run."[31] Their debate focused on two questions: "In the short run, could technological innovation lead to lower employment or lower wages? If there were long-run negative effects, were these innovations still worthwhile?"[32] David Ricardo initially acknowledged that the application of technology to productivity was "a general good" although he later concluded that the "substitution of machinery for human labour is often very injurious to the interests of the class of labourers … [It] may render the population redundant and deteriorate the condition of the labourer."[33] Ricardo's change in views is reflective of the "long- versus short-run effects of technological change."[34] Moykr et al. challenge policy-makers and government to design policies and programs that will mitigate the worst effects on displaced workers. They make their point by looking back to the great transformation of the 19th century in Western Europe: "The path of transition to this economy of the future may be disruptively painful for some workers and industries, as transitions tend to be. However, while the earliest transitions such as the Industrial Revolution were done

[30] Ibid., 31.
[31] Ibid., 33.
[32] Ibid., 33.
[33] Ibid., 33.
[34] Ibid., 33.

with little governmental support for those displaced, this one will require public policy to ameliorate the harshest effects of dislocation."[35]

The emergence of new labour saving technologies that increase productivity and lower the need for human workers has, over the last two centuries, caused many to worry about the disappearance of middle class jobs and long-term unemployment. David Autor (2015) begins his discussion about history of automation and its influence on employment with a reminder: "the past two centuries of automation and technological progress have not made human labour obsolete: the employment-to-population ratio rose during the 20th century even as women moved from home to market; and although the unemployment rate fluctuates cyclically, there is no apparent long-run increase."[36] Even so, society has frequently expressed considerable technological anxiety, linking automation to joblessness, some going as far as to declare the end of work is right around the corner. Autor cites a *Time* article from 1961 to illustrate his point:

> The number of jobs lost to more efficient machines is only part of the problem. What worries many jobs experts more is that automation may prevent the economy from creating enough new jobs…Throughout industry, the trend has been to bigger production with a smaller work force…Many of the losses in factory jobs have been countered by an increase in the service industries or in office jobs. But automation is beginning to move in and eliminate office jobs too…In the past, new industries hired far more people than they put out of business. But this is not true of many of today's new industries … Today's new industries have comparatively few jobs for the unskilled or semiskilled, just the class of workers whose jobs are being eliminated by automation.[37]

Autor probably selected this passage from the *Time* article because it so perfectly mirrors the twenty-first century debate on the impact of digital technologies on jobs. In 1950s and 1960s, experts were concerned that automation was destroying more jobs than were being created and that the workforce was shrinking in size. They argued that the new service industries were closed to the ordinary worker and employed fewer workers, which represented a break from the past. Experts today have similar concerns about digital technologies and their effect on joblessness and unemployment. Once again fears that

[35] Ibid., 47.
[36] David H. Autor, "Why Are There Still So Many Jobs? The History and Future of Workplace Automation," *Journal of Economic Perspectives* 29, no 4 (2015): 4.
[37] Ibid., 3.

technology eliminates jobs, causes joblessness and long-term unemployment have regained prominence. Much of the recent literature is based on the contention that this time is really different than past times of technological change. Autor summarizes present day worries about technological unemployment: "those concerned about automation and employment are quick to point out that past interactions between automation and employment cannot settle arguments about how these elements might interact in the future: in particular, the emergence of greatly improved computing power, artificial intelligence, and robotics raises the possibility of replacing labour on a scale not previously observed."[38] Scholars who are afraid of what the digitization of work could mean for ordinary workers claim that there is no rule or guarantee in economics that states "every adult will be able to earn a living solely on the basis of sound mind and good character."[39] They believe their concerns about the future of work and how new digital technologies contribute to it, are valid and worth discussing.

Autor believes journalists and expert commentators "tend to overstate the extent of machine substitution for human labour and ignore the strong complementarities between automation and labour that increase productivity, raise earnings, and augment demand for labour."[40] He acknowledges that new technologies are a substitution for labour, which is frequently the point, and directs attention to how technology changes job availability, wages and complements labour. Autor believes more focus is needed on how digital technologies have the potential to complement human labour. Given the challenges of substituting machines for workers in tasks requiring complex non-routine and social interactions, digital technologies create a comparative advantage for humans who can perform those tasks, which raises the value of the task that only workers can supply.

Autor's earlier work (2003) describes how the computerization of tasks results in substitution or the complementarity of labour. He aims to discover "What is it that computers do – or what is it that

[38] Ibid., 4.
[39] Ibid., 4.
[40] Ibid., 5.

people do with computers – that appears to increase demand for educated workers?"[41] Autor's analysis is based on two points:

> (1) that computer capital substitutes for workers in carrying out a limited and well-defined set of cognitive and manual activities, those that can be accomplished by following explicit rules (what we term "routine tasks"); and
>
> (2) that computer capital complements workers in carrying out problem-solving and complex communication activities ("non-routine tasks").

Autor accepts that the computerization of labour is skill-biased, but notes the literature does not offer an explanation as to why this is the case. He proposes a task model to show how computers "affect the tasks that workers and machines perform".[42] Autor's task model asks a basic question: which tasks can be best performed by a computer? Jobs are divided into two categories. Routine tasks can be accomplished by machines following explicit programmed rules. Non-routine tasks are those that are too complex or not well understood enough to be specified into computer code and executed by machines.[43] Autor's work is significant because he is able to demonstrate how computers affect jobs and tasks. He answers his question of what computers do and how workers use the technology: "Computer technology substitutes for workers in performing routine tasks that can be readily described with programmed rules, while complementing workers in executing non-routine tasks demanding flexibility, creativity, generalized problem-solving capabilities, and complex communications"[44] Autor provides the evidence of what has been assumed to be true in the past: that educated workers with the right skills have a comparative advantage in non-routine tasks, which increases demand for their labour.

Goos and Manning are interested in how technology affects employment patterns. They observe that job polarization, which describes the increasing gap between high and low-income occupations and the hollowing of middle class jobs, has occurred in the United Kingdom since 1975. Goos and Manning find that the recent literature on the impact of technology on the labour market in recent years "tended to

[41] David H. Autor, Frank Levy and Richard J. Murnane, "The Skill Content of Recent Technological Change: An Empirical Exploration," *The Quarterly Journal of Economics* 118, no 4 (2003): 1322.
[42] Ibid., 1282.
[43] Ibid., 1282.
[44] Ibid., 1322.

emphasize the role played by Skill-Biased Technical Change (SBTC), the idea that technology is biased in favour of skilled workers and against unskilled workers.[45] Goos and Manning compare skill-biased technical change with Autor et al's routinization hypothesis:

> The SBTC hypothesis predicts that the demand for "skilled" jobs is rising relative to that for "unskilled" jobs, while the ALM hypothesis suggest a more subtle impact of technology on the demand for labour of different skills. The routine task in which technology can substitute for human labour include jobs like craft manual jobs and bookkeeping jobs that require precision and, hence, were never the least-paid jobs in the labour market. The non-routine tasks which are complementary to technology include skilled professional and managerial jobs that tend to be in the upper part of the wage distribution. The non-routine manual tasks that make up many of the unskilled jobs such as cleaning are not directly affect by technology, but the impact of technology in other parts of the economy is likely to lead to a rise in employment in these unskilled jobs.[46]

Goos and Manning believe a new approach, developed by Autor et al (2003), is more nuanced and provides a better explanation for job polarization. Autor found that routine jobs are more likely to experience change because of digital technologies whereas jobs requiring the performance of non-routine and intangible tasks, like complex thinking, reasoning and interaction are less likely to be changed due to their limitations. These analytic and interactive jobs execute non-routine tasks and need high levels of advanced education and training. Digital technologies of today are able to substitute jobs and tasks that are primarily routine, manual and even analytic and interaction (Figure 2). This job risks framework applies to northern Saskatchewan. Aboriginal workers tend to work in mining jobs that are routine and manual, which are at risk of being lost to digital technologies.

[45] Maarten Goos and Alan Manning, "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain," T*he Review of Economics and Statistics* 89, no. 1 (2007): 118.
[46] Ibid., 118.

Figure 2. Non-Routine & Routine Workplace Tasks

	Routine tasks	Non-routine tasks
	Analytic and interactive tasks	
Examples	• Record-keeping • Calculation • Repetitive customers service	• Forming/testing hypotheses • Medical diagnosis • Legal writing • Managing others
Computer impact	Substantial substitution	Strong complementarities
	Manual tasks	
Examples	• Picking or sorting • Repetitive assembly	• Janitorial services • Truck Driving
Computer impact	Substantial substitution	Limited opportunities for substitution or complementarity

Source: Data from David H. Autor, et al, "The Skill content of Recent Technological Change: An Empirical Exploration," *The Quarterly Journal of Economics*, 118 no.4 (2003).

Pratt (2015) describes how a major past evolutionary episode can inform thinking about what is next for robotics and human work. The growing applications and capabilities of robots may be similar to the Cambrian Explosion, which is known for the rapid diversification of life that occurred about a half a billion years ago on earth. Like the incredible diversification of life that arose during the Cambrian Explosion, Pratt suggests "technological developments on several fronts are fomenting a similar explosion in the diversification and applicability of robotics."[47] Recent developments in "Cloud Robotics" (robots learning from robots) and "Deep Learning" (robots learn and generalize their associations from the cloud) increase what robots can do. For Pratt, the questions are when can we expect a Cambrian Explosion of robots and what are the implications for work. The emergence of robots based on advanced Cloud Robotics and Deep Learning technologies will be a "disruptive economic force, in large part because of its much-discussed potential to make certain human jobs redundant."[48] But this may not result in the end of work, since the global economy has been changed by new technologies before.

Pratt looks to the past interactions between technology and the labour market for insights and possible modern-day implications. Labour is impacted by new technologies, but even as jobs are lost the

[47] Gill A. Pratt, "Is A Cambrian Explosion Coming for Robotics?" *Journal of Economic Perspectives* 29, no. 3 (2015): 51.
[48] Ibid., 57.

creation of new industries have absorbed surplus labour. This pattern has repeated itself throughout history:

> Technology enabled an increase in output in certain areas. Demand for the good produced in that area became at least somewhat satiated, but the people were not satiated in their wants and instead soon discovered new areas of demand. Some human labour was displaced as technology expanded, but supply and demand in the labour market drove a series of transitions so that labour shifted to meet the new demand in other areas, and there was no sustain trend to greater unemployment.[49]

Today, the worry is that new digital technologies will destroy more jobs, reduce the need for human labour and result in massive unemployment and underemployment. Proponents of this view argue that this time is truly different because the technologies in question are more powerful and capable than in the past and that the speed of change is unprecedented. Pratt summarizes this line of thinking, which emphases the capabilities of digital technologies, the accelerated rate of change and the diminishing need for human labour:

> When robot capabilities evolve very rapidly, robots may displace a much greater proportion of the workforce in a much shorter time than previous waves of technology. Increased robot capabilities will lower the value of human labour in many sectors. Human abilities as suppliers, even in highly educated societies, evolve slowly. In other words, the increase in robot capabilities may be so rapid that many human workers may find themselves with little to sell.[50]

In their 2014 book *The Second Machine Age* on the potential implications of digital technologies on society and work, Erik Brynjolfsson and Andrew McAfee noticed that digital machines, like computers, software and communications networks, were starting to do things long thought impossible and even competing with or outperforming humans in certain tasks. They called this an "inflection point" that marks the beginning of a 'second machine age.' From this point onwards, digital technologies will bring about massive change, result in wonderful advances and progress, but they will also create challenges and a lot of uncertainty. Brynjolfsson and McAfee argue that the digital economy is likely to make high-skilled, educated workers better off, but have the opposite effect on ordinary, low-educated

[49] Ibid., 57.
[50] Ibid., 58.

workers. For these workers, digital technologies usually complement their task, which according to Brynjolfsson and McAfee means: "there's never been a better time to be a worker with special skills or the right education, because these people can use technology to create and capture value" whereas the opposite is true for "a worker with only 'ordinary' skills and abilities to offer, because computers, robots and other digital technologies are acquiring these skills and abilities at an extraordinary rate."[51]

Martin Ford describes an undesirable future for workers and society in *Rise of the Robots*. His central point is that the future will not be kind to human workers because automated robots, computers and software will increasingly encroach on human jobs and tasks. The new era of work will challenge old assumptions about who works and in what ways. New and emerging digital technologies are the main contributor to the rise of robots and decline of human work. They are not only disruptive to work and jobs but also cause rapid and revolutionary change. How disruptive remains to be seen, but Martin Ford offers an assessment of what the jobs of the future will be and imagines what a digital economy might look like. The new digital economy and the digital technologies that are making it possible are resulting in a "fundamental shift in the relationship between workers and machines."[52] Ford describes the shift and his vision of the future in a new twenty-first century digital era:

> That shift will ultimately challenge our most basic assumptions about technology: that machines are tools that increase the productivity of workers. Instead machines are themselves are turning into workers, and the line between the capability of labour and capital is blurring as never before.[53]

Martin Ford believes digital technologies will create new industries, but overall, the global economy will be less-labour intensive and difficult for disrupted workers to adapt and find new jobs.[54] In the digital economy, machines will not only be tools to increase human productivity, but will be capable of replacing humans in more and more jobs.

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[51] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Work Progress and Prosperity in a Time of Brilliant Technologies* (New York: W.W. Norton & Company, 2014), 11.
[52] Martin Ford, *The Rise of the Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books, 2015), xii.
[53] Ibid., xii.
[54] Martin Ford, *The Rise of the Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books, 2015), xxii.

In 2013, the McKinsey Global Institute released a report on the "economically disruptive technologies" that will have the greatest potential to upset the status quo and affect employment, business models and the world economy. According to their report, "the nature of work is changing" and it is time to "find ways to turn the disruptions into positive change."[55] The goal of the report was not to predict the future, but to identify the disruptive technologies and assist policy-makers, governments and business leaders in preparing for their potential impacts on economic activity. These digital technologies, such as the mobile internet, the Internet of Things and advanced robotics, will bring large-scale changes in both economies and societies.

Nearly half the jobs in the United States are at risk of being lost to new digital technologies, due in large part to recent advances in Machine Learning (ML) and Mobile Robotics (MR). Frey and Osbourne (2013) found that 47 percent of total US employment is at risk.[56] The authors were influenced by John Maynard Keynes' prediction of "technological unemployment" caused by machine substitution in an ever increasing number of human jobs. They set out to quantify the impact of technological progress on the future of employment.[57] Frey and Osbourne believe computerization, which refers to job automation by means of computer-controlled equipment, will have greater impact on low-income manual jobs than high-income cognitive jobs. These lower skilled, ordinary workers are susceptible of job computerization based on current digital technologies, which makes predictions about the future of employment difficult, considering the rapid pace of development and the computerization of more jobs.

In 2015, McKinsey and Company investigated the impact of digital technologies on work in different sectors. Their multi-year study is based on the assumption that new and emerging digital technologies, such as artificial intelligence and advance robotics, have the potential to cause transformative change in how work is done in nearly all sectors of the economy. The digitization of work

[55] James Manyika, Michael Chui, Jacques Bughin, Richard Dobbs, Peter Bisson and Alex Marrs, *Disruptive Technologies: Advances that will Transform Life, Business and the Global Economy*, McKinsey & Company, 2013, 21.
[56] Carl B. Frey and Michael A. Osborne, *The Future of Employment: How Susceptible Are Jobs to Computerization?* Oxford University, 2013, 1.
[57] Ibid., 3.

because of new digital and automation technologies has received a lot of attention in recent years, but lesser known is what the overall impact of automation will be on jobs requiring different levels of education and competencies in different sectors. Plentiful are examples of the digital technologies that will cause change to work.

Clarifying the potential of automation and its impact on jobs was the central focus of a recent report published by the McKinsey & Company. The authors concluded that 45 percent of tasks that humans are paid to do in the United States can be performed "by adapting currently demonstrated technologies." But they stop well short of declaring massive job losses or the end of work for humans:

> Our results suggest, first and foremost, that a focus on occupations is misleading. Very few occupations will be automated in their entirety in the near or medium term. Rather certain activities are more likely to be automated, requiring entire business processes to be transformed, and jobs performed by people to be redefined…[58]

McKinsey and Company has produced evidence that suggests the percentage of jobs that can be entirely automated by current technology is "fewer than 5 percent."[59] Instead of whole occupations eliminated, the McKinsey and Company views the digitization of work as the automation of tasks. This shift away from occupations to tasks or activities allows for a more accurate description of how digital technologies affect work. Automation and related digital technologies will not eliminate work as is sometimes proclaimed in the recent literature, but redefine it through substitution or complementarity. This perspective is based on an understanding of what happens when automation technologies are introduced in the workplace. According to McKinsey & Company automation works by:

> …disaggregating jobs into their component tasks and subtasks and the hiving off those that can be automated. It will force companies to figure out how to reassemble the remaining tasks into something that makes a new kind of sense, even as it conceptualizes the very idea of what a job is.[60]

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[58]Michael Chui, James Manyika and Mehdi Miremadi, *Four Fundamentals of Workplace Automation*, McKinsey and Company: McKinsey Quartley, 2015, 2.
[59] Michael Chui, James Manyika and Mehdi Miremadi, *Four Fundamentals of Workplace Automation*, McKinsey Quartley, 2015, 5.
[60] Aaron De Smet, Susas Lund and William Schaninger, *Organizing the Future*, McKinsey and Company: McKinsey Quartley, 2016, 3.

Recent insights from McKinsey & Company indicate that machines are becoming more sophisticated and capable of doing a growing number of human tasks. They have also examined the susceptibility of tasks or activities in various sectors to automation. Their work shows "automation will eliminate very few occupations entirely in the next decade," but "it will affect portions of almost all jobs to a greater or lesser degree, depending on the type of work they entail."[61] McKinsey & Company report stresses how occupation tasks will change because of current automation and related digital technologies, and avoids trying to figure how many and which jobs will be eliminated. Such an approach provides a clearer idea of where machines could replace humans and where they can't (yet).

The report shows that the occupational category at greatest risk for automation is physical work, like welding, assembly line work, and food preparation. In related unpredictable physical work, such as construction, forestry or raising livestock, the technical feasibility of automation is low. Job tasks requiring more knowledge tasks and complex social interaction between people, such managing or developing people are the hardest to automate. This is because computers are excellent at performing well-defined tasks as instructed but lack the ability to reason, be creative and interact socially.

While Frey and Osbourne (2013) focused on the potential for computerization in occupations, a more recent study by the Organization for Economic Cooperation (OECD) examined how digital technologies affect work and jobs in 21 OECD countries. The OECD applied a task-based approach rather than an occupation-based approach. The basic assumption of the OECD study was:

> Rather than assuming that it is occupations that are displaced by machines, we argue that it is certain tasks that can be displaced. To the extent that bundles of tasks differ across countries and also within occupations, occupations at risk of being automated according to Frey and Osbourne may well be less prone to automation when considering the fact that most occupations contain tasks that are difficult to substitute at least in the foreseeable future.[62]

The OECD authors point to the problem of an occupation-approach which may lead to "an overestimation of job automatability, as occupations labelled as high-risk often still contain a substantial

[61] Michael Chui, James Manyika and Mehdi Miremadi, *Where Machines Could Replace Humans – And Where They Can't (Yet)*, McKinsey and Company: McKinsey Quartley, 2016, 1.
[62] Melanie Arntz, Terry Gregory and Ulrich Zierahn, *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis*, Paris OECD Publishing, 2016, 8.

share of tasks that are hard to automate."[63] This is because of the "heterogeneity of workers' tasks within occupations" and the adjustments of firms and workers in digitization and automation processes. The OECD concluded that 9% of jobs are automatable, a figure much lower than the 47% of jobs at risk of computerization as proposed by Frey and Osbourne. The risk of job automation is highest for low qualified workers and lowest for more highly qualified and paid workers.

Until recently, data on how automation and related digital technologies might affect the Canadian workforce has not been available. A recent report by the Brookfield Institute for Innovation and Entrepreneurship titled the *Talented Mr. Robot: The Impact of Automation on Canada's Workforce* fills the gap in the existing literature. The report follows a similar approach to Frey and Osbourne (2013) and, importantly, builds on critiques of their work. It examines the probability of jobs being restructured or completely lost. According to the Brookfield Institute, 42% of Canada's workforce is at high risk of being affected (i.e. significantly changed or permanently lost) by automation in the next 10 to 20 years.[64] Canadian workers in this category earn less and are less educated than the rest of Canada's workforce. The occupations at high risk of being automated are in trades, transportation and equipment operation, natural resources and agriculture, sales and service occupations, manufacturing and utilities, office support and general administration, and technical occupations in health, natural and applied sciences. Jobs requiring higher levels of education and those that pay more, such as in the arts and culture, management and supervision, education, law and healthcare, are supposedly at lowest risk of being affected by automation.[65]

The World Economic Forum (WEF) argues the world is going through a technological revolution that will transform how work is done, resulting in the loss of some jobs, growth in others and changes in the skill requirements in many existing and new jobs. In the WEF's *Future of Jobs* project, the focus is on addressing the foreseeable challenges in the next couple of decades. New and emerging digital

[63] Ibid., 4.
[64] Creig Lamb, *The Talented Mr. Robot: The Impact of Automation on Canada's Workforce*, Brookfield Institute for Innovation and Entrepreneurship, 2016, 3.
[65] Ibid., 10.

technologies are predicted to drive significant change in jobs, which highlights the importance of preparing for digital work. The Fourth Industrial Revolution, made possible by recent technological advances in genetics, artificial intelligence, robotics, nanotechnology, 3D printing and biotechnology, is changing the nature of work and leading to adjustments in employment, including training and education, around the world.

The *Future of Jobs* report identifies the digital technologies that are the drivers of change. Its list includes mobile and cloud technology, advances in computing power and Big Data, the Internet of Things, advanced robotics and autonomous transport, artificial intelligence and machine learning and advanced manufacturing and 3D printing. These technologies will unevenly disrupt different sectors of the economy. According to the WEF report, Digital disruption is "likely to be highly specific to the industry, region and occupation in question and the ability of various stakeholders to successfully manage change"[66] The challenge is to figure out how technologies are going to "change the skill set required in both old and new occupations in most industries and transform how and where people work…"[67] The WEF's *Future Jobs* report purpose is to show how certain industries and jobs are likely to be changed. It calls on the world and its leaders to prepare for the coming digital disruption in work. Preparations should be focused on planning to mitigate jobs displacement and equipping people in the most affected sectors and jobs for new kinds of work.

Summary

Jobs have been lost in large numbers before and did not return to previous levels. The agricultural sector in Western Canada, for example, witnessed the loss of work for many on-farm labours post-World War II, but these workers did not find the same job at another farm in a different location. They moved to the cities in large numbers for industrial jobs in factories and trades. The work was often difficult, routine and required someone capable of doing manual tasks for long hours. Farmers were well-suited for that

[66] World Economic Forum, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, Global Challenge Insight Report, 2016, 8.
[67] Ibid., 8.

kind of work. Technological change in the twentieth century created more jobs than were destroyed. Unemployed workers found they had the right skills and background to perform tasks in several different sectors. Work was plentiful, especially during the several decades following World War II and the transition between jobs, whether lost or not, was easy to do and usually resulted in higher pay and better working conditions.

The technological transformation is different in the second decade of the twenty-first century than in previous centuries. New and emerging digital technologies are quickly demonstrating human abilities, such as complex thinking, decision-making, social interactions and human movements. They are challenging and redefining the traditional definition of work and the role of human labour. Digital technologies are starting to undermine the economic basis of modern society. In the new digital age, the idea that humans sell their labour for income which allows them to buy goods and services and to live well will be called into question. Recent evidence suggests that fewer jobs are being created than in the past, even as population increases. The polarization of the labour market seems to be gaining momentum and does not appear to be slowing down anytime soon. The goal of the subsequent chapters is to define the policy problem for Aboriginal work in northern Saskatchewan, which is largely dependent on the mining industry for work. Mining is an important source of employment for Aboriginal peoples in the north, but it seems digital technologies are contributing more to workforce vulnerability than to job creation.

Chapter 2: Historical Development of Mining in Northern Canada

Industrial mining expanded substantially in northern Canada during the Second World War, 1939-1945. Low-skilled, decent paying jobs were plentiful in northern Canada, particularly for Canadians with European heritage. Before World War II, a few small-scale mines were operating across the vast Canadian north. In the northern Canadian territories, miners produced silver (Yukon), radium/uranium (Northwest Territories, NWT) and gold (NWT). War time demand led to a significant expansion of the existing mines and more mine exploration and development. Mine exploration and development continued through the 1950s and 1960s, the decades of post-war economic boom in northern Canada.[68] The post-war northern Canadian mines were industrial and large-scale, a development pattern that had a transformative impact on economic activity and the natural environment. Industrial mining became the dominant industry of the Canadian north, employing large numbers of workers. By the 1960s, industrial mining was the main source of jobs in the Canadian north, including for Aboriginal peoples. Mining for metals and fuel production accounted for over 80 percent of northern territorial economic output by the 1950s.[69]

The mining industry transformed Canada's northern regions. Mine expansion laid the groundwork for increased southern involvement in northern affairs. Mining also drew southern Canadian investment and labour into the North. At the same time, the Canadian Government became a larger presence and imposed its state power in the remote, predominantly Aboriginal north. The mining industry attracted massive amounts of public and private investments in physical infrastructure (roads, bridges, airstrips, and energy projects). Mining companies were also investing heavily in the application of new mechanical technologies in underground mining and above ground processing. The location of the mines influenced the distribution of northern Aboriginal peoples. Mine workers and sometimes their families settled in the towns and communities that emerged beside or a short distance from the new mine sites.

[68] Keeling, Arn and Sandlos, John, "Environmental Justice Goes Underground? Historical Notes from Canada's Northern Mining," *Environmental Justice* 2, no. 3 (2009): 119.
[69] Ibid., 119.

Dependence on mining strongly influenced the path of economic and social development in Canada's north.

Large-scale mine development disrupted traditional Aboriginal culture and practices. Mechanized mining activities such as (staking, drilling, line cutting and excavation) interfered with traditional Aboriginal peoples' practices like hunting, fishing and trapping. Noise, waste and activity at large mine operations, for example, disrupted the land, animals and the wider natural ecosystem. In one case, seasonal changes in weather caused mine tailings to overflow and leak, which proved harmful to fish populations and nearby communities that relied on fish for food.[70] Significantly, Aboriginal peoples did not experience substantial economic benefits of mines on their traditional lands. Mining companies hired Aboriginal workers in seasonal casual labourer jobs like guiding, wood cutting and meat hunting. Wage labour jobs at the mine were generally not available to Aboriginal peoples, in large part due to discriminatory hiring practices, difficulties Aboriginal workers had adjusting to industrial wage labour, the absence of regional training opportunities and lack of transportation to the mine. The Aboriginal mining labour force in 1968, for example, was 3.4% of the total in the Yukon Territory and 5.4% in NWT, in predominantly in lower paid, unskilled positions.[71]

Twentieth Century Mechanical Technological Change

The mechanization of underground operations and the automation of above ground processing facilities transformed the Canadian mining industry and decreased the number of mines workers. New mechanical technologies were capable of working with minimal human intervention. Mechanical and automated technologies handled heavy lifting, which reduced the need for human muscle.[72] Mechanization and automation created demands for certain skills and eliminated the need for some types of workers. Mine workers were either not required in the same numbers as in the past or removed entirely from the cycle of work, including drilling, blasting and transporting of ore. Traditional mining work relied

[70] Ibid., 118.
[71] Ibid., 118.
[72] Clement Wallace, "The Subordination of Labour in Canadian Mining," *Labour* 5 (1980): 133-148.

on simple technologies and lacked continuous performance enhancing innovations. Significant transformative change began in mining production in the late 1960s, a process that disrupted the nature of mine work across the Canadian North and around the world.

Trackless mining equipment changed production activity, for instance. Diesel ore moving machines such as scoop trams and load-haul-dumps moved large quantities of ore. Multi-boom jumbo drills, which was lever controlled by workers standing on a platform, lowered the cost of drilling compared to conventional drills. These machines reduced the number of unskilled and minimally skilled workers, replacing them with machine operators.[73] Underground mines accommodated heavy diesel equipment, like diesel powered, front-end loaders. These machines maximized company returns and reduced, often significantly, the need for northern workers.

Uranium Mining in Northern Saskatchewan

The opening of a radium mine on the eastern shore of the Great Bear Lake in the Northwest Territories in the 1930s marked the beginning of the Canadian Government's strategic and economic interest in mining uranium in the north. The federal government was eager to find uranium deposits for allied military purposes. In 1942, the Eldorado Gold Mining Company, which had been the lone uranium mining outfit in northern Canada, was nationalized by the Federal Government. Initially, renamed Eldorado Mining and Refining Limited, the new federal crown corporation eventually become Eldorado Nuclear Ltd. Exploration for and mining of uranium was restricted to Eldorado in partnership with the Geological Survey of Canada.[74]After World War II, uranium was discovered in northern Saskatchewan in the remote Athabasca region. The Eldorado Company started mining for uranium at Beaverlodge in 1953.

By the 1960s, the number of uranium mines operating decreased, even as more uranium was discovered. Uranium was no longer needed in large quantities for military application. The federal

[73] Ibid., 140.
[74] World Nuclear Association Website, "Brief History of Uranium Mining in Canada," Accessed May 2016, http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/appendices/uranium-in-canada-appendix-1-brief-history-of-uran.aspx.

government directed the Canada mining industry to a domestic, civilian energy program from military purposes. In response to a renewed government focus, new deposits of uranium were found and later developed in northern Saskatchewan's Athabasca Basin.[75] The closure of the depleted Beaverlodge mine in 1982 marked the end of labour-intensive uranium mining in northern Saskatchewan and caused the regional economy to collapse. Nearby Uranium City became accustomed to boom-bust cycles, but even it did not survive, the residents left and the population fell from about 2,500 in 1981 to 200 in 1986.[76] In the years following, uranium mining required fewer workers than in the past.

Northern Saskatchewan uranium mining has been concentrated in the Athabasca Basin for decades, beginning with the development of the Rabbit Lake mine which began producing in 1975. In the mid-1970s, Cluff Lake and Key Lake uranium deposits were found in the west and south of the Athabasca Basin. Mining in these locations started between 1980 and 1983. The 1980s was the high point of uranium exploration in northern Saskatchewan. In the early 1980s, a series of uranium deposits were discovered in the Midwest at McClean Lake and Cigar Lake. Uranium was found again in 1988 at the massive McArthur River deposit.

Northern Saskatchewan Aboriginal communities were among the first, and often most vocal supporters of expanding uranium mining in the 1980s. The La Ronge Indian Band, the largest in northern Saskatchewan, was a proponent of developing uranium mining, even though it had concerns about the potential harmful impacts on its culture and the environment. During the 1980s, the Indian Band had a fast-growing population and not enough jobs, a problem that would be alleviated with further mine development.[77] Job creation and future economic prosperity factored into local decision-making. The La Ronge Indian Band believed job creation and business start-up would follow the expansion of uranium mining.

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[75] Ibid., World Nuclear Association.
[76] Lesley McBain, "Uranium City," The Encyclopedia of Saskatchewan: A Living Legacy, accessed May 2016, http://esask.uregina.ca/entry/uranium_city.html.
[77] McIntyre, J and Chief H.D. Cook, *Corporate Social Responsibility and Aboriginal Relations*, International Atomic Energy Agency, 2000, 115.

Uranium mining has been the primary source of economic development and jobs in northern Saskatchewan for several decades. In 1988, a merger between the Saskatchewan Mining Development Corporation and the Eldorado mine company formed the Cameco Corporation, which is currently the main mine operator in northern Saskatchewan. Ownership of the northern mines was transferred to Cameco, which made the mining company the largest and most influential in northern Saskatchewan. Cameco successfully trained and employed large numbers of Aboriginal peoples living in northern Saskatchewan, made Aboriginal recruitment an important priority for the mine company.[78] Cameco has been a leading voice encouraging the Canadian mining industry to hire Aboriginal workers in all types of mine work. One of Cameco's stated corporate goals is to hire at least 50% of its operational workforce from northern Saskatchewan. Over the years, Aboriginal workers have represented about half of Cameco's operational workforce. There have been attempts to recruit Aboriginal workers to middle and senior management positions, but finding suitable candidates proved a difficult task. Training and education programs have been developed to help Cameco meet its employment targets.[79]

In recent years, Cameco made it clear that Aboriginal employment, training and engagement were top priorities for the company. Cameco has worked towards maximizing local economic and social benefits by aggressively employing Aboriginal workers. From 1992 to 2000, 50% of all new employees hired were of Aboriginal ancestry. In 2000, 450 employees were Aboriginal, which represented 45% of the operational workforce.[80] Cameco has been acknowledged as one of Canada's strongest proponents of corporate social responsibility in mining and including Aboriginal peoples in its mining operations.[81] Cameco has also remained committed to ensuring Aboriginal communities receive a fair share of the economic benefits from northern mining. Whenever possible Cameco has done business with local supply

[78] Ken Coates et al., *Unearthing Human Resources: Aboriginal Skills Development and Employment in Natural Resource Sector*, McDonald-Laurier Institute, 2015, 8.
[79] Cameco Corporation, "On-the-Job Training," accessed May 2016, https://www.cameco.com/careers/students/training.
[80] McIntyre, J and Chief H.D. Cook, *Corporate Social Responsibility and Aboriginal Relations*, International Atomic Energy Agency, 2000, 116.
[81] McIntyre, J and Chief H.D. Cook, *Corporate Social Responsibility and Aboriginal Relations*, International Atomic Energy Agency, 2000, 118.

and service businesses and has included employment, training, community benefits and business opportunities in their collaboration agreements with northern settlements.

Aboriginal peoples have viewed mining projects with mixed-feelings, even after decades of positive economic contributions to the northern region. The development of mines on traditional lands creates jobs and provide economic stimulus in remote, poor communities. Public and private dollars are invested in public infrastructure like schools, hospitals, roads, community projects and bridges. Aboriginal communities have experienced positive economic spin-off from mine development which has led to the creation of support businesses and the emergence of a local service industry.[82] Economic gains have not been achieved with serious costs to traditional culture and lifestyle. Many Aboriginal communities have experienced both positive and negative outcomes caused by mine development. The negative impact of mine operations on natural ecology, including people is a frequently cited disruption. Northern Canadian mines have caused ecological and social harm to northern Canadian Aboriginal communities, resulting in "a loss of ability to hunt, fish and gather; a loss of freedom of movement; locals being forced to resettle or relocate and; a fundamental disrespect for traditions." [83]

Mining Economic and Employment Development Agreements in northern Saskatchewan

The uranium mining industry in northern Saskatchewan recognizes the importance of hiring Aboriginal peoples and is committed to recruiting them for jobs. The Cameco Corporation is the largest mining company and largest private-sector employer of Aboriginal workers in northern Saskatchewan. Recent employment statistics (Table 2) show that is a major employer of local northern residents. Aboriginal leaders and the northern mining companies are worried about future employment opportunities in the northern Saskatchewan mining sector. These anxieties over future work are based on the rapid population increase of Aboriginal peoples and the emergence of new digital technologies. Adding to this

[82] Gavin Hilson, "An Overview of Land Use Conflicts in Mining Communities," *Land Use Policy* 19 (2002): 66.
[83] Ibid., 66.

simmering anxiety is the depressed market for northern minerals and uncertainty about price, two factors of considerable importance to employment levels.

Table 2. Cameco Local Hires

	2010	2011	2012	2013	2014
Local Employees	703/1,410	761/1,505	756/1,531	747/1,500	794/1,600
% of employees from local northern communities	49.9%	50.6%	49.4%	49.8%	49.6%
Senior management from local communities / total senior management	1 of 38	1 of 33	2 of 28	2 of 28	2 of 26
% senior management from local communities	2.6%	3.0%	7.1%	7.1%	7.7%

Source: Cameco Corporation, *2015 GRI Update*, (2015).

The Government of Saskatchewan requires that mining companies to demonstrate that there will be long-term economic benefits from mining operations for northern residents. Mine companies in the Northern Administration District have signed two socio-economic agreements that are designed to share the natural resource wealth of the region and create economic opportunities for northern communities. Cameco is required to meet the terms of the Mine Surface Lease Agreement (MLSA) and the Human Resource Development Agreement (HRDA). The province of Saskatchewan monitors the progress of both agreements, which are focused on:

> maximizing northern employment, training and business opportunities and increasing communication. The intent is to help to develop a skilled northern mine labour force and contractor base, as well as increase the capacity over the longer term of individuals and communities in northern Saskatchewan.[84]

The Mine Surface Lease Agreement grants northern Crown land for mining. In return the mine operator has to "use and report on their best efforts to maximize training, employment and business benefits for local communities."[85] The MSLA is the primary mechanism for communication and building positive partnerships, serving as "a platform for the relationship between the mining industry and

[84] Government of Saskatchewan, *2014 Northern Benefits Summary: Saskatchewan Mine Surface Lease Agreements*, Regina, SK: 2015, 1.
[85] Government of Canada, *Mine Surface Agreement, In Good Practices in Community Engagement and Readiness: Compendium of Case Studies from Canada's Minerals and Metals Sector*, Sudbury, ON: Energy and Mines Ministers Conference, 2014, 58.

government in northern Saskatchewan."[86] Northerners, industry and the provincial government have learned that MSLAs build and maintain relationships, and that information sharing wins public trust and goodwill. MSLAs agreements extend beyond providing northern employment to maximizing "business participation, education and training opportunities, as well as to provide compensation for loss of commercial income to traditional land users who previously held the lease or permit for the land."[87] The MSLA compels northern mine operators to not only provide employment and training opportunities, but to contribute to positive socio-economic development. Mine operators have made a concerted effort to fulfill the conditions of MSLA, believing that positive relations with communities are in the best interest of all stakeholders. As part of MSLA, each mine operator has to negotiate a separate Human Resource Development Agreement.

Similarly, the Human Resource Development Agreement requires each mine site to have a specific human resources plan that focuses on "recruiting, hiring, training, jobs advancement opportunities for residents of Saskatchewan's north."[88] Together, these socio-economic benefit agreements provide economic opportunities for residents in northern Saskatchewan and establish mechanisms for government-mining sector partnership that aids in long-term planning for labour, training and contracting needs. The agreements ensure that Aboriginal peoples have opportunities to find work in the northern mining industry, which may be located on traditional lands and requires the mine operators to contribute to wider economic development. As part of the agreements, the mine companies provide an annual report on employment statistics and economic, social and sustainability initiatives to government and communities in the Northern Administration District (NAD). Mine operators report to government on how well they are meeting the conditions of the MSLA, all results and related documents are publicly

[86] Government of Saskatchewan, *2014 Northern Benefits Summary: Saskatchewan Mine Surface Lease Agreements*, Regina, SK: 2015, 1.
[87] Ibid., 1.
[88] Government of Saskatchewan, *2014 Northern Benefits Summary: Saskatchewan Mine Surface Lease Agreements*, Regina, SK: 2015, 2.

available. These reports are the primary mechanism through which the mine operators are evaluated by government and communities.

Cameco's policy is to give northerners preference in recruiting and to have 50% of the total workforce come from northern communities. Northern workers represent the majority of workers in low-skilled, labourer jobs. There are few Aboriginal peoples in managerial or professional jobs, a fact which Cameco openly acknowledges and is committed to addressing. Millions of dollars have flowed to northern workers, communities and the provincial government through wages, community investment and procurement contracts (Table 3). Northern Saskatchewan has received direct economic benefit from wages and benefits to northern workers, community investments and procurement contracts.

Table 3.Direct Economic Value to Northern Saskatchewan Economy

	2010	2011	2012	2013	2014
Employee wages and benefits	599,731	653,582	453,242	462,242	462,164
Payment to providers of capital	159,991	206,550	201,587	224,073	236,244
Payments to government	63,222	30,616	35,906	96,357	233,716
Community investments	4,794	5,294	5,284	4,085	4,279

Source: Cameco Corporation, *2015 GRI Update*, (2015). Note: All figures in Canadian dollars (1,000s).

Cameco has spent millions of dollars in northern Saskatchewan on the acquisition of local supplies and services. It is the main source of economic spending in the region and the largest employer. Table 4 illustrates the significant economic footprint of Cameco in northern Saskatchewan. The mining company prefers, whenever possible, to acquire goods and services from local northern businesses. This belief is codified in Cameco's official procurement policy which outlines its commitment to supporting the region's local economy. The local procurement percentage has fluctuated, but has remained significant from 2010 to 2014.[89]

[89] Ibid., 3.

Table 4. Local Spending in Northern Saskatchewan

	2010	2011	2012	2013	2014
Total services	$381,599,332	$533,877,071	$629,563,957	$670,539,245	$466,883,286
Local service procurement	$296,268,979	$393,191,740	$458,009,603	$451,619,699	$333,493,389
% of Local procurement for services	78%	74%	73%	67%	71%

Source: Cameco Corporation, *2015 GRI Update*, (2015).

In 2014, the Government of Saskatchewan reports that all northern mining operations employed 3,464 northern and non-northern people in total. Northerners miners accounted for 1,007 of total mine site employment in 2014. Northerner employment and the total size of the workforce were highest in 2012. The number of northern employees fell from 1, 914 in 2012 to 1,007 in 2014, a trend which was mirrored by a decline in the total mine site workforce (northerners and non-northern).

Table 5. Direct and Indirect Employment of Northern Workers, 2012-2014

Year	Northern Mine Workers (Direct)	Total Mine Site Workforce (Northern and Non-Northern)
2014	1,007	3,464
2013	907	3,570
2012	1,914	4,062

Source: Data adapted from Government of Saskatchewan, *Northern Benefits Summary 2012-2014.*

Summary

Mine exploration and development grew following the Second World War in northern Canada. After World War II, demand for uranium grew and northern Canada became a leading source of the high value substance. Mines and single-industry resource communities were constructed and established in northern Saskatchewan's Athabasca region throughout the twentieth century. The uranium mines supported a large number of jobs in exploration, production and processing, specialized services (e.g. suppliers) and in-direct low and high-skilled jobs in services, healthcare, social services and education. Aboriginal workers found employment; many earned an hourly wage for the first time, in labour intensive parts of the mining cycle. Mine development and wage income made it easier to purchase goods and services. Mines disrupted traditional lands for hunting and harvesting, but wages allowed hunters, fishers and harvesters to acquire new tools and equipment. New diesel powered machines caused the

mechanization of mining labour and transformed work at mine sites. By the early 1980s, individual mines in northern Saskatchewan did not require as many workers as in the past, but mine development increased, so the overall number of workers in the industry actually increased. The new uranium mines were less labour intensive than other mines, requiring a smaller workforce and relying on the output from machines and automated technologies to perform tasks in production and processing.

Chapter 3: The Digitization of Work in Northern Saskatchewan

New and emerging digital technologies such as information and communications technologies (ICTs), advanced computers and the Internet of Things (IoT) are disrupting business models and the nature of work in the northern Saskatchewan mining sector. Writing in the early 1930s and fascinated with the new mechanical machines and the industrial organization of production, John Keynes wondered about the future of work and life for the children of the twentieth century. Keynes' question is the main underlying question of this chapter. In the twenty-first century, what are the future possibilities of work and life for Aboriginal youth and workers in northern Saskatchewan? As has already been noted, digital disruption is economy-wide, affecting different jobs and economic sectors. This chapter examines northern Aboriginal population growth, related labour market challenges (i.e. job creation to satisfy work ready Aboriginal peoples), several digital technologies in development or already operating in the mining sector. A description of digital technologies is provided, followed by an assessment of their potential impact on the workforce. Special attention is paid to how the workforce has been or is likely to be disrupted. Some digital technologies will redefine and eliminate jobs rapidly, but create entirely new ones.

Making Room in the Public Policy Agenda: Preparing for Northern Digital Change

The full implication of the digital economy, which refers to the use and reliance on digital technologies for economic activity, is relatively unknown. Digital technologies are causing the most fundamental technological change since the first Industrial Revolution. Almost every sector of the economy will be disrupted because of digital technologies.[90] Table 6 shows what could happen to jobs in the mining sector as new and emerging technologies change the nature of work and the skills required. In the first column, incremental technological change is a gradual process occurring over several years to decades while in the row below disruptive technological change is quite the opposite, with rapid

[90] David A. Wolfe, *A Policy Agenda for the Digital Economy*, Innovation Policy Lab, Munk School of Global Affairs, 2016, 2.

advancements that disrupt productive activity such as work and value chains. From a public policy standpoint, it is important to distinguish between the different policy problems associated with both incremental and disruptive technological change so that policy instruments have a better chance of achieving state outcomes. As Table 6 illustrates, disruptive technologies are challenging to identify and the effects on labour are difficult to determine, resulting in reactive policies that have to deal with potentially massive upheaval in employment, markets and regions.

Table 6. Preparing for Digital Technologies in Northern Employment

	Impact on Skills		
Type of technological change	**Labour Demand**	**Labour Supply**	**Mismatch**
Incremental Technology – slow change with known human skills requirements	• Anticipated needs, proactive skills training	• Skills available • Limited job displacement	• Small skills gap • Policy makers can identify and plan to meet present (supply) and future (demand) skills needs
Disruptive Technology – rapid change that disrupts work	• Unanticipated needs, reactive skills training	• Skills shortage • Potential for significant 'technological unemployment'	• Significant skills gap • Public policies for mitigating job losses due to labour saving technologies

Source: Data Adapted from McKinsey Global Institute, Disruptive Technologies: Advances that will Transform life, business, and the Global Economy, 2013 and OECD, Oslo Report on Measuring Innovation (2005).

The Employment Gap in Northern Aboriginal Communities

Aboriginal workers, in large numbers, have been able to find employment in northern Saskatchewan for several decades, primarily in the natural resource industry. They have found employment in production jobs located at northern mines, in large part due to recruiting and job training by Cameco. The future of work in the Canadian north will be more digital and require digital skills in the workplace. This is even the case in the northern mining sector, which is already highly automated. A second wave of digital technologies powered by artificial intelligence, the Internet of Things and self-driving vehicles and robots are reducing the need for human workers in certain mining jobs. Job tasks involving human movement and thinking that were previously thought safe from automation are at risk

due to advances in machine learning and robotics. As digital technologies improve, more jobs that large numbers of Aboriginal workers are paid to perform are at risk of being lost to machines.

This is a significant challenge for a region that is experiencing rapid population growth and lacks jobs opportunities. The mining sector has long been the main source of jobs and an anchor industry for northern Saskatchewan. In a new digital age and less labour intensive northern economy, which is based on the use of new digital technologies that are capable of doing a lot of human tasks, the gap between the number of people ready to work and the availability of jobs is anticipated to widen.

Table 7. Population Size and Ethnicity of Saskatchewan's Northern Administration District, 2011

Characteristic	Total
Total population	36,785
All Aboriginal Identity	31, 960
First Nations	24, 700
Metis	7, 160
Non-Aboriginal	4, 820

Source: Data adapted from Statistics Canada, *Aboriginal Peoples in Canada: First Nations People, Métis and Inuit: National Household Survey, 2011.*

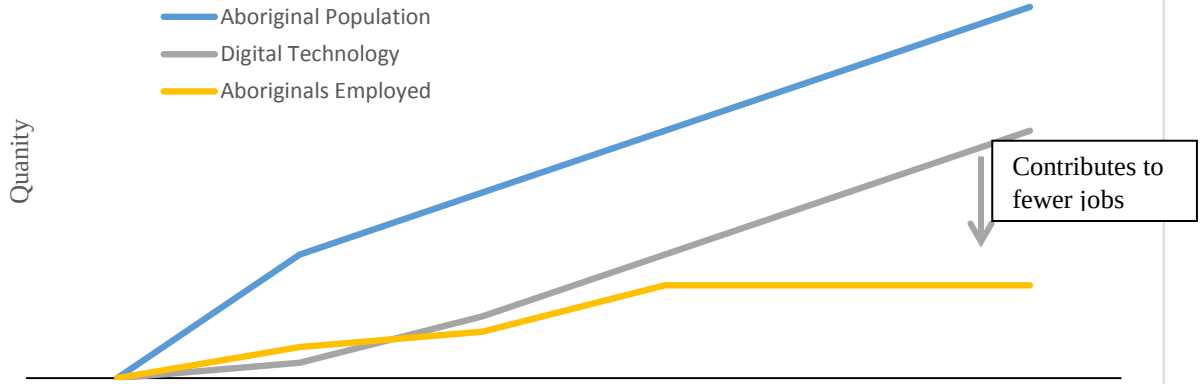
Population growth in northern Saskatchewan (Census Division 18) increased by 7.8 percent between the years 2006-2011. The rate of population growth in the northern region outpaced Saskatchewan (6.7%) and Canada (5.8%) in the same time period. Actual population growth was 2, 628 people from 2006-2011, mostly due to natural increases in Aboriginal population.[91] National Canadian Household Census data prepared by Statistics Canada from 2011 showed that the Aboriginal population was the youngest in Saskatchewan, with a median age of 20 years.[92] The Aboriginal population is younger than the non-Aboriginal population and fertility rates and family size is higher than the non-

[91] Ryan Gibson, *Is Northern Saskatchewan's Population Growing?*, ICNGD Discussion Paper #1, International Centre for Northern Governance and Development, 6.
[92] Statistics Canada, *Aboriginal Peoples in Canada: First Nations People, Métis and Inuit: National Household Survey, 2011*, Ottawa, ON: 2013, 5.

Aboriginal population. Overall, Aboriginal peoples are the fastest growing segment of people in Canada.[93]

Present and future employment for Aboriginal peoples in northern Saskatchewan will be influenced more significantly than in the past by advances in digital technology. Aboriginal workers are left with fewer employment choices and tough decisions. Many young Aboriginal workers will be forced to leave their home community for education and work. The rapid expansion of Aboriginal population and the digitization of work in northern Saskatchewan are represented in Figure 3. The Aboriginal employment gap is a model that shows forces which are creating a less labour intensive northern economy. The gap is described as follows: Aboriginal population growth creates a higher expectation for work, meanwhile the implementation of digital technologies decreases the total number of jobs in the northern Saskatchewan mining sector. The population growth of Aboriginal peoples creates a job mismatch by creating more demand for jobs than supply of jobs.

Figure 3. Aboriginal Employment Model



Source: Data Adapted from Ken S. Coates et al, *Unearthing Human Resources: Aboriginal Skills Development and Employment in the Natural Resource Sector*, MacDonald-Laurier Institute (2015).

[93] Indigenous and Northern Affairs Canada, "Fact Sheet – Urban Aboriginal Population in Canada," accessed August 31, 2016, https://www.aadnc-aandc.gc.ca/eng/1100100014298/1100100014302.

Summary of the Disruptive Digital Technologies that Affect Work in Northern Saskatchewan Mining

The digitization of work is caused by new and emerging digital technologies that are becoming more powerful and capable of performing human tasks (Table 8). The worldwide "Fourth Industrial Revolution" and its transformative changes are powered by the implementation of digital technologies.[94] These digital technologies disrupt workplaces and labour markets by substituting for or complementing human labour. The disruption may result in the elimination of whole occupations or significant change (the more likely outcome) in job tasks. Jobs requiring routine and non-physical tasks are the most susceptible to digitization and being eliminated. High education and income jobs, such as lawyer or teacher, are the least susceptible to jobs losses, in large part because jobs involving complex social interactions are not easily digitized for social, political and technological reasons. A list of the drivers of digital change is provided below.

Table 8.The Digital Technologies Driving Workforce Change

Digital Technology	Description
Mobile Internet and Cloud Technology	Users are able to transfer and access data without using local software or computers.
Advances in computing power and big data	Improved computing power for handling large flows of data.
The Internet of Things (IoT)	Virtually connected remote sensors, communications, and processing power in industrial equipment and everyday objects that produces enormous amounts of data. Operators can see patterns and design systems on a scale never before possible.
Advanced robotics and autonomous transport	Autonomous driverless vehicles and smart robots that are capable of complex reasoning and replicating human movements.
Artificial intelligence and machine learning	Recent advances in artificial intelligence, machine learning, and natural user interfaces (e.g. voice recognition) can automate knowledge-worker abstract and physical tasks that have long been regarded as impossible or impractical for machines to perform.
Advanced	3D printing builds objects layer-by-layer from design software, which allows

[94] World Economic Forum, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, Global Challenge Insight Report, 2016, 5-8.

manufacturing and 3D printing	on-demand production and disrupts global supply chains and production networks.

Source: Data from World Economic Forum, *Future of Jobs Report*, 2016.

Job loss because of the introduction of digital technologies is beginning to accelerate in several parts of northern Canadian economy, consist with global digitization of work and jobs. The mining sector has managed to avoid significant digital technological unemployment. This is changing as mining companies look to emerge from a lengthy depression in prices for minerals by capitalizing on the economic opportunities of the new digital technologies. These innovations may improve productivity and increase the profit margins for the natural resources companies, but they also cause severe workforce vulnerability, especially for Aboriginal workers who typically have lower education and potential for technologically-based employment.

Canadian mining companies have been embracing disruptive digital technologies as part of a wider competiveness strategy and in response to continued low commodity prices.[95] Powerful digital technologies such as automation, artificial intelligence, smart robots, 3D printing, cloud computing, and the Internet of Things (IoT) are improving and continue to create new possibilities for work and productive activity.[96] These digital technologies are contributing to technological change in the Canadian mining sector which is digitizing work and establishing a new digital economy, likely with fewer workers.[97] They are also affecting jobs in exploration, production and processing of the mining cycle that historically required the greatest proportion of Aboriginal human labour, in the case of northern Saskatchewan.

For example, autonomous driverless vehicle is disrupting the workforce in the oil and gas industry in northern Alberta. Suncor, an oil sands company, announced it has plans to completely replace

[95] Rick Howes, "We Need Disruptive Innovation Mining Sector, As Well," *Globe and Mail*, February 20, 2016, accessed February 21, 2016, http://www.theglobeandmail.com/report-on-business/rob-commentary/we-need-disruptive-innovation-in-the-mining-sector-as-well/article28817988/.
[96] James Manyika, Michael Chui, Jacques Bughin, Richard Dobbs, Peter Bisson and Alex Marrs, *Disruptive Technologies: Advances that will Transform Life, Business and the Global Economy*, McKinsey & Company, 2013.
[97] Darrell M. West, *What Happens If Robots Take the Jobs? The Impact of Emerging Technologies on Employment and Public Policy*, Washington D.C.: Centre for Technology Innovation at the Brookings Institute, 2015.

its traditional human driven trucks with automated haul trucks. These self-driving vehicles will eliminate hundreds of driving and related jobs. The company estimates 800 truck operator jobs will be lost by 2020.[98] This does not include the expected job losses in truck servicing (repairs and routine maintenance).

There is growing awareness in the northern Saskatchewan mining sector of the significant potential for using digital technologies to improve productivity and worker safety and lower costs. Mine operations in northern Saskatchewan have already become more digitized. Cameco Corporation, the largest mining company and the main source of private sector full-time, well-paying jobs in the region in northern Saskatchewan, has been making use of digital technologies in exploration and their mine operations, particular at tier one mines, which are low-cost and highly automated.[99] These northern mines continue to digitize their operations primarily to lower cost and increase productivity.[100]

Digital mines, for example, require fewer workers and yet are more productive and efficient. New digital technologies such as exploration drones, autonomous trucks, remote drilling and advanced underground surveying techniques are revolutionizing work in northern mining. [101] The digitization of work in mining may lead to the technological unemployment of large numbers of Aboriginal workers. Mining has been a reliable source of employment for Aboriginal peoples and for wider economic development for the region. The workforce situation is likely to deteriorate as digital technologies become more capable of substituting for human labour.

The application of digital technologies in northern Canadian mining operations has been diverse. New digital technologies can be found throughout the mining cycle, from exploration to mineral processing. Digital innovation has been supported by the Canadian mining industry as part of a wider strategy to respond to persistently low commodity prices and to meet global competition. Mining

[98] Financial Post, "Driverless Vehicles are Going to Change Our World, but at what cost?" National Post, May 20, 2016, accessed May 20, 2016, http://business.financialpost.com/news/transportation/driverless-vehicles-are-going-to-change-our-world-but-at-what-cost.
[99] Meng Yap, Process automation snapshot, *Canadian Mining Journal*, February 1, 2006, accessed May 17, http://www.canadianminingjournal.com/features/process-automation-snapshot/.
[100] Cameco Corporation, *2012 Sustainable Development Report*, 2012.
[101] Deloitte Canada, *Tracking The Trends 2015: The Top 10 Issues Mining Companies Will Face This Year*, 2015, 11-12.

companies have been keen to lower costs, increase productivity and stay competitive. New and emerging digital technologies are having an effect on work in northern Canadian mining. The presence of digital technologies has not been easy to detect, given the reluctance of mining companies to share information about technology adoption for fear of giving away trade secrets or losing competitive advantage. Industry organizations such as research institutes, associations and Canadian mining publications have been excellent sources of information, providing many examples of new digital technologies used in Canada. An extensive search of industry websites and publications has provided a wealth of secondary information. A survey of reports, articles and interviews has made it possible to speculate on which digital technologies are changing the Canadian mining industry and their impact on the workforce. Digital technologies are organized according to their use in the mining cycle, which consists of exploration, extraction, processing, transportation and remediation.

Training

Production and processing mine workers must obtain some combination of prior and on the job training. Their jobs tend to be physical and situated in difficult and sometimes dangerous settings. Training will depend on the jobs, but new and emerging digital technologies are enhancing job training and safety. Mine simulators and virtual reality are two types of digitally based technologies that are having positive benefits on the delivery and workplace safety.

Mine Simulator

Northlands College in La Ronge Saskatchewan purchased mine simulators to aid in training students for mining work. The mine simulator offers a realistic, virtual training environment complete with actual equipment cabs and controls. Students learn how to operate a scoop tram and drills.

Virtual Reality

Learning in a virtual environment is superior to traditional methods, according Immersive Technologies, which has released its findings. For several years, Immersive Technologies has created

replica and customized mines for training and education purposes.[102] The advantages of virtual reality training are claimed to be greater learning, accommodation of diverse learning styles, safe and risk free learning at a low cost.

Exploration

A mineral deposit must be located and analyzed prior to mine development. Mine exploration has traditionally been labour intensive, time consuming and expensive. The adoption of digital software to locate mineral deposits and advanced remotely operated drones has greatly reduced need for human labour and lowered costs. Drones are the best of example an emerging disruptive digital technologies in exploration.

Remote Operated Drones

Drones have been deployed to search for mineral deposits in remote, isolated parts of northern Saskatchewan. Remote operated drones have become an increasingly popular tool. They come equipped with high-resolution cameras which "take snapshot after snapshot, slowly mapping the curves and contours of the terrain, regardless of where it is, and on command, they turn around head back from base."[103] The information gleaned from the drone is used to inform decisions about whether to further investigate or development.

Mining companies have opted for drones over physical inspections of difficult to reach places. The inspections required small groups of workers to cover large tracts of land over several days or weeks. Physical inspection was expensive, dangerous and time-consuming. Drones have proved to be an efficient and effective tool for mineral inspection.

[102] Canadian Mining Journal, "Training: Immersive Technologies Introduces Virtual Reality," Last Modified February 9, 2016, accessed May 2016, http://www.canadianminingjournal.com/news/training-immersive-technologies-introduces-virtual-reality/.
[103] Greene, Nicholas, "A Look At How Drones Are Coming Into Their Own In The Mining Sector," Canadian Mining Journal, April 2, 2015, accessed May 2016, http://www.canadianminingjournal.com/features/a-look-at-how-drones-are-coming-into-their-own-in-the-mining-sector/.

Operations and Processing

Mineral extraction can be the most labour intensive activity of the entire mining cycle. Northern Saskatchewan mine operations predominantly employ northerners of Aboriginal heritage. As digital technologies improve in physical and non-routine tasks operations jobs will face greater risk of digitization. Some jobs today face high probability of digitization due to present day technologies, such as autonomous driverless trucks.

Smart Drilling

Automated drills have reduced the cost of drilling and increased mine productivity. Precision or smart drilling is more accurate and efficient than even a well-trained and experienced human operator.[104] Remote operating centres located anywhere in the world can directly control automated drilling. Mine safety is increased because workers are not required to be in the drilling area. Human operators require breaks and tire out, whereas automated drills are more consistent, accurate and decrease wear and tear on the machine, which increases the expected lifespan of machines.[105]

Wearables

Attached to clothing and accessories, wearables use computer and advanced electronic technologies to collect and transmit personal data. [106] Wearable technology is being developed to help Canadian mining operations reduce accidents, fatalities and improve overall mine safety. Sensors located on the miner collect data about worker health and well-being. Wearables can track miner fatigue, which is a leading cause of accidents, injuries and death.[107] Other sensors detect external hazards around the miner

[104] Chen, David, "The Best In New Technology, Canadian Institute of Mining," Metallurgy and Petroleum, May 2016, accessed May 20, 2016, http://www.cim.org/en/Publications-and-Technical-Resources/Publications/CIM-Magazine/2016/May/tools-of-the-trade/The-best-in-new-technology.aspx.
[105] Canadian Mining, "The Operator-Less Bench," September 1, 2013, accessed May 2016, http://www.canadianminingjournal.com/features/the-operator-less-bench/.
[106] Das Biswajit, *Wearables: Imagine the Possibilities*, Impact on the Mining Sector, Deloitte, 2015, 2.
[107]Ibid., 5.

created by smoke, machines and the surrounding rocks.[108] Wearables provide the mining control centre with tremendous amounts of real-time data. Above ground managers and supervisors have access to a continuous stream of personalized information which can remove people from dangerous situations.

Autonomous Driverless Vehicles

Autonomous vehicles have been hauling mineral ore in Australia for several years. Rio Tinto bought 69 autonomous trucks to be tested at three different mine locations in the Pilbara Region of Australia. The haul trucks were controlled from a remote command centre and could drive for longer periods than human operators. Rio Tinto's autonomous vehicle fleet lowered costs, while improving productivity and safety.

Until recently, it was not known whether automated trucking technologies was truly more efficient and effective than human operators. Rio Tinto gathered data on the productivity of their autonomous and human operated trucks. The data revealed that autonomous trucks were more efficient than human operated fleets. A single truck was found to save Rio Tinto 500 work-hours per year, primarily by reducing breaks, absenteeism and the time caused by shift changes. The mining company also saved on training truck drivers and maintenance costs. [109]

The Internet of Things (IoT) has the potential to transform the mining sector by increasing productivity, enhancing worker safety and improving processes and systems. Defined as "...the connection of objects such as computing machines, embedded devices, equipment, appliances and sensors to the Internet, the Internet of Things is an essential component of digital mining.[110] Internet of Things

[108] Braul, Peter, "Know No Fear: How Miners can Collect The Necessary Data to Prevent Deaths," Canadian Institute of Mining Metallurgy and Petroleum, February 2016, accessed May 2016, https://www.cim.org/en/Publications-and-Technical-Resources/Publications/CIM-Magazine/2016/February/feature/Know-no-fear.aspx.
[109] Canadian Mining Journal, "Automation: Autonomous Fleet Performs 12% Better than Manned Fleet," Canadian Mining Journal, November 3, 2015, accessed May 2016, http://www.canadianminingjournal.com/news/automation-autonomous-fleet-performs-12-better-than-manned-fleet/.
[110] Joe Lee and Kelley Prowse, *Mining & Metals and Internet of Things: Industry Opportunities and Innovation*, MaRS Market Insights, 2014, 11.

involves layers of connectivity, including human & external interface (management, integrated remote operations centres and markets), IoT platforms (big data collection and processing), the communicators & controllers (local and global networks) and the things (autonomous haulage trucks and drilling rig and sensors). These connected mine operations components produce huge volumes of big data and analytics. Mining companies, like Rio Tinto and Cameco, already use IoT to achieve productivity maximization. Rio Tinto shared its insights on the value and huge potential of big data, stating "This is about improving your asset utilisation, it's about improving your labour productivity, [and] it's about improving the utilisation of your capital. And if you're not analysing your data to those things, how can you improve those processes?"[111] Their statement reveals the power of big data to identify and manage operational effectiveness, efficiency and significant cost reduction. Cameco is optimistic about the predictive power of big data and its ability to lower maintenance costs and maximize productivity. Both Rio Tinto and Cameco know that the ultra-low cost automated or the digital mine of future is made possible by the Internet of Things.[112]

Recent Examples of Digital Change in Northern Saskatchewan

New technologies for business activity, especially in the natural resource industry, have made their way to the northern Saskatchewan region in the past. Today, much like before, new and emerging digital technologies are beginning to create new possibilities for work in the mining sector and throughout the entire northern Saskatchewan economy. When transformative changes have occurred in the northern Saskatchewan mining industry, they have happened because of new digital technologies and resulted in job losses for Aboriginal peoples. The next few paragraphs describe how digital technologies have changed work and eliminated jobs for Aboriginal peoples.

MARS (Mineral Administration Registry Saskatchewan)

[111] Richard Roberts, "Uranium Miner Joins Big Data Revolution, Mining Journal," March 4, 2015, accessed July 2016, http://www.mining-journal.com/technology/mining-ict/uranium-miner-joins-big-data-revolution/.
[112] Richard Roberts, "Uranium Miner Joins Big Data Revolution, Mining Journal," March 4, 2015, accessed July 2016, http://www.mining-journal.com/technology/mining-ict/uranium-miner-joins-big-data-revolution/.

Exploration for mineral deposits involved the staking and claiming of land in remote parts of northern Saskatchewan. Aboriginal people were the largest group of employees in this activity, and relied on this source of seasonal employment. This type of work was a convenient source of income for Aboriginal people because they made enough money to support traditional activities in the fall and winter months. Their jobs in staking and claiming provided income and offset the costs of traditional activities like hunting and trapping in the winter months.

Making a claim on land believed to have mineral deposits required thousands of dollars and a large number of manual workers. The workers encountered harsh conditions due to unpredictable weather, mosquitoes and rough terrain. This work typically required several days or sometimes weeks away from base camps and even longer absences from home. Cell phone or internet service was not available in areas where physical staking occurred. If there was an injury or need for supplies, someone would have to trek back to base camp or the nearest community.

Physical staking and claiming ended with the introduction of the computerization of the exploration activities.[113] The Government of Saskatchewan launched the Mineral Administration Registry Saskatchewan (MARS), a web-based application which replaced the physical work (staking and cutting) with an online digital process of making land claims for potential mine exploration. MARS is accessible to computers connected to the internet. The system has greatly reduced the cost of exploration for minerals and streamlined the issuing of permits, claims and leases.[114]

MARS permanently eliminated physical staking and claiming jobs in northern Saskatchewan. Seasonal jobs in staking and claiming were an important source of income in a region with few jobs for Aboriginal peoples. MARS eliminated jobs filled primarily by Aboriginal peoples, permanently shutting them out of this sector in northern Saskatchewan. The disruption extended well beyond the front line

[113] Lisa Shick, "High-Tech Mining in Saskatchewan," Prince Albert Now, April 24, 2011, accessed May 2016, http://panow.com/article/56761/high-tech-mining-saskatchewan.
[114] Doug MacKnight, Ministry of the Economy, *Recent Developments in Mineral Rights Regulation in Saskatchewan*, Presentation in Calgary, AB, April 14, 2011, 5.

workers to include the northern businesses and individuals who supplied the staking workers with support services like fuel, food, hotels, airplanes and helicopters.

Cameco Layoffs April 2016

In April 2016, Cameco Corporation announced it was laying off 500 northern workers. Cameco connected the job losses to persistent low commodity prices and the resulting pressure to cut costs. [115] The CEO of Cameco stressed that the 500 workers would find work in low-cost Tier 1 mines or would receive some kind of severance pay, along with retraining opportunities. The Saskatchewan government reacted by deploying its rapid reaction team to help people cope with unemployment and to connect them to retraining programs or to offer assistance in the job search.

The majority of layoffs occurred at Cameco's Rabbit Lake mine. This mine opened in the 1970s and was classified as a Tier 2 mine, meaning it was older, less technologically sophisticated and more costly to operate. A Cameco workforce of about 150 remained in non-production and maintenance jobs. In effect, Cameco shut down production at the inefficient Rabbit Lake mine and shifted the bulk of its production to the modern, more technologically advanced mines in the region, such as McArthur River/Key Lake and Cigar Lake.

The closure of Rabbit Lake signaled a major transition in northern Saskatchewan mining. Cameco implemented digital technologies, like automated systems and equipment, in its northern mining operations to reduce costs and increase productivity. The digitization of work has decreased the number of workers required in their mines. Cameco's closure of the Rabbit Lake mine is evidence of the increasing prominence of digital technologies. It is also a warning about the future of mining in northern Saskatchewan. The shift away from older mines like Rabbit Lake to newer, more digital mining operations has increased the number of jobs lost to digitization, resulted in fewer jobs and is creating a less-intensive sector in the region.

[115] Andrew Topf, "500 Jobs Lost After Cameco Shuts Down Rabbit Lake," Mining.com, April 24, 2016, accessed April 25, 2016, http://www.mining.com/500-jobs-lost-after-cameco-shuts-down-rabbit-lake/.

The digitally enhanced Tier 1 mines do not employ as many people as did an older mine like Rabbit Lake. Most of the jobs that are available in Tier 1 mines require medium to high-levels of education, and the ability to use computer-based technologies. In a less-labour intensive northern economy, fewer jobs in mining means more people will be out of work and will likely have difficulty finding new, equally high-paying jobs.

Summary

The Aboriginal population in northern Saskatchewan is young and growing fast compared to the rest of Saskatchewan and Canada. Digital technologies are contributing to change in the northern natural resources economy and increasing the vulnerability of Aboriginal workers. New and emerging digital technologies redefine traditional conceptions of work and have the potential to automate or significantly change jobs. Aboriginal workers, as a group, are most likely to be in jobs that are low-income and require low skill. These are the jobs that are most affected by the digitization of work. Jobs in this category are highly susceptible to task automation and whole occupation elimination. A less-labour intensive northern resource economy contributes to the vulnerability and joblessness of the Aboriginal labour force. Fewer jobs in mining, coupled with advancements of digital technologies and the fast-growing Aboriginal population, results in an expectation gap. Aboriginal workers prepared for jobs in mining will far exceed the need of northern mining companies, particularly Cameco the largest mining company in northern Saskatchewan. The mismatch in jobs supply and demand is the basis of the northern expectation gap. There will be too many people and too few jobs.

Chapter 4: Making Public Policy for the Future of Work

The main issue in this chapter is the level of preparation in the Saskatchewan government and the mining industry for the impact of digital technologies on northern employment. McAfee and Brynjolfsson in their book the *Second Machine Age* are troubled by the potential impact of digital technologies on work, society and life. They argue the digital disruption of work and jobs is present in nearly all parts of the economy. Change in the twenty-first century digital economy is more rapid in work and economic life, while governments struggle to keep up and do poor job of mitigating the negative impacts of rapid change and digitization of work. McAfee and Brynjolfsson believe governments need to adopt forward-looking models to guide policy-making, and drop reactive and temporary policy fixes. This chapter identifies the provincial institutions that have programs for job training and education, which are primarily delivered by third-party companies and colleges. Training and education programs are assessed on the basis of their ability to prepare and retrain Aboriginal workers for digital work.

The ability of young and experienced workers to learn quickly will give these individuals an upper hand in keeping and finding new jobs. Workers, at all skill and income levels, will have to learn how to adapt to a rapidly changing workplace because digital technologies are competing for tasks and jobs, a trend that is expected to accelerate as artificial intelligence improves. This will not be easy for some workers. For generations, the education system industrial model has produced workers with a specialization and not encouraged adaptive learning. Following this sort of education is a huge mistake according to Joel Mokyr professor of economics at Northwestern University. Mokyr believes students today should not be treated like clay – which as he points requires someone to "shape it, then bake it, and that is the way it stays"[116] but like putty, which is easy to reshape. The human mind will need to be like putty, it will have to pick up new skills and abilities in response to automation of work. Workers unable or unwilling to do this will be left behind. Dreambox Learning supplies elementary classrooms in the United States with adaptive learning software, which it describes as "…a computer-based and/or online

[116] The Economist. *Re-educating Rita: Artificial Intelligence will have Implications for Policymakers in Education, Welfare and Geopolitics*, Print Edition, June 25, 2016.

educational system that modifies the presentation of material in response to student performance."[117] Adaptive learning software, which personalizes education based on individual needs, could help develop young malleable minds and reshape the minds of workers out of work or looking to learn new skills or abilities.

Public Policy Agenda Setting

Policy makers and political actors frame policy problems according to their pre-existing biases, preferences and goals. The framing process gives a particular policy problem meaning and certainty. Individuals and institutions assemble the existing knowledge, weigh the potential consequences of choosing a path of problem solving, and assess feasibility. Central to this work is the use of evidence, political calculations, and, perhaps greatest of all, the ability to wield power to establish the normative-evidence based policy frame. Defining the problem and setting is an inherently contested and political activity, requiring sufficient financial and political resources to elevate, define and pursue agenda setting. Hisschemoller and Hoppe stress the importance of problem defining and solving, describing these interconnected processes as "setting the alternatives for public policy."[118] They also note "opportunities for improvement" is an accurate description. Policy makers and politicians prefer to focus on a structured or moderately structured problem, instead of a messy, intractable or conflict-ridden problem. Problems may exist in the real world that do not capture the attention of policy makers, but that does not make them any less a problem, especially for the affected individuals and groups. Choosing a more structured problem narrows the policy perspective of governments. It also prevents urgent or real problems from making it onto the official agenda. By better understanding the nature of problems, Hisschemoller and Hoppe show it is possible to avoid stubborn, intractable problems "through a productive process of learning by problem structuring and problem choice."[119]

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[117] Dreambox Learning. "Adaptive Learning." accessed July 2016, http://www.dreambox.com/adaptive-learning.
[118] Matthijs Hisschemoller and Robert Hoppe, "Coping with Intractable Controversies: The case for Problem Structuring in Policy Design and Analysis," *Knowledge and Policy* 8, no. 4 (1995): 45
[119] Ibid., 43.

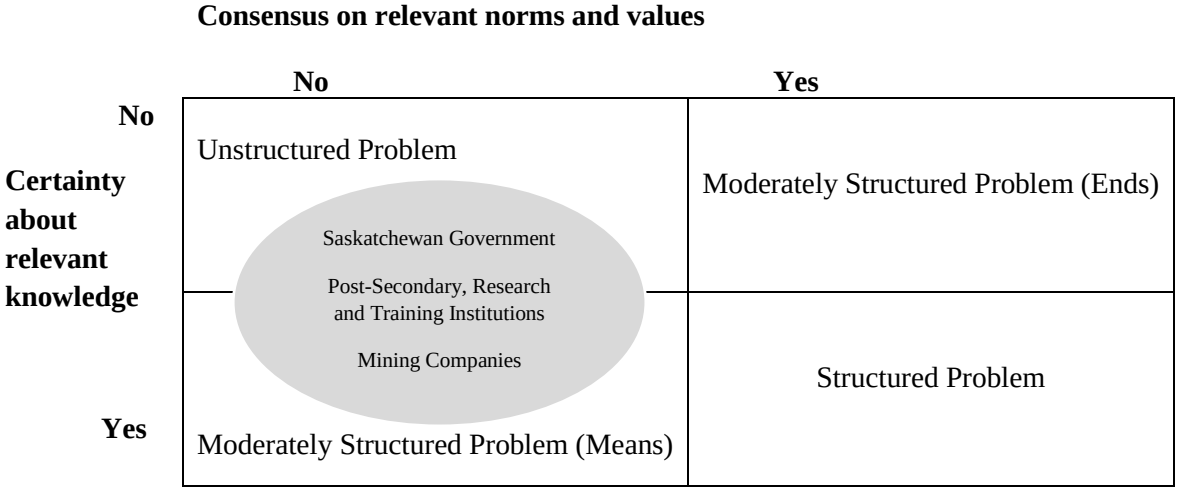
Policy-makers, politicians and community leaders concerned about northern Saskatchewan want to encourage long-term economic development and greater employment of Aboriginal peoples. They share this objective. The Provincial Government of Saskatchewan and its policy-makers deliver employment training programs geared toward skill development and retraining. Meanwhile, politicians promote economic growth and jobs through incentive-based initiatives and the creation of a comparative advantage. The key to job creation, for the Government of Saskatchewan, follows a simple formula: low-taxes, and emphasis on the ease of doing business and certainty in policy and regulatory environments. Northern community leaders and companies understand the needs of their region. Economic development and job-creation for this group is time-specific and a top priority. Joblessness and difficult economic times are typically felt by northern Aboriginals first, which underpins their desire for rapid policy action. The longer it takes to define the policy problem, establish an agenda and make decisions, the more intractable the problem can become for the northern region.

Job creation and economic development are shared interests of the Saskatchewan government and northern leaders, economic development organizations, private companies and communities. These groups want to see a prosperous northern economy that meets the needs of present day workers and the young people looking for employment. The current policy emphasis on northern job creation and economic development is influenced by the region's long-term economic dependence on mining and related support industries. Agenda setting for the region typically includes encouraging relevant stakeholders to carry out activities to achieve the stated objectives: more jobs and economic opportunities. There is agreement about the perceived policy problem and the measures need to address it. But the time has come to engage in problem definition and problem solving that reconsiders the problem definitions and determines how the issue can be addressed. Such an initiative would pinpoint the real, multi-dimensional, policy problem, allow for the piloting or the adoption of innovative solutions, and, in both exercises, build consensus, coordinate resources and establish relationships.

Survey Participant Location in Hisschemoller and Hoppe's Typology of Four Types of Policy Problems

The survey participants answered questions on how they viewed the potential impact of digital technology on work and jobs in the northern Saskatchewan mining sector. Individual survey responses were located into Hisschemoller and Hoppe's typology of four types of policy problems (see Figure 4 below). Their answers to the five survey questions indicate that there is weak certainty of about the policy problem and consensus on what is at stake for Aboriginal workers. The participants fit into one of three broad categories established to group like participants, including: the Government of Saskatchewan; Post-Secondary, Research and Training Institutions; or Mining Companies. Individual responses and categories have mixed or varying degrees of certainty about the problem and the potential impact of digital technology on Aboriginal workers. Each participant understood that digital technologies may impact work and Aboriginal workers, but there was uncertainty about how much work will be affected in general and for Aboriginal workers in all categories. All of the participants (and their categories) overlap between Hisschemoller and Hoppe's unstructured and moderately structured problem. This positioning of categories was possible through an analysis of where individual responses fit best in the problem typology. While reviewing individual responses and comparing findings within the same and across categories a pattern emerged: all individuals fit into the unstructured and moderately structured categories, but not in exclusively one. A careful examination of individual responses demonstrates varying levels of certainty and consensus on norms and values.

Figure 4. Survey Participant Categories in Hisschemoller and Hoppe's Typology of Policy Problem



Source: Data from Matthijs Hisschemoller and Rob Hoppe, "Copping with Intractable Controversies: The Case for Problem Structuring in Policy Design and Analysis." *Knowledge and Policy* 8 no. 4, 1995: 44.

Survey Method

The purpose of the survey was to collect preliminary information and prepare for the subsequent informal key informant interviews. Participants were recruited based on job title, recommendations and referrals. Survey participants openly shared information, suggested additional participants and brought their own personal and institutional perspective. The surveys were distributed, completed and returned electronically. Anonymity was granted to all participants as a condition of their participation. Fifteen surveys were completed by senior officials from the following organizations:

- Cameco Corporation
- Centre for Northern Innovation in Mining, Yukon College
- International Engagement, Ministry of the Economy
- International Mineral Innovation Institute
- Keewatin Community Development Corporation
- Labour Market Development, Ministry of the Economy
- Labour Market Services, Ministry of the Economy
- Mineral, Lands and Resource Policy, Ministry of the Economy
- Mosaic Company
- Northern Engagement, Government Relations
- Northlands College
- Oil, Gas and Mineral Resources, Energy, Mines and Resources

- Petroleum and Natural Gas Division, Ministry of the Economy
- Rio Tinto
- Saskatchewan Geological Survey, Ministry of the Economy
- School of Mining, Energy and Manufacturing, Saskatchewan Polytechnic

Survey Questions

1) *In the next 25 years, the new digital technologies will change the nature of work in the following contexts:*

   Globally: (a) Significantly; (b) Somewhat; (c) Not all or: (d) Unsure

   Nationally: (a) Significantly; (b) Somewhat; (c) Not all or: (d) Unsure

   Provincially or Territorially: (a) Significantly; (b) Somewhat; (c) Not all or: (d) Unsure

   Natural Resource Sector Generally: (a) Significantly; (b) Somewhat; (c) Not all or: (d) Unsure

   Mining Sector Specifically: (a) Significantly; (b) Somewhat; (c) Not all or: (d) Unsure

2) *Will the new technologies lead to:*

   (a) More Jobs

   (b) About the same number of jobs

   (c) Fewer jobs

   (d) Unsure

3) *Provincial government policy in the field of digital technologies and the future of work is:*

   (a) Well developed

   (b) Just starting to be developed

   (c) Not currently under development

   (d) Unsure

4) *Canadian government policy in the field of digital technologies and the future of work is:*

   (a) Well developed

   (b) Just starting to be developed

   (c) Not currently under development

   (d) Unsure

5) *In your province or territory, post-secondary institutions are preparing students for the world of digitally-enhanced work:*

   (a) Extremely well

   (b) Well

(c) Neutral

(d) Not sufficiently

(e) There are problems

(f) Unsure

6) *How will the digital transformation of work effect northern and Aboriginal workers?*
(a) Much more than other workers

(b) The same as other workers

(c) Much less than other workers

(d) Unsure

Closing the Gap in Aboriginal Education

Aboriginal youth and adults face a unique set of challenges in gaining access to Saskatchewan's post-secondary institutions. Many Aboriginal families do not have the money to send their children great distances for education. The lack of high school educational attainment of young people and adults in Aboriginal communities prevents many from even considering post-secondary education or job training. Poverty among Aboriginal families on and off-reserves is perhaps the greatest reason why so many Aboriginal youth and adults fail to obtain basic education, which is the requirement for further education and employment. Historic underfunding for Aboriginal education on reserves, towns and cities throughout Saskatchewan has negatively impacted educational outcomes. The related problems of low education and employment levels among Aboriginal peoples are not caused by cultural inferiority or a lack of intelligence. It is more complex, stemming from the colonial history of Canada, decades of underfunding and neglect and deeply rooted racial prejudices, which together, have interfered with positive education and meaningful employment.

The Government of Saskatchewan has recognized that Aboriginal youth in the province have a difficult time attaining education.[120] On reserve, Aboriginal schools in the province are funded by the Federal Government of Canada. Education on-reserves is an exclusive federal responsibility and is an

[120] The Joint Task Force on Improving Education and Employment Outcomes for First Nations and Metis People, *Final Report*, Prepared by the Saskatchewan Government and the Federation of Saskatchewan Indian Nations, 2013.

obligation found in many historic treaties signed between the federal-government and Aboriginal peoples groups. Federal funding for Aboriginal schools has been insufficient and lower compared to off-reserve schools. The gap in education funding has contributed to low Aboriginal educational attainment, employment and wider socio-economic problems, such as poverty, crime and addictions.

The final report of Joint Task Force on Improving Education and Employment Outcomes for First Nations and Metis People, organized by the Federation of Saskatchewan Indian Nations (FSIN), the Metis Nation and the Government of Saskatchewan, made several policy recommendations to close the gap in education and employment in the province. The Joint Task Force found that poverty, racism, jurisdictional issues and negative attitudes towards Aboriginal and Metis cultures and languages were major roadblocks to Aboriginal education at all levels. These causes are rooted in the Canadian-Aboriginal colonial experience and the legacy of residential schools, which resulted in generations of cultural destruction and long-term socio-economic dysfunction.

In recognition of the poor rates of Aboriginal education and employment on and off reserves, the federal government has worked with the provinces, including Saskatchewan, and the territories, to close the gap. The Canadian and Saskatchewan governments have been keen to improve employment outcomes for Aboriginal peoples. This focus on Aboriginal employment was pronounced during the natural resources boom in Saskatchewan, which began in 2007. Since then, the issue has received public attention and become a high priority of the provincial government.

The provincial government has partnered with northern industry representatives, including Cameco and other resource firms, Aboriginal community leaders and groups, northern colleges and the University of Saskatchewan to identify labour market needs and address current and future gaps in the market. This group is known as the Northern Labour Market Committee, and has been in existence for several years. The Committee has shared information, worked together to match industry workforce needs and the regional labour force and guided skills training in resource companies, colleges and universities.

The Labour Market Development unit in the Ministry of the Economy recognizes the challenges associated with emerging digital technologies and work, but is more focused on how to address the demographic gap in the province. In the next few years, thousands of workers are expected to retire and there are not enough workers to fill the vacancies, a fact which is reflected in the programs and initiatives delivered. Labour Market Development operates labour market service offices in northern Saskatchewan, which kept track of the region's workforce issues and coordinated employment resources. Northern Labour Market Development oversees human resources agreements with Cameco and other mining companies. This branch of government gathers statistics on Aboriginal employment and reports on northern employment. Labour market development and Cameco have partnered on initiatives to develop the northern Aboriginal workforce.

The province operates labour market service offices in northern Saskatchewan, which keep track of the region's workforce issues and coordinate employment resources. Labour market offices are located in Ille-a-la-Crosse, Meadow Lake, La Ronge and Creighton. Northern Labour Market Development oversees human resources agreements with Cameco and other mining companies. This branch of government gathers statistics on Aboriginal employment and reports on northern employment. Labour market development and Cameco have partnered on initiatives to develop the northern Aboriginal workforce.

The primary mechanism for federal-provincial government cooperation are various skills and training development programs. It serves as the basis for the province's response to Aboriginal and wider labour market development. In the agreements for the labour market development programs, the Saskatchewan government is required to list its top priorities and challenges, activities for the year and funding arrangements. The 2013-2014 annual plan (the most recent copy available) mentions gaps in Aboriginal education as a significant challenge and barrier to increasing employment.[121]

[121] Government of Saskatchewan, *2013-14 Annual Plan: Labour Market Development Agreement (LMDA) and Labour Market Agreement (LMA*), 2014.

The Federal Government provides direct funding to Aboriginal post-secondary institutions in Saskatchewan, including the Gabriel Dumont Institute and First Nations University of Canada. The neighbouring provinces Manitoba and Alberta, for instance, had 4 and 13 Aboriginal organization respectively receive funding in 2015-16. The funding is distributed by Employment and Development Canada to "projects contributing to the skills development and training of Indigenous workers for long-term, meaningful employment."[122]

Northern Post-Secondary Education and Job Training Institutions

Post-secondary institutions and non-profit organizations are primarily funded by the Province of Saskatchewan to provide students and workers with the skills and experience to sustain a career in the northern mining industry. Colleges, particularly Northlands College in La Ronge and Saskatchewan Polytechnic in Saskatoon offer courses, certificates and diploma programs tailored to meet the labour market needs of the northern mining industry, which are influenced by commodity prices and short-to-medium term employment demands. Northlands College is recognized as the college of the north for northerners and Aboriginal peoples. Northlands Mine School was established to prepare northern Aboriginal peoples with the skills and knowledge for careers in mining industry. The Mine School's mine equipment simulators provide students with an immersive and safe learning environment.

Northlands College – Mine School

A college designed for northerners, Northlands College is geared to preparing northern Aboriginal peoples for work in region. The college has programs in business, health, adult education and technical trades. It recently opened a mine school for northerners and Aboriginal peoples to develop the skills and knowledge to work in the northern mining sector. In addition to increasing Aboriginal involvement in the mining sector, the new mine school was established to support industry in fulfilling its strategic employment needs over the long-term. Training is specific to preparing workers for skilled-

[122] Employment and Social Development Canada, "*Funding: Skills and Partnership Funds*," Accessed June 2016, http://www.esdc.gc.ca/eng/jobs/Aboriginal/partnership_fund/index.shtml.

labour, technical and professional. Students interested in a mining career can choose from certificate programs in Civil Technician, Industrial Mechanic (Millwright), Power Engineering Technician, Radiation Environment Monitoring Technician. The mine school made significant purchases in mine equipment simulators, in collaboration with the mining sector. International Minerals Innovation Institute based in Saskatoon and Western Economic Diversification provided the funding. [123]

Regional colleges in Saskatchewan have programs designed for students interested in acquiring the skills and education necessary to work in particularly industries, like mining. The majority of programs are developed in consultation with regional industries, labour market development organizations (provincial government) and industry associations. Together, these groups share information about the current and future needs of the regional economy and plan to meet new demand in skills and education.

Gabriel Dumont Institute

Gabriel Dumont Institute is a Saskatchewan-based Metis post-secondary institution providing education, training and employment services to Aboriginal and non-Aboriginal students. The Institute offers basic education, skills training and university programs. Several of the skills training, like heavy equipment truck and transport mechanic or industrial mechanic, are applicable to jobs in the northern natural resources sector.

Saskatchewan Indian Institute of Technologies (SIIT)

SIIT has campuses in Regina, Saskatoon, and Prince Albert in addition to several career and learning centres in communities throughout the province. The institution offers certificates and diplomas in the trades and industrial studies, business and technology, health and community studies and adult basic education.[124] Aboriginal education and leadership is central to the operations of the institute where over 90% of the study body are Aboriginal peoples. Registered students have access to culturally sensitive

[123] Toby Greschner, Collen Durocher and Randy Johns, *Northlands College Mine School*.
[124] Saskatchewan Indian Institute of Technologies, "About Us," accessed June 2016, http://www.siit.ca/pages/about-us.html.

academic and employment advising. Aboriginal students can enroll in a program that best matches their interest and capability. Several of the programs educate and train students for work in the mining sector, including programs like mining industry pre-employment, heavy equipment operator, and power engineering (4th Class).

International Minerals Innovation Institute (IMII)

IMII promotes partnerships, education, skills training and innovation in the Saskatchewan mining sector. It works collaboratively with mining companies in all parts of the provinces on issues deemed important by the membership and the IMII. Since its inception in 2012, the IMII has funded several projects focused on addressing Aboriginal employment and wider skills training. The organization has been an advocate and supporter of increasing the number of Aboriginal peoples working in the mineral sector. It has provided millions of dollars to mining programs in Saskatchewan colleges for programs, courses, and acquiring hi-tech equipment.

Saskatchewan Mining Association (SMA)

SMA is an industry funded provincial industry association and representative body for Saskatchewan mining companies. The SMA's mission is to enhance cooperation, provide policy research to its members and lobby government on behalf of the membership. Skills training and education have been important for mining companies in Saskatchewan. In response, the SMA has worked with the Mining Resources Human Resources Council on producing reports on the workforce gaps and needs of the province. SMA has partnered with mining companies, education and training institutions and the Ministry of the Economy on mining innovation themed events.

Summary

Aboriginal post-secondary education, skills development and training organizations in Saskatchewan have been working to close the gap in education and employment. Aboriginal peoples, when compared to the non-Aboriginal people, have lower educational attainment and much higher rates of unemployment. The federal and provincial government, post-secondary institutions and Aboriginal

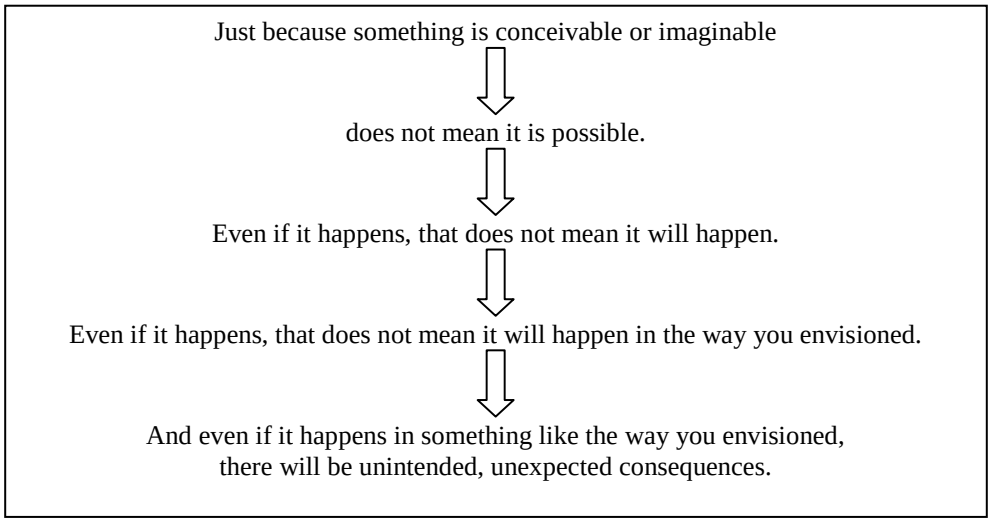
community leaders have recognized the problem and tried to close the gap. Success has been limited thus far, but there is reason to believe improvements will come with continued focus and action to bring down the barriers to education and employment.

It is important that educators and trainers not lose sight of the changing nature of work and the need to prepare young people and adults for the jobs of the future. The progress on Aboriginal education and labour market challenges of 2016 will be lost if Aboriginal peoples are not prepared for digital work and jobs. New and emerging digital technologies are having a dramatic impact on how work is done and creating new demands for advanced skills and educations. Educating and training Aboriginal peoples for the jobs of today or the near future is short-sighted since many of jobs will be change significantly, disappear entirely or require fewer workers. The economic opportunity for Aboriginal peoples lies in the emerging digital economy and the jobs demands it may create.

Chapter 5: Preparing Aboriginal Workers for the Digital Economy

Predictions about the future are notoriously difficult to make and usually end up being wrong in whole or in part. Scholars and experts frequently warn us that new and emerging digital technologies are going to revolutionize work by performing an ever-growing number of human tasks. News reporting in respectable publications and even serious scholarly work typically overstates the threat. There is really no disputing the disrupting impact of digital technologies on work. There is plenty of evidence that demonstrates machines are rapidly increasing their abilities to perform more human physical and thinking tasks. No one is entirely certain what this will mean for the future of work. Some are beginning to sound the alarm, while others are worried but more reserved in their warnings. The problem with making predictions about the future is that it is impossible to know, with any real certainty, what will happen. Adam Keiper, an American Fellow at Ethics and Public Policy Centre warns serious thinkers against leaps of logic and the "chain of uncertainties" (Figure 5).[125] Bold claims about how digital machines will affect the workforce tend to be either too optimistic (more leisure time) or pessimistic (massive unemployment).

Figure 5. The Pitfalls of Making Predictions in Times of Rapid Change and Great



Source: Data from Adam Keiper, *The Transformative Impact of Robots and Automation*, Testimony Presented to the United States Joint Economic Committee, May 25, 2016.

[125] Adam Keiper, *The Transformative Impact of Robots and Automation*, Testimony Presented to the United States Joint Economic Committee, May 25, 2016, 3.

The future of work in northern Saskatchewan is uncertain, like in urbanized areas of Canada and the world. Ignoring how digital technologies will impact the northern Aboriginal workforce will cause greater job dislocation and seriously undermine the ability of northern workers to find work, particularly in the new digital industries. Andrew McAfee and Brynjolfsson, MIT scholars, worry that policy inaction now will worsen the impact of digitization on the workforce.

> Such a radical reshaping of work will call for new policies to protect the vulnerable while reaping the gains of the new age. The choices made now will prove particularly consequential. The wrong interventions will hurt the economic prospects of millions of people around the world and leave them losing a race against the machines, while the right ones will give them the best chance of keeping up as technology speeds forward.[126]

Many research organizations housed in academic institutions or linked to government, around the world are trying to figure out the future impact of digital technologies on work. The Massachusetts Institute of Technology (MIT) established the Initiative on the Digital Economy to discover how new and emerging digital technologies will affect work, life and society. The research initiative brings together leading academics and experts from the United States and the world, including Brynjolfsson and McAfee to study the policy challenges and prepare for change. They have given themselves a two part question to answer: "What will the workforce of the future look like, and how can we accelerate the transformations of institutions, organizations and human skills to keep with the quickening pace of digital innovation?"[127] The work done on this question at the Initiative on the Digital Economy is needed to inform policy decisions in the northern Saskatchewan context. It would also increase the chances of accurate problem definition and entry onto the public policy agenda. A similar initiative could be established by making use of existing research talent drawn from the universities and colleges in Saskatchewan. The research questions would build off the global work on this topic and, like Initiative on the Digital Economy, involve stakeholders, such as the provincial government, workforce representatives from the northern region, regional leaders and related organizations. A northern Saskatchewan-based initiative would guide

[126] Andrew McAfee and Erik Brynjolfsson, *Human Work in the Robotic Future: Policy for the Age of Automation*, Foreign Affairs, July/August 2016, 140.
[127] MIT Initiative on the Digital Economy. "Productivity, Employment and Inequality, "accessed July 2016, http://ide.mit.edu/.

policy action designed to prepare the northern workforce for future digital work and to mitigate the immediate and long-term negative impacts of the digitization of work. It would also produce valuable research and contribute to wider discussions on the new digital economy.

There is a lack of understanding of how digital change will affect northern regions and Aboriginal peoples' cultural and economic well-being. Access to reliable statistical data about Aboriginal peoples in Canada is very difficult. Available data produced by Statistics Canada provides some idea of what is going on in the northern labour market, but poor reliability makes gaining a true picture of events nearly impossible. Policy-makers, academics and businesses need reliable data to understand the shift that is happening in work and jobs, so that steps can be taken to reduce the negative impacts on workers and their communities.

Government funded colleges, universities and similar job training and education institutions and the provincial government are important actors in preparing northern workers for the future of work. The research community is certain that digital disruption of the workforce will affect nearly all jobs in different sectors and occupations – many will be changed or eliminated, while new jobs are likely to appear in all parts of the economy. To date, however, the Canadian north is only beginning to attract research interest. Northern regions and the natural resource sectors located there are already being impacted by digital technologies and will continue to be in the near future. Northern research on digital job disruption should follow a task-based approach, which will allow a more nuanced understanding of how digitization affects the Aboriginal workforce.

In Europe, policy-makers have recently acknowledged the disruptive potential of digital technologies on labour markets and are starting to frame policy discussions and coordinate policy development and implementation to mitigate disruption and take advantage of new industries, jobs and digital technologies. An informal meeting of Europe's employment ministers in July 2016 provides some insights into current thinking at the highest levels of government. The Slovak Minister for Labour, Jan Richter described the problem for governments: "The experience tell us that technological changes have two significant

impacts: they eliminate certain jobs by replacing human work with work of robots and they change qualification requirements placed on workers in many professions or create new professions."[128] The Slovak Minister summed up the essence of digital disruption on the workforces. He adds that predicting jobs is not enough, the challenge of equal importance is to "define which skills and knowledge will become obsolete because they will be taken over by robots and computers systems, and which skills and knowledge workers need to acquire to master new technologies.[129] Saskatchewan would benefit from a similar meeting of local, regional and provincial leaders in government, education and business. Bringing these key stakeholders together is a crucial primary step to action. They stand to enhance job training and education so that northern Saskatchewan Aboriginal peoples are able to take advantage of the jobs and business opportunities in the new digital economy.

Fewer jobs in the natural resources sector and the related service sectors because of current and emerging digital technologies will cause higher unemployment resulting in social disruption. Aboriginal workers will have a difficult time finding new jobs in their region and the great majority may never find work again. A basic income is worth considering in northern Saskatchewan as it alleviates the loss of income from joblessness and could provide a more robust social safety net. The Brookfield Institute for Innovation and Entrepreneurship at Ryerson University is supportive of Ontario's decision to launch a basic income system. They believe that as digital technologies become more capable of human physical and cognitive tasks, "people's relationship with the labour market changes, they become more likely to create their own jobs and pursue entrepreneurship."[130] The Ontario Government recently announced a basic income pilot, designed and implemented by the province, to "...test the growing view that a basic income could help deliver income support more efficiently, while improving health, employment and

[128] SK-EU2016. "Europe is Preparing for Digitalisation and Automation of Work," July 15, 2016, accessed July 2016, http://www.eu2016.sk/en/press-releases/europe-is-preparing-for-digitalisation-and-automation-of-work.
[129] SK-EU2016. "Europe is Preparing for Digitalisation and Automation of work," July 15, 2016, accessed July 2016, http://www.eu2016.sk/en/press-releases/europe-is-preparing-for-digitalisation-and-automation-of-work.
[130] Matthew Seddon, *Basic Income: A Helping Hand for Entrepreneurship? Brookfield Institution for Innovation and Entrepreneurship*, June 2016.

housing outcomes for Ontarians."[131] A northern Saskatchewan basic income has potential to provide Aboriginal people with enough income to cover basic needs without eliminating the incentive to find work. The initiative would require sufficient data collection for evidence to enable a determination of overall effectiveness and efficiency.

Enrico Moretti, professor of economics at University of California, encourages jobs creation in the innovation or knowledge sector of the economy in his 2012 book *The New Geography of Jobs.* Moretti explains that "good jobs" with high incomes will be found in large numbers in the new industries. He believes the best way to create local jobs is by attracting highly educated and skilled talent. His research shows a jobs multiplier effect in cities that attract high-tech job: "…for each new high-tech job in a city, five additional jobs are ultimately created outside of the high-tech sector in that city, both in skilled occupations (lawyer, teacher, nurses and in unskilled ones (waiters, hairdressers, carpenters).[132] Moretti's research demonstrates that new digital and knowledge-based jobs produce more jobs. The creation of high-tech jobs in northern Saskatchewan could produce a job multiplier effect and increased employment of Aboriginal peoples. Job creation in the new digital economy continue to occur in occupations that will remain difficult to automate for some time (e.g. complex social interactions and physical movements), but new possibilities for jobs exist in the digital economy.

High-speed broadband internet is the foundation of the digital economy, but without the infrastructure to support it, northern Saskatchewan will not be able to attract or start-up businesses or entrepreneurs that use digital technologies. Rick Heeks, a British professor, argues internet infrastructure is only the "starting point" for wider economic development.[133] According to Heeks, establishing the infrastructure for advanced digital technologies should not be the end of development, but rather, the first stage of long-term development. If northern Saskatchewan improved its internet service and coverage, the region could

[131] Ontario Government, "Ontario Moving Forward with Basic Income Pilot, Ministry of Community and Social Services," June 24, 2016, accessed July 2016, https://news.ontario.ca/mcss/en/2016/06/ontario-moving-forward-with-basic-income-pilot.html?utm_source=ondemand&utm_medium=email&utm_campaign=p.
[132] Enrico Moretti, *The New Geography of Jobs* (New York, NY: Houghton Mifflin Harcourt, 2012), 13.
[133] Richard Heeks, "Do Information and Communication Technologies (ICTs) Contribute to Development?" *Journal of International Development* 22, no. 5 (2010): 627.

establish a digital economy strategy, following the United Kingdom's example. The UK Government's Digital Economy Strategy for 2015-2018 supports UK businesses to innovate using new digital technology. Its purpose is to encourage business to use digital technology and "how they can develop and build their confidence in new digitally-enabled ways of doing business."[134] Infrastructure development would be a central objective of a similar digital strategy for northern Saskatchewan and the provincial government. Education and skills training would also be key objectives. Providing Aboriginal youth and adult workers with the opportunity to learn about, work with and operate the latest digital machines, such as autonomous vehicles, unmanned drones, the Internet of Things and advanced robotics, will aid in preparations for digitally enhanced work.

Specific Recommendations

Government of Saskatchewan should consider the following policy options:

- Define the nature of the problem for the provincial government and identify the potential impacts on the northern labour market.
- Develop an Aboriginal-specific and northern place-based response to mitigate the challenges of digital job displacement and to capitalize on the opportunities for new kinds of production, work and jobs in the twenty-first century digital economy.
- Co-produce with the northern mining industry, post-secondary institutions and Aboriginal leaders the right policy mix to encourage Aboriginal participation in digital education, training and opportunities.

Mining Industry should consider such possibilities as:

- Clarify the companies' jobs commitment to northern Aboriginal workers and communities in the new digital economy.
- Share insights with government, Aboriginal communities, and educational institutions about how new and emerging digital technologies will change northern Aboriginal work and jobs.
- Identify the jobs or tasks with the potential to be complemented or substituted by digital technologies in the northern Saskatchewan mining industry.

Post-Secondary Institutions should consider moving forward with such actions as:

- Develop an Aboriginal and place-based education and training strategy focused on delivering the knowledge and competencies required for digitally enhanced work and new jobs.
- Work with the Government of Saskatchewan, the mining industry and northern Aboriginal communities on a northern Aboriginal digital jobs and economy action plan.

[134] Innovate UK, *Digital Economy Strategy 2015-2018*, Technology Strategy Board (2015).

- Make more accessible the education and training for the jobs of the future to Aboriginal workers and communities in northern Saskatchewan.

Aboriginal Communities in Northern Saskatchewan should examine the potential utility of such initiatives as:

- Focus on the possibilities for work, life and society in the new digital economy and strive to achieve the desired outcomes.
- Support the use of the new and emerging digital technologies in northern post-secondary institutions.
- In collaboration with the northern mining industry, encourage Aboriginal workers and youth to explore the near and medium-term digital work and jobs.

Conclusion

In times of rapid change caused by new technologies, government intervention and leadership are needed to mitigate the negative economic and social impacts. Citizens left worse off expect their government will be responsive to their needs and be creative in order to support for new opportunities. Digital transformation affects jobs in the mining and support industries, the largest source of private employment in northern Saskatchewan. New and emerging digital technologies can displace and replace workers, reduce the need for human labour and improve educational attainment. The northern Saskatchewan Aboriginal workforce is vulnerable to digital change. Aboriginal workers, compared to non-Aboriginal peoples, are most likely to lose their jobs, find it more difficult to obtain new jobs in the region and lack access to public institutions that offer the relevant digital training and education for jobs in the new digital economy.

Digital technologies affect work in different jobs and sectors. More jobs will be changed or eliminated because of digital technologies and their power to replace humans in performing tasks. Low to middle income ordinary jobs are at the greatest probability of automation. These jobs involve routine and physical tasks. Digital machines, such as artificial intelligence and advanced robotics, have recently improved capabilities related to routine and physical task performance. Aboriginal peoples are employed in large numbers of ordinary jobs that digital machines are able perform. Higher income and skilled jobs that require advanced education and several years of experience are safer from digitization. In northern Saskatchewan today, these non-production jobs predominantly employ non-northerners and non-Aboriginal peoples. Many live out of the north and fly in from Saskatoon. Greater sophistication and breakthroughs in future digital technologies will raise the probability of automation in higher income and skilled professional jobs that require complex social interaction and reasoning. Current technological limitations in computing power and software prevent digital machines from substituting advanced human tasks.

Digital technologies contribute to the disruption and vulnerability of Aboriginal workforce. Northern job displacement, characterized as job losses and long-term unemployment, is concentrated in the ordinary jobs performed by Aboriginal workers. A less labour intensive northern resource economy with fewer jobs in mining and related service sectors has produced an expectation gap for work. New and emerging digital technologies cause fewer jobs for Aboriginal workers throughout substitution or complementarity. Production in the twenty-first century requires powerful digital machines and a smaller number of workers. The digitization of work reduces the need for human labour while demand for jobs, influenced by population growth, increases.

This mismatch in job supply and demand is the fundamental policy problem for policy-makers: there are too few jobs and too many workers. Government intervention can mitigate the negative consequences of short-term job disruption, but long-term policies are required to prepare Aboriginal workers for future work in the new digital economy. One of the objectives for policy-makers is to identify the new industries and jobs and develop a plan to educate and train northern workers for new types of work. The policies and programs, coupled with the leadership and coordination, initiated by the provincial government of Saskatchewan now and in near future will determine the economic possibilities available to the Aboriginal peoples in the northern region over the long-term. A forward looking, creative and evidence-based regional digital economy opportunities strategy, implemented as soon as possible, will go a long way to preparing current and future Aboriginal workers for the high-quality jobs of the new digital economy.

Appendix: Survey Questions and Results

10 Minute Pre-Interview Survey

Introduction

We live in an age of remarkable technological development, not a week goes by without media reports of some new digital machine that has amazing potential to disrupt how things get done. One leading scholar on work in the digital economy believes that "machines themselves are turning into workers, and the line between the capability of labour and capital is blurring like never before." The question for the mining sector, government and the education system answer is: how prepared is northern Canada for the digital revolution in work?

There have been major technological developments in the mining sector and nowhere is this more evident than in Australia's northwest Pilbara region. Australia's mining sector demonstrates that digital mines are viable and will replace 20th century mining processes. The adoption of autonomous haul trucks, trains and drills are disrupting the nature of work in Australian mines and completely changing how things get done and which skills are in demand by employers. Other digital technologies are doing the same.

Canadian oil sands companies in Alberta have taken note and have announced they will begin testing autonomous haul trucks. It seems inevitable that the mining sector in Canada will follow suit. The impact on workers and their employment is worth considering, as they stand to be most affected. Mine labourers and, indeed, all workers who have little education and low skills will face job displacement and difficulty finding new jobs in an economy that privileges advanced digital skills.

Instructions

Please answer the questions below. This survey is used for research purposes only. Know that reference will be made to the type of professionals and organizations that participated, that you will not be identified, and will remain anonymous. Your answers will be aggregated, analyzed and reported as part of my Master's thesis. Skip any questions you do not wish to answer. Once you are finished, please click 'submit'. If this explanation is unclear, or you have questions, do not hesitate to contact me directly at raymond.thomson@usask.ca. Thank-you.

Questions

1) *In the next 25 years, the new digital technologies will change the nature of work in the following contexts:*

	Significantly	Somewhat	Not at all	Unsure	Total Responses
Globally	13 (86.7%)	2 (13.3%)	0 (0.0%)	0 (0.0%)	15
Nationally	14 (93.3%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	15
Provincially or Territorially	13 (86.7%)	2 (13.3%)	0 (0.0%)	0 (0.0%)	15
Natural resource sector generally	9 (60.0%)	6 (40.0%)	0 (0.0%)	0 (0.0%)	15
Mining sector specifically	9 (60.0%)	6 (40.0%)	0 (0.0%)	0 (0.0%)	15

2) *Will the new technologies lead to:*

Response	Chart	Percentage	Count
More jobs		0.0%	0
About the same number of jobs		40.0%	6
Fewer jobs		40.0%	6
Unsure		20.0%	3
		Total Responses	**15**

3) *Provincial government policy in the field of digital technologies and the future of work is:*

Response	Chart	Percentage	Count
Well developed		0.0%	0
Just starting to be developed		53.3%	8
Not currently under development		20.0%	3
Unsure		26.7%	4
		Total Responses	**15**

4) *Canadian government policy in the field of digital technologies and the future of work is:*

Response	Chart	Percentage	Count
Well developed		0.0%	0
Just starting to be developed		60.0%	9
Not currently under development		6.7%	1
Unsure		33.3%	5
		Total Responses	**15**

5) *In your province or territory, post-secondary institutions are preparing students for the world of digitally-enhanced work:*

Response	Chart	Percentage	Count
Extremely well		0.0%	0
Well		33.3%	5
Neutral		26.7%	4
Not sufficiently		13.3%	2
There are problems		6.7%	1

Unsure		20.0%	3
		Total Responses	**15**

(6) How will the digital transformation of work effect northern and Aboriginal workers?

Response	Chart	Percentage	Count
Much more than other workers		60.0%	9
The same as other workers		20.0%	3
Much less than other workers		13.3%	2
Unsure		6.7%	1
		Total Responses	**15**

Bibliography

Arntz, Melanie, Terry Gregory and Ulrich Zierahn. *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis*. Organization for Economic Cooperation and Development: Social, Employment and Migration Working Paper, No.189, 2016.

Autor, David H. "Why Are There Still So Many Jobs? The History and Future of Workplace Automation," *Journal of Economic Perspectives* 29, no. 3 (2015): 3-30.

Autor, David H., Frank Levy and Richard J. Murnane. "The Skill Content of Recent Technological Change: An Empirical Exploration." *The Quarterly Journal of Economics* 118, no. 4 (2003): 1279-1333.

Bardach, Eugene. *A Practical Guide for Policy Analysis: The Eightfold Path to More Effective Program Solving*. Los Angeles, CA: SAGE, Fourth Edition, 2012.

Baumgartner, Frank and Jones, Bryan D. "Agenda Dynamics and Policy Subsystems." The Journal of Politics 53, no. 4 (1991): 1044-1074.

Bloom-DiCIcco, Barbara. "The Qualitative Research Interview," *Medical Education* 40, no. 4 (2006): 314-321.

Boote, David N. and Penny Beile. "Scholars before Researchers: On the Centrality of Dissertation Literature Review in Research Preparation." *Educational Research* 34, no. 6 (2006): 3-15.

Braul, Peter. Know No Fear. How Miners Can Collect the Necessary Data to Prevent Deaths. *Canadian Institute of Mining, Metallurgy and Petroleum*. Last Modified February 2016. Date Accessed May 2016. https://www.cim.org/en/Publications-and-Technical-Resources/Publications/CIM-Magazine/2016/February/feature/Know-no-fear.aspx.

Brookfield Institute for Innovation and Entrepreneurship. Automation Potential of Canadian Occupations. Accessed June 2016. https://brookfieldinstitute.ca/research-analysis/automation/.

Brynjolfsson, Erik and Andrew McAfee. *The Second Machine Age: Work Progress and Prosperity in a Time of Brilliant Technologies*. New York, NY: W.W. Norton & Company, 2014.

Cameco Corporation. "History." Last Modified 2016. Accessed May 2016. https://www.cameco.com/about/history.

Cameco Corporation. "On-the-job Training." Accessed May 2016.

Cameco Corporation. *2012 Sustainable Development Report*. 2012.

Cameco Corporation. *2015 GRI Update*. 2015.

Canadian Mining Journal. Automation: Autonomous Fleet Performs 12% Better than Manned Fleet. Last Modified November 3, 2015, Date Accessed May 2016. http://www.canadianminingjournal.com/news/automation-autonomous-fleet-performs-12-better-than-manned-fleet/.

Canadian Mining Journal. Training: Immersive Technologies Introduces Virtual Reality. Last Modified February 9, 2016. Date Accessed May 2016.

http://www.canadianminingjournal.com/news/training-immersive-technologies-introduces-virtual-reality/.

Canadian Mining, Metallurgy and Petroleum. The Operator-Less Bench. Last Modified September 1, 2013. Date Accessed May 2016. http://www.canadianminingjournal.com/features/the-operator-less-bench/.

Chen, David. The Best In New Technology. Canadian Institute of Mining.

Chui, Michael, James Manyika and Mehdi Miremadi. *Four Fundamentals of Workplace Automation*. McKinsey and Company: McKinsey Quarterly, 2015.

Chui, Michael, James Manyika and Mehdi Miremadi. *Where Machines Could Replace Humans – and Where They Can't (Yet)*. McKinsey and Company: McKinsey Quarterly, 2016.

Coates, Ken S., Greg Finnegan, Craig J. Hall and Kelly J. Lendsay. *Unearthing Human Resources: Aboriginal Skills Development and Employment in the Natural Resource Sector*, Ottawa, ON, MacDonald-Laurier Institute, 2015.

Creswell, John W. *Research Design: Qualitative and Mixed Methods Approaches*. Lost Angeles, CA: Sage Publications, 2014.

Das, Biswajiit. *Wearable: Imagine the Possibilities -- Impact on the Mining Sector*. Deloitte, 2015.

Deloitte Canada. *Tracking the Trends 2015: The Top 10 Issues Mining Companies Will Face This Year*. 2015.

Dreambox Learning. "Adaptive Learning." Accessed July 2016. http://www.dreambox.com/adaptive-learning.

Financial Post. Driverless Vehicles are Going to Change Our World, But at What Cost? *National Post*, May 20, 2016, http://business.financialpost.com/news/transportation/driverless-vehicles-are-going-to-change-our-world-but-at-what-cost.

Ford, Martin. *The Rise of the Robots: Technology and the Threat of a Jobless Future*. New York: Basic Books, 2015.

Frey, Carl B. and Michael A. Osborne. *The Future of Employment: How Susceptible are Jobs to Computerization?* Oxford University, 2013.

Gibson, Ryan, *Is Northern Saskatchewan's Population Growing?*, ICNGD Discussion Paper #1, International Centre for Northern Governance and Development.

Goos, Maarten and Alan Manning. "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain." *The Review of Economics and Statistics* 89, no. 1 (2007): 118-133.

Government of Canada. Funding: Skills and Partnership Fund. Last Modified May 2016. Accessed May 2016. http://www.esdc.gc.ca/eng/jobs/aboriginal/partnership_fund/index.shtml.

Government of Canada. *Mine Surface Lease Agreement. In Good Practices in Community Engagement and Readiness: Compendium of Case Studies From Canada's Minerals and Metals Sector*. Sudbury, ON: Energy and Mines Ministers Conference, 2014: 55-58.

Government of Saskatchewan. *2013-2014 Annual Plan: Labour Market Development Agreement (LMDA) and Labour Market Agreement (LMA)*, 2014.

Government of Saskatchewan. *2014 Northern Benefits Summary: Saskatchewan Mine Surface Lease Agreements*. 2015.

Greene, Nicholas. A Look At How Drones Are Coming Into Their Own In the Mining Sector. *Canadian Mining Journal*. Last Modified April 2, 2015. Date Accessed May 2016. http://www.canadianminingjournal.com/features/a-look-at-how-drones-are-coming-into-their-own-in-the-mining-sector/

Greschner, Toby, Colleen Durocher and Randy Johns. *Northlands College Mine School*. Presentation. Date Unknown.

Groves, Robert M. *Survey Methodology*. Hoboken, New Jersey: John Wiley & Sons, Inc., 2009.

Heeks Richard. "Do Information and Communication Technologies (ICTs) Contribute to Development?" *Journal of International Development* 22, no.5 (2010): 625-640.

Hilson, Gavin. "An Overview of Land Use Conflicts in Mining Communities." *Land Use Policy* 19, no. 1 (2002): 65-73.

Hisschemoller, Matthijs and Hoppe, Robert. "Coping with Intractable Controversies: The Case for Problem Structuring in Policy Design and Analysis." *Knowledge and Policy* 8, no. 4 (1995): 40-60.

Howellet, Michael, Ramesh, M. and Perl, Anthony. *Studying Public Policy: Policy Cycles & Policy Subsystems*. London, UK, Oxford University Press, Third Edition, 2009.

Howes, Rick. We Need Disruptive Innovation in the Mining Sector, As Well. *Globe and Mail*, February 20, 2016, http://www.theglobeandmail.com/report-on-business/rob-commentary/we-need-disruptive-innovation-in-the-mining-sector-as-well/article28817988/.

Indigenous and Northern Affairs Canada Fact Sheet – Urban Aboriginal Population in Canada. Accessed August 30, 2016: https://www.aadnc-aandc.gc.ca/eng/1100100014298/1100100014302.

Innovate UK: Technology Strategy Board. *Digital Economy Strategy*: 2015-2018.

Keeling, Arn and John Sandlos. "Environmental Justice Goes Underground? Historical Notes from Canada's Northern Mining Frontier." *Environmental Justice* 2, no. 3 (2009): 117-125.

Keiper, Adam. *The Transformative Impact of Robots and Automation*. Testimony Presented to the United States Joint Economic Committee. May 25, 2016.

Keynes, John Maynard. *Economic Possibilities for Our Grandchildren (1930)*. Chapter in Essays in Persuasion. New York: W.W. Norton and Company, 1963, pp. 358-373.

Lamb, Craig. *The Talented Mr. Robot: The Impact of Automation on Canada's Workforce*. Brookfield Institute for Innovation and Entrepreneurship, 2016.

Lee, Joe and Kelley Prowse. *Mining & Metals and Internet of Things: Industry Opportunities and Innovation*. MaRS Market Insights, 2014.

MacKnight, Doug. Ministry of Energy and Resources. *Recent Developments in Mineral Rights Regulation in Saskatchewan*. Presentation in Calgary, Alberta. April 14, 2011.

Manyika, James, Michael Chui, Jacques Bughin, Richard Dobbs, Peter Bisson and Alex Marrs. *Disruptive Technologies: Advances that will Transform Life, Business, and the Global Economy*. McKinsey Global Institute, 2013.

McAfee, Andrew and Erik Brynjolfsson. *Human Work in the Robotic Future: Policy for the Age of Automation*. Foreign Affairs. July/August 2016.

McBain, Lesley. "Uranium City." The Encyclopedia of Saskatchewan. Accessed May 2016. http://esask.uregina.ca/entry/uranium_city.html.

McIntyre, J. and Chief H.D. Cook. *Corporate Social Responsibility and Aboriginal Relations*. International Atomic Energy Agency, 2000.

Mining Industry Human Resources Council. *Canadian Mining Industry Employment, Hiring Requirements and Available Talent 10 Year Outlook*. 2015.

Mining Industry Human Resources Council. *Saskatchewan Mining Industry Hiring Requirements and Available Talent Forecasts*. 2015.

MIT Initiative on the Digital Economy. "Productivity, Employment and Inequality." Accessed July 2016. http://ide.mit.edu/.

Mokyr, Joel, Chris Vickers and Nicolas L. Ziebarth. "The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?" *Journal of Economic Perspectives* 29, no. 3 (2015): 31-50.

Moretti, Enrico. *The New Geography of Jobs*. Mariner Books, 2013.

Ontario Government. "Ontario is Moving Forward with Basic Income Pilot." Last Modified June 24, 2016. Accessed July 2016. https://news.ontario.ca/mcss/en/2016/06/ontario-moving-forward-with-basic-income-pilot.html?utm_source=ondemand&utm_medium=email&utm_campaign=p.

Pratt, Gill A. "Is A Cambrian Explosion Coming For Robotics?" *Journal of Economic Perspectives* 29, no.3 (2015): 51-60.

Rifkin, Jeremy. *The End of Work: The Decline of the Global Labour Force and the Dawn of the Post-Market Era*. New York: Putman Books, 1995.

Roberts, Richards. Uranium Miner Joins Big Data Revolution. *Mining Journal*. Last Modified March 4, 2015, Data Accessed July 2016.

Rocco, S. Tonette and Maria Plakhotnik. "Conceptual Frameworks, and Theoretical Frameworks: Terms, Functions and Distinctions." *Human Resource Development Review* 8, no. 1 (2009): 120-130.

Saskatchewan Government. "What is the Northern Administration District?" Economic Development. Accessed May 2016. https://www.saskatchewan.ca/business/first-nations-metis-and-northern-community-businesses/economic-development/northern-administration-district.

Saskatchewan Government. Lands and Mineral Tenure. *Saskatchewan Operating Mines List*. 2014.

Saskatchewan Indian Institute of Technologies. About Us. Accessed June 2016. http://www.siit.ca/pages/about-us.html.

Schumpeter, Joseph A. *Capitalism, Socialism & Democracy*. London, UK: Routledge, 2003.

Seddon, Matthew. *Basic Income: A Helping Hand for Entrepreneurship?* Brookfield Institute for Innovation and Entrepreneurship. June 2016.

Shick, Lisa. High-Tech Mining In Saskatchewan. *Prince Alberta Now*. April 24, 2011, Accessed May 2016. http://panow.com/article/56761/high-tech-mining-saskatchewan.

SK-EU20016. "Europe is Preparing for Digitisation and Automation of Work." Last Modified July 15, 2016. Accessed July 2016. http://www.eu2016.sk/en/press-releases/europe-is-preparing-for-digitalisation-and-automation-of-work.

Smet, Aaron De., Susan Lund and William Schaninger. *Organizing for the Future*. McKinsey and Company: McKinsey Quarterly, 2016.

Statistics Canada. *Aboriginal Peoples in Canada: First Nations People, Metis and Inuit, National Household Survey 2011*. Catalogue No. 99-011-X2011001, 2013.

Statistics Canada. Census Program. *National Household Survey Profile, Division No. 18, CDR, Saskatchewan, 2011*. 2013.

Stone, Deborah A. "Causal Stories and the Formation of Policy Agendas." *Political Science Quarterly* 104, no 2 (1989): 281-300.

The Economist. Re-educating Rita: Artificial Intelligence will have Implications for Policymakers in Education, Welfare and Geopolitics. Print Edition, June 25, 2016.

The Joint Task Force on Improving Education and Employment Outcomes for First Nations and Metis People. *Final Report*. Prepared by the Saskatchewan Government and Federation of Saskatchewan Indian Nations, 2013.

Topf, Andrew. 500 jobs lost after Cameco Shuts Down Rabbit Lake. *Mining.com*. Last Modified April 24, 2016. Accessed April 25, 2016. http://www.mining.com/500-jobs-lost-after-cameco-shuts-down-rabbit-lake/.

Wallace, Clement. "The Subordination of Labour in Canadian Mining." *Labour* 5 (1980): 133-148.

West, Darrell M. *What Happens If Robots Take the Jobs? The Impact of Emerging Technologies on Employment and Public Policy*. Washington D.C.: Centre for Technology Innovation at the Brookings Institute, 2015.

Whyte-Durrant, Hugh, Ryan Geraghty, Ferran Pujol and Richard Sellschop. *How Digital Innovation Can Improve Mining Productivity.* McKinsey Global Institute, 2015.

Winkel, James D. *Northern Saskatchewan: A Transformation*. Saskatchewan Northern Affairs, 2002.

Witham, Brittany. *Attracting Foreign Investment to Northern Saskatchewan: Two Approaches for the 21st Century*, 2016.

Wolfe, David A. *A Policy Agenda for the Digital Economy. Innovation Policy Lab*. Munk School of Global Affairs, 2016.

World Economic Forum. *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*. Global Challenge Insight Report, 2016.

World Nuclear Association. "Brief History of Uranium Mining Canada: Uranium in Canada Appendix 1." Accessed May 2016. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/appendices/uranium-in-canada-appendix-1-brief-history-of-uran.aspx.

Yap, Meng. Process Automation Snapshot. *Canadian Mining Journal*, February 1, 2006, http://www.canadianminingjournal.com/features/process-automation-snapshot/.