Journal of Rural and Community Development

Digitalization, the Changing Mobility Equation and Regional Development: Experiences in the Mining Sector in Canada and Australia

Author: Keith Storey

Citation:
Storey, K. (2025). Digitalization, the changing mobility equation and regional development: Experiences in the mining sector in Canada and Australia. *The Journal of Rural and Community Development, 20*(1), 84–102.

Publisher:
Rural Development Institute, Brandon University.

Editor:
Dr. Doug Ramsey

ISSN: 1712-8277 © Authors
www.jrcd.ca

Digitalization, the Changing Mobility Equation And Regional Development: Experiences in the Mining Sector in Canada and Australia

Keith Storey
Memorial University of Newfoundland
St John's, Newfoundland, Canada
kstorey@mun.ca

Abstract

Mining has undergone a number of significant technological and organizational changes in the past fifty years. The organization of mining around the residential mine town of the pre- and post-World War 2 era gave way to the fly-in/fly-out arrangements in the 1980s. This is now challenged by a shift to the remote operations arrangements of the current digitalization era, which may see many mining jobs relocate to metropolitan areas. Each of these organizational arrangements has different implications for the regional development prospects of mining regions. Using examples from Canada and Australia, this paper explores those implications and considers some of the potential actions that may be necessary if the value proposition of mining is to continue to be acceptable to those affected by the changes.

Keywords: mining, fly-in/fly-out, digitalization, regional development, value propositions

Numérisation, équation de mobilité changeante et développement régional : expériences dans le secteur minier au Canada et en Australie

Résumé

L'exploitation minière a connu un nombre de changements technologiques et organisationnels importants au cours des cinquante dernières années. L'organisation de l'exploitation minière autour de la ville minière résidentielle d'avant et d'après la Seconde Guerre mondiale a cédé la place aux dispositions d'arrivées et de départs de transports aériens, dans les années 1980. Cette situation est désormais remise en question par le passage aux modalités d'opérations à distance de l'ère actuelle de numérisation, qui pourrait voir de nombreux emplois miniers délocalisés vers les zones métropolitaines. Chacune de ces dispositions organisationnelles a des implications différentes pour les perspectives de développement régional des régions minières. À l'aide des exemples du Canada et de l'Australie, cet article explore ces implications et considère des actions potentielles qui pourraient être nécessaires si l'on veut que la proposition de valeur de l'exploitation minière continue d'être acceptable pour les personnes touchées par les changements.

Mots-clés : exploitation minière, arrivée et départ, digitalisation, développement régional, propositions de valeur

1.0 Introduction

More than forty years after "fly-in/fly-out" (FIFO) arrangements were adopted in the mining sector, the House of Representatives Standing Committee on Regional Australia presented a report on its impacts, "Cancer of the bush or salvation for our cities?" (Australia, 2013). The title illustrates the longstanding divergent views on the regional benefits and costs of this type of work organization. The geography of mining changed significantly with the introduction of FIFO as an alternative to residential mining towns, and now digitalization, particularly in Canada and Australia, appears to be another disruptive change underway, the potential outcomes of which seem worthy of more attention than they have received to date.

The mining town has long been a focus of research (e.g., Blainey, 1963; Bradbury, 1979; Bowles, 1982; Tonts et al., 2012), and while there is now a considerable and growing body of work on the regional development impacts of FIFO (e.g., Storey, 2001; Markey, 2009; Deacon et al., 2017), there is as yet little information or analysis on the development outcomes of digitalization. As such, this paper is an exploratory exercise. Based on EBSCOhost, Google Scholar and other searches, examples were drawn from academic, industry and government literature to illustrate the main potential and known consequences of this new geography. Digitalization technologies offer considerable benefits, but may also have significant costs. It is hoped that this discussion of effects and responses may contribute to the development of strategies which maximize the positives and minimize the negatives for those affected.

2.0 Theoretical Context and Issue Relevance

In the 1980s, there was a significant revival of interest and new thinking about "movement" and related studies. The "mobility turn" marked a shift in focus from the static spatial analysis that had characterized much of the geographic thinking of the time to the dynamics of movement and flows (Sheller & Urry, 2006; Cresswell, 2011). Several factors encouraged this paradigm shift, including technology changes in the transportation (air, high-speed rail) and tele-communications (mobile telephones, fax machines, the internet) sectors, plus increased connectedness associated with globalization (international trade, multinational corporations), labour migration, urban growth, tourism and the rise of consumer culture. These and other changes collectively contributed to a growing recognition of the centrality of mobility in understanding contemporary social, economic, and cultural processes, which in turn has led to new research questions, new methodologies, and new theoretical frameworks.

A particular subset of these interests is that of economic-related geographic mobility (ERGM), which Cresswell et al. (2016, p. 1787) define as "frequent and/or extended travel from places of permanent residence for the purpose of, and as part of, employment". They further note that ERGM captures patterns that "exceed standard definitions of 'commuting' in terms of the time, length, and complexity of journeys to and from work" (p.1787). While there is an awareness that the number and type of mobile workers—those engaged in more extended and/or complex forms of ERGM—has increased significantly in the past fifty years, data are generally poor in both Canada and Australia. A KPMG study estimated that there were 44,610 mine workers throughout Australia involved in some form of long-distance commuting in 2011 (KPMG, 2013), but by 2015 the Chamber of Minerals and Energy estimated that there were 60,000 in Western Australia alone (Parker et al., 2018). More recent

estimates suggest that in Australia as a whole the number was greater still at 100,000 plus in mining and oil and gas by 2023 (AUSINET, 2023). In Canada, company information about FIFO numbers is available for some mines, but there is no agency with the authority (or perhaps the interest) to compile an overall or even a regional database. At best, based on the estimated number and size of mines using FIFO, it can be concluded that the total number of workers involved in this form of commuting in this sector in Canada while considerable, is significantly fewer than in Australia.

While ERGM covers a broad spectrum of employment mobility types in many different sectors, the focus here is on FIFO-type work in mining, which has significantly affected the residential and job locations of workers, and development pathways for many resource and non-resource regions. While the community and regional development consequences of FIFO and its variants have been the subject of considerable study and policy concern in recent years (e.g., Mckenzie et al., 2014; Perry & Rowe, 2015), significant changes are now underway that seem likely to further disrupt the current geography of extractive mining activities and related mobilities in different ways.

Until the 1980s, the establishment of mining towns was the only option for the development of mineral resources. Mobility was associated with the movement of capital, labour, technology and entrepreneurship *to* the resource. The introduction of FIFO changed the mobility equation in that labour no longer needed to be based at the resource location, thereby changing the roles of both mining host communities and their regions, and other non-mining communities and regions elsewhere. Now, with the introduction of digitalization technologies, the mobility equation is changing yet again. This time, the change has primarily been the result of the increased mobility of data. The ability to move data quickly, efficiently, safely and cheaply has led to the development of new products and processes (e.g., automation, use of AI and machine learning, and predictive analytics) which have permitted new and greater flexibility in terms of *where* many mining activities can be carried out. One outcome has been the emergence of the phenomenon of the "urban miner," whose work locations, often in metropolitan locations, may mean that those workers need never set foot in the mine itself. Where "remote work" in mining once referred to work at isolated locations at a distance from other urban places, it now increasingly refers to work which is remote from the resource.

Whether continued growth in the demand for minerals will mean more workers in the sector in the future remains uncertain. What is more certain is that what those workers will do and where they do it will change. New concentrations of mining activities in larger urban centres will mean that fewer workers are required at the mine site. Labour mobility and its consequences may not continue to be a primary focus of government and the research community, as has been the case in the FIFO era. Rather, the relocation of mining work has potentially significant implications for the value proposition of mining for existing mining communities and regions; if there is a geographic shift in jobs and business opportunities to other locations, what benefit is mining to the resource hosts? How this will play out remains to be seen, but it is a question that seems likely to become one of increasing importance.

The implications of failing to address this issue include increased difficulty for mining companies to secure a social licence to operate and the consequent disruption of the mine development process at a time when the supply of critical minerals is itself a critical issue. In both Canada and Australia much of the search

for and development of new mineral resources is on land owned or occupied by Indigenous groups. If governments are serious about reconciliation and redressing past injustices to Indigenous peoples, then careful consideration of the implications of the new technologies should be a high priority. Similarly, if Indigenous groups are to be able to anticipate and respond to corporate decisions that will impact their well-being, then the potential impacts of digitalization must be made clear. Difficulties in reaching agreements with local residents and traditional land owners have already increased in recent years, and mutual trust seems to be in decreasing supply. This implies that the mining companies will need to understand the outcomes of their actions and prioritize the development of strategies that are acceptable to all parties if they want to be able to proceed. Overall, increased collaboration between companies, residents and governments will be essential.

3.0 FIFO and Regional Development

Particularly since the late 19th century, residential mining towns have been a characteristic of the Canadian and Australian landscapes. For the most part, these towns are enclave communities with weak forward and backward linkages to other communities or industrial activities in their regions while showing stronger linkages to the metropolitan sources of their capital, technology and industrial inputs and their foreign markets (Radetzki, 1982). At the same time, benefits from mining have more often benefited the mining companies or higher levels of government than local communities and regions to the point that Markey and others have described hinterland areas as 'resource banks' which governments use to fund provincial infrastructure and services, without adequate attention to rural reinvestment (Markey et al., 2008). Tonts et al. (2013) also note that, overwhelmingly, the wealth generated by resource booms has been concentrated in the cities, while public expenditure in resource regions remains comparatively low, and development continues to be oriented more towards extraction rather than diversification. These relationships are perhaps best illustrated when mining ends and a new future for the mining community needs to be considered. To date, there have been very few mining towns in either Canada or Australia that have made the successful transition to a community with a non-mining or diversified economic base.

When FIFO began to be widely used in the 1980s, there was little in the way of regulation of its potential impacts, but most government authorities appeared happy to see the mining industry take the initiative, not only in the development of new resources but also in removing them, government, from the burden of creating, operating (and later often closing) the new towns that came with that development. In addition, it was felt that FIFO offered the opportunity for Indigenous workers to participate more fully in the industrial economy without having to permanently leave their communities, offering a potentially significant opportunity for regional economic development (Hobart, 1989; Gagnon, 1992). From the company perspective, FIFO offered significant cost savings over the traditional 'new town' and helped address labour shortage issues in the mining regions (Kinhill Engineers, 1991; Fortescue, 2011). For these and other reasons, FIFO initially appeared to be a win-win situation for all parties involved, a view that is now not necessarily generally accepted.

The shift from a 'new town' to a 'no-town' system, based on fly-in/fly-out (FIFO)-type travel arrangements and camp-style accommodations, has had significant

impacts on the geography of mining and in both Canada and Australia and temporary migration between home and work regions has become standard practice for workers at new mines and even for many at residential operations. In neither country have there been any purpose-built mining towns constructed since the mid-1980s. FIFO has also had impacts on places other than those in the immediate vicinity of the mine. Some communities have emerged as 'source' areas for mine labour, others as 'host' communities in the mining region for mobile workers, and yet others as transportation 'hubs' to facilitate the movement of workers between their place of residence and their workplaces (Mckenzie et al., 2014; Storey, 2018; Butters, 2020). These developments have increased the geographic space where mining impacts are felt, providing new economic opportunities for some communities. They have also tempered the local effects of downturn and closure of mines by spreading the effects of employment losses among more centres. However, they have also recreated some of the problems of the single industry community by tying some communities to distant resource operations through their labour supply roles and creating situations of 'dependence at a distance' (Storey & Hall, 2017).

From a local business perspective, FIFO initially saw supply and service functions, which in pre-FIFO days would have been performed in the mining community, now being sourced in distant metropolitan areas and lost to the region. In the 1980s, the leakage and associated loss of benefits from these 'fly-over' effects (Storey & Shrimpton, 1989), was one of the key issues prompting governments to implement requirements for benefits agreements. Since the introduction of such agreements, leakages have been significantly reduced. For example, in Canada in 1987, only 23% of expenditures by the Lupin gold mine, some 350 km northeast of Yellowknife, were made with firms based in the Northwest Territories (Shelley et al., 1987). However, by 2006, the Ekati diamond mine, 310km north of Yellowknife, was spending 78% of its total expenditures with Aboriginal and northern-owned businesses in the Northwest Territories (NRCan, 2016). Today, in Canada in particular, many supply and service functions for the mines and the camps are provided by local Indigenous companies, either independently or in partnership with other suppliers. Thanks to the provisions of benefits agreements, some of the benefits from mining now stay within the mining region during operations, though whether those agreements have been able to provide a platform for long-term sustainable development beyond the life of the mine is questionable (Rixen & Blangy, 2016; O'Faircheallaigh, 2021).

FIFO arrangements also offer workers greater choice in terms of where they can live. With mining companies willing to pay all or part of worker travel costs between home and work, many workers have relocated and subsequently travel to their workplaces from their preferred new locations. Data from the former Polaris mine, opened in 1981 in what is now Nunavut and one of Canada's earliest FIFO mines, for example, showed that in 1987 54% of current northern hires had relocated to more southerly locations (Storey & Shrimpton, 1989), while in Saskatchewan in 2016 33% of northern hires are reported to have moved to communities further south from which they now commute (Saskatchewan, 2016).

In Australia, many FIFO workers have chosen to relocate to 'sea change' communities such as Busselton, Margaret River, Denmark and Jurien in Western Australia or 'tree change' communities such as Dubbo, Tamworth and Griffith in

New South Wales and Ballarat, Shepparton and Wodonga in Victoria (PRD, 2024).[1] There has been little research on the impacts of FIFO workers relocating, but losing active participants in the labour force who hold well-paid jobs is unlikely to be beneficial to the social composition and local economic characteristics of small Indigenous communities (Gagnon, 1992; McBain, 1995), and may well have contributed to the income disparities and rising housing costs experienced in sea and tree change communities (Mckenzie et al., 2014).

Near–town commute operations pose another set of challenges associated with 'free-rider' or 'fly-through' effects (Baumol, 1952; Storey, 2014), in which companies and workers use local infrastructure and services without paying their full/fair share of the associated costs. This may include, for example, additional direct costs associated with use of roads, other infrastructure and services, and indirect costs to community residents from noise, air pollution, overcrowding and social tensions. While companies pay taxes and royalties from the development of resources, these typically go to state/provincial governments, which may not necessarily return them to the communities that bear the costs.

While growth can bring new opportunities to local businesses, it may also have negative effects locally through a variant of Dutch Disease (The Economist, 1977). Incoming resource companies drive up the price of local labour such that local non-resource-based companies cannot compete for labour and may be forced to reduce service levels or even close. At the same time, demands on housing from the comparatively well-paid transient commute population can have negative effects when companies and incoming workers rent or buy into the typically limited supply of housing, driving up costs to the detriment of some residents and incoming non-resource sector workers.

Rapid growth may also exceed a community's capacity to plan and manage that growth because of the limited availability of human resources. Furthermore, where growth-related decisions rest with non-local authorities, the capability to act may be severely constrained. Fort McMurray, for example, had among the most expensive residential land prices in Canada during the boom in the first decade of this century, a problem that was exacerbated over time by the failure of the provincial government to cancel oil leases and release Crown Land for residential and commercial development in a timely fashion (Alberta, 2006 [Recommendation 17c]).

Problems may be further heightened where the provision of infrastructure or services is dependent on funding from higher levels of government. For example, Highway 63, the road link between Fort McMurray, Edmonton, and the south, and the route for Drive in/Drive out workers and industry traffic moving to and from oil sands sites, had for many years been the location of serious accidents and other transport-related problems. In 2006, the province of Alberta announced that it would twin the mainly two-lane undivided highway, a project that was estimated to take at least five years to complete (Alberta, 2006). After numerous delays, and only after a particularly high-profile crash killed seven people in 2012, the government announced an accelerated timeline ("Alberta to twin Highway 63 by

[1] 'Sea change' is where individuals abandon city living for a perceived better life in rural coastal communities. The term originates with Shakespeare's *The Tempest*, but was popularised by the ABC TV series *SeaChange.* which prompted city-dwellers to escape to the coast. 'Treechange,' describes the movement of urban people to the countryside. The term being first coined by ABC Ballarat radio mornings presenter Steve Martin on his radio talk back show (Kelly & Haslam Mckenzie, 2005).

2016," 2012), and the twinning was finally completed in 2016, some ten years after the start date.

FIFO involves significant worker travel and to meet these needs some communities have established themselves as transportation hubs. More than 64,000 of the 126,000 mine workers in Western Australia work in the Pilbara, in the north west of the State, mainly in the iron ore sector (Western Australia, 2024). In 2016-2017, an estimated 60,000 persons in the State were engaged in FIFO or similar types of commute work (Parker et al., 2018), many of whom live in the suburbs of Perth (OECD, 2023). As a result, Perth has become the main air transportation hub for the region, and during the mining boom between 2000 and 2013, annual domestic traffic grew from 3.5 to 10.7 million passengers (Perth Airport, 2024).

In Canada, Fort McMurray, Alberta, is the main urban centre in the Athabasca oil sands region. It is a host community for commute workers who work elsewhere in the region and a transportation hub for those travelling to and from and within the area. Between 2009 and 2013, the number of passengers passing through the airport increased by 46% to 1.31 million passengers. Those who arrive there then need to be transferred to their work sites, while others living in Fort McMurray, and able to commute to work on a daily basis, also need transportation. Diversified Transportation Ltd, one of a number of bus companies in Fort McMurray, estimated that at the peak of the boom it moved approximately 4.8 million passengers per year from the airport and town to worksites in the region (Jones & Bascaramurty, 2015; Malik-Khan, 2017).

Transportation and related services for commute workers can offer significant employment and business opportunities, but the volatility of the sector can be damaging for those individuals and communities involved when conditions change. The reduction in oil sands activity after 2014 saw passenger numbers at the Fort McMurray airport decline by 54% to 595,316 in 2019, and as a result of COVID-19 by a further 62% to 228,627 in 2021, resulting in staff reductions and other cost-cutting measures at the airport (Fort McMurray International Airport, 2024).

In some cases, communities that began as residential mine towns have become commute operations. In Western Australia, the town of Telfer, built in 1976, became a commute operation in 1996 (Moore, 1997), while Leinster, built as a residential company town in 1976 and which had a population of 1,098 in 2001, is now primarily a commute operation (approximately 700 workers) with a similar residential population (The Shire of Leonora, 2024). Transitions such as these, as discussed below, could become more common in the future as digitalization practices reduce the requirements for onsite mine labour. In Queensland, commute work has also been used by companies as a labour selection tool. In the first decade of the 2000s, a number of coal companies in the Bowen Basin adopted a 100% FIFO approach, in which only workers from outside, but not within, the region were hired (Queensland Government, 2015). This appears to have been a tactic to control labour action and minimize the power of the unions. In the *Strong and Sustainable Resource Communities Act 2017*, the State recognized that companies would need to bring some of their labour in from outside the region, but legislated that 100% FIFO would not be permitted for a number of designated projects (Queensland Government, 2017).

Commute work has thus had both geographic spread and concentration impacts as far as employment is concerned, which present both additional and different impact

management concerns and require different management approaches to those of traditional mine towns. Commute work also presents a different set of implications for the social, economic and other relationships between workers and the companies, workers and their families, and companies and governments. Digitalization technologies and processes now offer the prospect of further significant organizational and spatial disruptions in the mining sector.

4.0 Digitalization and Regional Development

Digitalization, sometimes referred to as 'industry 4.0' (Schwab, 2017), centres on the way that the use of data can help improve industry processes and practices to lower costs, increase productivity and increase safety. The principal benefits focus on enhanced efficiency and productivity across the mining value chain through data-driven decision-making.

The spatial consequences of the utilization of digitalization technologies vary, but perhaps the most significant is the increased ability to operate remotely. Since the early 2000s, there have been rapid advances in the development of autonomous equipment and the ability to communicate over distance, both above and underground. As a result, an increasing number and types of mining activities that once required workers to operate machinery and work on site can now be managed from centres far removed from the resource.

In 2008, Rio Tinto introduced its *Mine of the Future* program, which marked the beginning of efforts by large-scale mining companies to adopt digitalization technologies and practices (Rio Tinto, 2008). Among those practices was the establishment of an integrated remote operations centre in Perth, where autonomous and semi-autonomous work activities, including their autonomous vehicles and load-haul system at their Pilbara operations, could be monitored and managed. Since then, BHP (in 2013), Roy Hill (in 2013) and Fortescue Mining (in 2020) have each established similar centres in Perth to manage operations at their own Pilbara operations, and the COVID-19 pandemic has encouraged other companies to adopt similar arrangements elsewhere (Gallardo et al., 2020).

Remote operating centres not only monitor autonomous load haul, rail, and ship-loading operations but integrate these activities and other elements of the value chain as part of a 'pit-to-port' system designed to minimize cost and maximize system effectiveness, efficiency and safety. Data on the number of workers at these remote operations centres is limited, but in 2013, Rio Tinto reported 400 employees at its Perth centre, a number which had increased to 800 by 2019 (Perth Airport, 2019), while BHP reported some 300 employees at its Perth IROC in 2013 when it first opened (Kakulas, 2013). Operational responsibilities at all centres have since increased to include more mines, additional activities and more equipment. In Rio Tinto's case, the Perth centre now manages and oversees activities at 17 iron ore mines, four port terminals, 2,000 km of rail network, as well as its autonomous trains, trucks, drills and other equipment in the region (Rio Tinto, 2023).

To stimulate development in the Pilbara, local authorities have long sought to minimize FIFO and increase the residential workforce (Perera, 2018; OECD, 2023). Digitalization and the relocation of work now present an additional challenge. Overall growth in mining activity may have served to hide job losses from automation, and this may have contributed to the relatively low levels of concern expressed by Pilbara authorities over the local impact of these changes. However,

there has been surprisingly little reaction to the relocation/creation of jobs in Perth rather than in the mining region.

The use of autonomous equipment may have particular regional impacts, and the number of autonomous vehicles in use is increasing rapidly. In 2023, the leading users of autonomous mining load haul vehicles (ALHVs) were Australia (882), China (326), Canada (250) and Chile (132) (Tunnicliffe, 2024). The initial cost of these vehicles may be prohibitive for some companies (a Caterpillar 797 may cost US $5M+), but for those with the investment capacity, the long-term benefits from increased safety, productivity, machine utilization, lower maintenance, operating costs and environmental benefits, compared with driver-operated machines, offset this and have contributed to the rapid growth in demand for new autonomous vehicles and conversions (Long et al., 2024; Beal et. al., 2019).

The introduction of ALHVs means job displacement for drivers, but potential gains in related areas. Suncor Energy was the first Canadian oil sands operation to adopt ALHVs in Canada, and in 2018 announced that it would grow its fleet to more than 150 vehicles over the next six years. The company estimated that this would result in a reduction of 500 driver positions but would see the creation of 100 other new jobs ("Suncor to begin using autonomous vehicles over the next 6 years," 2018). The significance of these changes, however, is not simply in the numbers. A study by the Mining Industry Human Resources Council included an index of occupational vulnerability from automation. The scores reported indicated that Heavy Equipment Operators (except crane) were among the most vulnerable, and that Indigenous workers were especially vulnerable as they had a large representation in this occupation category (MiHR, 2020).

This may be particularly concerning for this group of workers as there are strong incentives to implement automation, but few regulatory or contractual constraints that offer any job protection. In addition, in spite of the relatively high possibility of skills transfer to other mining operations or other sectors, the limited labour mobility of members of this group may significantly reduce the take up of any such opportunities elsewhere. In keeping with 'just transition' considerations, mining companies (e.g., Suncor) have claimed that they will attempt to redeploy workers to other similar positions elsewhere in their organization and offer retraining opportunities for different jobs. How effective this has been to date is unknown, but retraining semi-skilled workers who may have limited education and basic skills training is likely to be a difficult task.

The job/place implications of digitalization can also have indirect effects on mining host regions. If FIFO is reduced, fewer support workers are likely to be required in associated service sector occupations. Reductions in the number or frequency of flights directly to camps or to mining region hubs, for example, may lead to transport-related employment reductions. Similarly, fewer FIFO workers may mean that fewer camp staff are required—occupations which often support local Indigenous workers and businesses. Furthermore, the new technologies may require new skill sets for their implementation, operation and maintenance. While some local businesses and workers may be able to transition to meet new requirements, business and employment opportunities may be lost to out-of-region specialist providers, reigniting 'fly-over' concerns that were a feature of early FIFO days.

The regional development implications of digitalization for urban centres, which become hosts for remote operating centres, are potentially quite different. For

companies, urban-based work means that FIFO transportation and accommodation costs are reduced, as are camp administrative and social management requirements, while bringing workers with different functions together under one roof offers benefits of integration through easier communication and collaboration. For many in the labour force, mining is seen as a dirty, dangerous, physically demanding and unattractive occupation (Khan, 2023). Living in an urban setting and working in an office-type environment, without the need to be involved in FIFO, may make mining more attractive to a broader group of workers. Issues associated with travel, extended periods of family/community separation, unattractive environmental and workplace conditions and other mine site characteristics, which may be discouraging factors for some job seekers, can be avoided or significantly reduced – benefits which may help address some of the industry's current labour shortfall problems.

The new technologies may also represent employment opportunities for 'new collar' workers with relevant skills developed in other sectors, including scheduling, visualization technologies and IT. Increased requirements for those with decision-making, multi-tasking, coordinating and collaboration skills may also attract a new segment of the labour force, again one which is more likely to be found in larger urban centres. Where training and education is required, it is also more likely to be accessible in those centres.

5.0 Discussion

The evolving geography of mining, which has included the evolution from 'new town' to 'no town' to 'metropolitan' locations, has had and will continue to have significant regional development implications. While the establishment of traditional mine towns is unlikely to be revived, their legacy remains, and their limited regional development impact will continue as before, as will the problems of what to do with those communities when mining ceases. Similarly, FIFO work arrangements will continue, though perhaps involving fewer workers, as there will always be a need for some workers on site during each stage of the mine cycle. Here the regional development impacts will continue to be largely dependent on the benefits agreements that host region organizations can negotiate. The implications for regional development of digitalization, however, are likely to be significantly different and require a different focus for any negotiated arrangements on the part of the host stakeholders if occupational requirements and work locations change.

Some authors argue that digitalization will result in significant reductions in the number of mine workers required (WEF, 2017; Lööw et al., 2019), others argue that an increase in mining activity and job opportunities created by new technologies and processes will compensate for any job losses, such that total numbers may not change significantly. What is more certain is that the key changes will be in the occupational structure of the workforce, with job losses amongst the less-skilled occupations (Kuzior, 2022) and opportunities created in those requiring greater skills (EY, 2019). At the same time, it is also anticipated that job locations will change, with fewer direct jobs available at the mine site and more at distant, often metropolitan, locations. This will also have knock-on effects for indirect employment opportunities as supply and service sector jobs become more specialized and the likelihood increases that in the future they may be provided by non-local companies. In addition, if fewer mine workers are required to commute, this will require fewer onsite support workers, and these changes, too, will have the greatest adverse employment impacts on mining region host communities and

regions. Conversely, metropolitan and other remote (from the mine) centres are more likely to benefit as source locations for new jobs and new collar workers.

These changes will alter the value proposition of mining for communities and groups near the mine. Traditionally, the benefits of mining have been their employment and business opportunities as well as access to mining-related services and infrastructure. Job relocation and reduction will eliminate some of these opportunities for those in the mining regions, and changes in the value proposition of mining for those regions will decrease the likelihood of agreements being reached regarding social licences to operate (SLO).

To date, SLOs have offered few formal guarantees to communities, though this is changing (Pepe, 2022). If communities see value in being involved in or approving the development of local mineral resources in these new circumstances, they may choose other, more formal, participation options. These may still involve mining employment and business opportunities but may also include some form of direct project ownership or financial return based on project performance (see, for example, Kung et al., 2022). Other options may include direct payments which can be invested in non-mining opportunities, obtaining greater access to mining infrastructure and services for community benefit, or training and skills development in non-mining disciplines (e.g., health care, heavy equipment repair and maintenance), funded by the mining company (Storey et al., 2024). In each case collaboration between the host community/organization, the mining company, and often government, is essential if the potential benefits of this new mining era are to be realized in the mining regions.

Many host communities and organizations involved in mining projects may still not have the capacity to adopt and implement these and other development strategies. This is one area where companies and governments can provide greater assistance. Anglo American, for example, has developed its ‘Future Smart’ program, which aims to identify those digitalization technologies that will affect the mine of tomorrow in terms of finding safer, more efficient, and environmentally friendly ways of unlocking mineral value (Anglo American, 2023). Recognizing that such innovations may not necessarily benefit local residents, the company has also adopted a collaborative regional development approach that rethinks a mine as an economic catalyst to create independent economic opportunities for the community and region. The approach is based on a concept that the company calls ‘a social licence to innovate’. This considers how the company should conduct itself in considering the community impacts of new technology and involves listening, engaging and collaborating with those affected, transparency, and being true to purpose in viewing new technology as improving people’s lives. Projects are designed to become part of the region’s development plan. Building local capacity to develop and manage such plans is also seen as a key requirement to ensure strong leadership in development management and governance and is part of the approach (Anglo American, n.d).

Another approach that might better prepare those in resource-host regions for when mining companies come looking to develop local resources, is the use of strategic foresight and the development of future scenarios. This approach dates back to the work of Herman Kahn at the RAND Corporation in the 1950s, when scenarios were used to investigate different military strategies for engaging the Soviet Union during the Cold War (Crews et al., 2017).

Though the scenario approach subsequently fell out of favour, in part because it has more often than not been seen as a tool for colonization designed to secure the future rule of the established power complex (Ossewaarde, 2017), it has recently re-emerged as a process that is seen as having value at the community level. Cadman et al. (2023), for example, describe a scenario planning process to help create a vision for the future of commercial fisheries in Nunatsiavut, Northern Labrador. In 2019, a group of fisheries stakeholders identified a need to develop a vision of the future of commercial fisheries for the region and led a scenario planning process to help them co-develop a set of objectives to help guide decision-making options for a future determined by and for Labrador Inuit. The approach encouraged dialogue and knowledge exchange among diverse stakeholders, an important first step towards further collaboration. More specifically, the elevation of Inuit voices in the process made the vision generated specific to the region and reframed fisheries not just as an economic activity, but also as a tool for cultural and political self-determination. This approach might be equally relevant to communities and organizations facing the prospect of mining development but want to identify their development values and goals *before* being presented with proposals on which they need to make decisions.

The shift from fossil fuels to renewable and low-carbon energy will undoubtedly entail the loss of jobs in some sectors and the creation of jobs in others. These potential disruptions have prompted a revival of the idea of the 'Just Transition' (JT), first used in the 1980s by US trade unions to protect workers affected by new water and air pollution regulations (Young, 1998). This is currently seen as a framework to encompass a wide range of social interventions needed to secure workers' rights and livelihoods for those economies shifting to sustainable production, primarily through combating climate change and protecting biodiversity, but may be equally relevant to current changes associated with digitalization. Digitalization in mining offers the promise of significant disruption to the way business is currently carried out. As discussed, the effects will be beneficial for some and adverse for others. It is important that those affected are involved in the decision process to try to ensure that a just transition is realized.

References

Alberta. (2006, December 29). *Investing in our future: Responding to the rapid growth of oil sands development.* Government of Alberta. https://open.alberta.ca/dataset/debe6f74-ef28-4b74-8acd-2fd3db839984/resource/933124df-a553-41df-ae6e-0be4dc8275ce/download/3866546-2006-investing-future-responding-rapid-oil-sands-development.pdf

Alberta to twin Highway 63 by 2016. (October 19, 2012). *CBC.* https://www.cbc.ca/news/canada/edmonton/alberta-to-twin-highway-63-by-2016-1.1219835

Anglo American. (2023). Collaborative Regional Development. *Anglo American*, (Sustainable Mining Plan). https://www.angloamerican.com/sustainable-mining-plan/collaborative-regional-development

Anglo American. (n.d.). Anglo American social way. Our integrated management system for social performance. *Anglo American*. https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group-v5/Social-Way-Toolkit/socialway-toolkit-v4.pdf

AUSINET. (2023). Life of a FIFO worker. *Author*. https://ausinet.com.au/fifo-workers-life-and-jobs/#:~:text=Long%20hours%3A%20During%20your%20shift,days%20depending%20on%20your%20roster

Australia. (2013). *Cancer of the bush or salvation for our cities?* Report of the House of Representatives Standing Committee on Regional Australia. Parliament of the Commonwealth of Australia. https___aphref.aph.gov.au_house_committee_ra_fifodido_report_fullreport%20(1).pdf

Baumol, W. (1952). *Welfare economics and the theory of the State*. Harvard University Press, Cambridge, Massachusetts.

Beal, C., Tomson, A., & Vinson, C. (2019). New technology & innovation. Report 2 – Autonomous mining equipment. *RFC Ambrian*. https://www.rfcambrian.com/wp-content/uploads/2019/04/RFCA-NTI-Report-2-Autonomous-Mining-Equipment-May-2019.pdf

Blainey, G. (1963). *The rush that never ended: A history of Australian mining*. Melbourne: Melbourne University Press.

Bowles, R. T. (1982). Little communities and big industries: Studies in the social impact of Canadian resource extraction. Toronto: Butterworths.

Bradbury, J. (1979). Towards an alternative theory of resource-based town development in Canada. *Economic. Geography*, *55* (2), 147–166. https://www.osti.gov/biblio/6205826

Butters, L. (2020). Identifying a fly-in/fly-out source-hub community: The case of Deer Lake, Newfoundland and Labrador. *The Extractive Industries and Society*, *7*(4), 1401–1410. https://doi.org/10.1016/j.exis.2020.09.011

Cadman, R. (2023). *Ocean back: Inuit-led governance for the future of fisheries in Nunatsiavut*. [Unpublished doctoral dissertation] Dalhousie University, Halifax, Nova Scotia, Canada. https://dalspace.library.dal.ca/bitstream/handle/10222/82708/RachaelCadman2023.pdf?sequence=8&isAllowed=y

Cresswell, T., Dorow, S., & Roseman, S. (2016). Putting mobility theory to work: Conceptualizing employment-related geographical mobility. *Environment and Planning A: Economy and Space*, *48* (9), 1787–1803. https://journals.sagepub.com/doi/abs/10.1177/0308518X16649184

Cresswell, T. (2011). Mobilities I: Catching up. *Progress in Human Geography*, *35(*4), 550–558. https://journals.sagepub.com/doi/10.1177/0309132510383348

Crews, C., Farrington, T., & Schlehuber, L. (2017, March). Understanding strategic foresight: The history of scenario planning. *Kalypso, A Rockwell Automation Business.* https://kalypso.com/viewpoints/entry/understanding-strategic-foresight-the-history-of-scenario-planning#:~:text=A%20Brief%20History%20of%20%20Scenarios,Union%20%20during%20the%20Cold%20War

Deacon, L., Papineau, J. W., & Lamanes, T. (2017). Transiency, fly-in-fly-out workers, and sustainability: perceptions from within a resource-based community. *WIT Transactions on Ecology and the Environment, 226,* 95–105. https://www.witpress.com/elibrary/wit-transactions-on-ecology-and-the-environment/226/36282

EY. (2019). The future of work: The changing skills landscape for miners. Report prepared for the Minerals Council of Australia. https://minerals.org.au/wp-content/uploads/2022/12/The-Future-of-Work-The-Changing-Skills-Landscape-for-Miners-February-2019.pdf

Fort McMurray International Airport. (2024). *Passenger Statistics*. https://flyymm.com/corporate/resources/passenger-statistics/#passenger-stats

Fortescue. (2011). *Submission 86 to the Parliamentary Inquiry into the use of 'fly-in, fly-out' (FIFO) workforce practices in Regional Australia*. Fortescue Metals Group. http_www.aphref.aph.gov.au_house_committee_ra_fifodido_subs_sub86.pdf

Gagnon, J. (1992). Native labour commuting to uranium mines in Northern Saskatchewan: Its economic significance for Indigenous communities. In C. M. Neil, M. Tykkylainen, & J. Bardbury (eds.), *Coping with closure: An international comparison of mine town experiences* (pp. 291–309. London: Routledge.

Gallardo, R., Goddard, D., Görner S., & Rubinstein, B. (2020, October 29). Remote operating centers in mining: Unlocking their full potential. *McKinsey & Company*. https://www.mckinsey.com/industries/metals-and-mining/our-insights/remote-operating-centers-in-mining-unlocking-their-full-potential

Hobart, C. (1989). Company town or commuting: Implications for native people. In R. Robson (ed.), *The commuting alternative: A contemporary response to community needs in the resource sector* (pp. 25–38). University of Winnipeg. https://winnspace.uwinnipeg.ca/bitstream/handle/10680/1116/158-1989-Robson-TheCommutingAlternative-WEB.pdf?Sequence=1&isAllowed=ywinnspace.uwinnipeg.ca

Jones, J., & Bascaramurty, D. (2015, April 9). Fort McMurray's oil woes trickle into airport layoffs. *Globe and Mail.* https://www.theglobeandmail.com/news/alberta/fort-mcmurrays-oil-woes-trickle-into-airport-layoffs/article23872043/

Kakulas, V. (2013, July 3). Ready to IROC. *Mining News.* https://www.miningnews.net/on-location/news/1230265/ready-iroc

Kelly, G., & Haslam Mckenzie, F. (2005, October 27–28). *Housing affordability in a sea change community: Market and policy responses to changing socio-demographics*. National Housing Conference, Perth, Australia. https://www.researchgate.net/publication/252125268

Khan, Y. (2023, June 1). A 'Dirty' Job That Few Want: Mining Companies Struggle to Hire for the Energy Transition. *The Wall Street Journal*. https://www.wsj.com/articles/a-dirty-job-that-few-want-mining-companies-struggle-to-hire-for-the-energy-transition-7d62d2ae

Kinhill Engineers. (1991). *Remote mining projects . Fly-in/fly-out study*. Report prepared for the WA Department of State Development, Perth.

KPMG. (2013). *Analysis of the long distance commuter workforce across Australia*. Report for the Minerals Council of Australia. https://www.appea.com.au/wp-content/uploads/2013/04/LDCWorkforceStudy-March-2013.pdf

Kung, A., Holcombe, S., Hamago, J., & Kemp, D. (2022). Indigenous co-ownership of mining projects: A preliminary framework for the critical examination of equity participation. *Journal of Energy & Natural Resources Law, 40*(4), 413–435. https://doi.org/10.1080/02646811.2022.2029184

Kuzior, A. (2022). Technological unemployment in the perspective of Industry 4.0. *Virtual Economics, 5*(1), 7–23. https://doi.org/10.34021/ve.2022.05.01(1)

Long, M., Schafrik, S., Kolapo, P., Agioutantis, Z., & Sottile, J. (2024). Equipment and operations automation in mining: A review. *Machines, 12*(10),713. https://doi.org/10.3390/machines12100713

Lööw J., Abrahamsson L., & Johansson, J. (2019). "Mining 4.0—the impact of new technology from a work place perspective." *Mining, Metallurgy & Exploration, 36*, 701–707. https://doi.org/10.1007/s42461-019-00104-9

Malik-Khan, K. (2017, October/November). Behind the scenes with diversified: The business of buses takes a team. *YMM Magazine*, 5(6), 29–30. https://ymmonline.ca/downloads/ymm-magazine/5.6/

Markey, S. (2009, May 14–17). A new regionalist perspective on the next rural economy. In *Space to Place: The Next Rural Economies* (239–250). CABI Digital Library. https://doi.org/10.1079/9781845935818.0239

Markey, S., Halseth, G., & Manson, D. (2008). Challenging the inevitability of rural decline: Advancing the policy of place in northern British Columbia. *Journal of Rural Studies, 24, 4*, 409–421. https://doi.org/10.1016/j.jrurstud.2008.03.012

McBain, L. A. (1995). *An analysis of the spatial distribution of the Northern labour force employed in uranium mining in Northern Saskatchewan* [Unpublished master's thesis]. University of Saskatchewan, Saskatoon, Canada.

Mckenzie, F., Haslam Mckenzie, F., & Hoath, A. (2014). Fly-in/fly-out, flexibility and the future: Does becoming a regional FIFO source community present opportunity or burden? *Geographical Research, 52*(4), 430–441. https://doi.org/10.1111/1745-5871.12080

MiHR. (2020). *The changing nature of work. Innovation, automation and Canada's mining workforce*. Mining Industry Human Resources Council. https://mihr.ca/wp-content/uploads/2020/05/MIHR_Innovation_Report_EN_WEB.pdf

Moore, G. (1977). *Mining towns of Western Australia*. Perth: Chamber of Minerals and Energy of Western Australia.

NRCan. (2016). *Ekati Diamond mine – Northwest Territories*. Government of Canada, Natural Resources Canada. https://natural-resources.canada.ca/maps-tools-and-publications/publications/minerals-mining-publications/vale-inco-newfoundland-and-labrador/ekati-diamond-mine-northwest-territories/8822

OECD. (2023). *Mining regions and cities case of the Pilbara, Australia*. Paris: OECD Rural Studies, OECD Publishing. https://doi.org/10.1787/a1d2d486-en

O'Faircheallaigh, C. (2021). Explaining outcomes from negotiated agreements in Australia and Canada. *Resources Policy, 70*, 101922. https://www.sciencedirect.com/science/article/pii/S0301420720309533

Ossewaarde, M. (2017). Unmasking scenario planning: The colonization of the future in the 'Local Governments of the Future' program. *Futures, 93*, 80–88. https://doi.org/10.1016/j.futures.2017.07.003

Parker, S., Fruhen, L., Burton C., McQuade, J., Loveny, S., Griffin, M., Page, A., Chikritzhs, T., Crock, S., Jorritsma, K., & Esmond, J. (2018, September). *Impact of FIFO work arrangements on the mental health and well-being of FIFO workers.* WA Mental Health Commission. https://www.mhc.wa.gov.au/media/2547/impact-of-fifo-work-arrangement-on-the-mental-health-and-wellbeing-of-fifo-workers-full-report.pdf

Pepe, L. M. (2022). The social license to operate toward a just transition. In G. Wood, G. Mete, & J. Górski (Eds.), *The Palgrave handbook of social license to operate and energy transitions* (pp. 1–17). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-74725-1_4-1

Perera, A. (2018, October 24). WA Nationals call for government to "do more" to reduce FIFO. *Pilbara News*. https://www.pilbaranews.com.au/news/pilbara-news/wa-nationals-call-for-government-to-do-more-to-reduce-fifo-ng-b88995920z

Perry, M. & Rowe, J. E. (2015). Fly-in, fly-out, drive-in, drive-out: The Australian mining boom and its impacts on the local economy. *Local Economy, 30*(1), 139–148. https://journals.sagepub.com/doi/10.1177/0269094214564957

Perth Airport. (2024). Airport Statistics. *Perth Airport*. https://www.perthairport.com.au/Home/corporate/about-us/airport-statistics

Perth Airport. (2019, July 3). Rio Tinto lease reinforces Perth Airport precinct as jobs centre. *Perth Airport*. https://www.perthairport.com.au/Home/corporate/articles/2019/07/10/02/23/rio-tinto-lease#:~:text=03%20July%2C%202019,agreement%20on%20the%20new%20lease

PRD. (2024). Roaring regions - Top 10 affordable regional areas 2024. *PRD*. https://www.prd.com.au/research-hub/article/roaring-regions-top-10-affordable-regional-areas-2024/

Queensland Government. (2017). *Strong and Sustainable Resource Communities Act 2017*. State Development and Infrastructure. https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2017-028

Queensland Government. (2015). *FIFO Review Report July 2015*. Department of State Development. https://www.statedevelopment.qld.gov.au/__data/assets/pdf_file/0017/11456/fifo-review-report.pdf

Radetzki, M. (1982). Regional development benefits of mineral projects. *Resources Policy*, *8*(3), 193–200. https://doi.org/10.1016/0301-4207(92)90036-9

Rio Tinto. (2023, December). *Our operations in Western Australia 2023*. [Brochure. Rio Tinto Iron Ore, p. 5]. https://www.riotinto.com/en/operations/australia/iron-ore-western-australia/western-australia-communities

Rio Tinto. (2008, January 18). *Rio Tinto chief executive unveils vision for "mine of the future."* [Rio Tinto Media Release]. https://www.aspecthuntley.com.au/asxdata/20080118/pdf/00804069.pdf

Rixen, A., & Blangy, S. (2016). Life after Meadowbank: Exploring gold mine closure scenarios with the residents of Qamini'tuaq (Baker Lake), Nunavut. *Extractive Industries and Society*, *3*(2), 297–312. https://doi.org/10.1016/j.exis.2015.09.003

Saskatchewan. (2016). *2016 Summary of Benefits from Northern Mining*. Government of Saskatchewan, Ministry of Government Relations, Municipal Relations and Northern Engagement. https://publications.saskatchewan.ca/#/products/86265

Schwab, K. (2017). *The fourth industrial revolution.* New York: Crown Publishing.

Shelley, G. C., Fraser, J. G., Pammenter, J. B., Stephenson, K. J., & Kyba, D. A. (1987). *Strategies to improve Northwest Territories business opportunities related to mining and exploration* [Report]. Energy, Mines and Resources Secretariat, Government of the Northwest Territories by Stevenson Kellogg Ernst & Whinney, Management Consultants.

Sheller, M., & Urry J. (2006). The new mobilities paradigm. *Environment and Planning A, 38*(2), 207–226. https://journals.sagepub.com/doi/abs/10.1068/a37268

Storey, K. (2018). From 'new town' to 'no town' to 'source', 'host' and 'hub' communities: The evolution of the resource community in an era of increased labour mobility. *Journal of Rural and Community Development, 13*(3), 92–114. https://journals.brandonu.ca/jrcd/article/view/1576

Storey, K. (2014, November 12–13). *Fly-in/fly-out work arrangements: Perspectives on the pros and cons* [Presentation]. Nordregio Forum 2014, Nordic Bioeconomy and Regional Innovation, Keflavik, Iceland. https://archive.nordregio.se/Global/Events/Events%202014/Nordregio%20Forum%202014/Presentations%20day%202/Storey_Fly%20in%20fly%20out.pdf

Storey, K. (2001) Fly-in/fly-out and fly-over: Mining and regional development in Western Australia. *Australian Geographer*, *32*(2), 133–148. https://doi.org/10.1080/00049180120066616

Storey, K. & Hall, H. (2017). Dependence at a distance: Labour mobility and the evolution of the single industry town. *Canadian Geographer, 62*(2), 225–237. https://doi.org/ 10.1111/cag.12390

Storey, K., Halseth, G., Murphy, L., & Markey, S. (2024). Digitalization and changing value propositions for mining regions: Options for action. *Resources Policy, 91*(April). 104861 https://www.sciencedirect.com/science/article/pii/S0301420724002289?via%3Dihub

Storey, K., & Shrimpton, M. (1989). *Impacts on labour of long-distance commuting employment in the Canadian mining industry* [Report no. 3]. Institute of Social and Economic Research, Memorial University of Newfoundland, St. John's, Newfoundland.

"Suncor to begin using autonomous vehicles over the next 6 years." (2018, January 30). *CBC News*. https://www.cbc.ca/news/canada/calgary/ calgary-suncor-autonomous-vehicles-1.4511489

The Economist. (1977, November 26). *The Dutch Disease*. https://www.uio.no/studier/emner/sv/oekonomi/ECON4925/h08/undervisningsmateriale/DutchDisease.pdf

The Shire of Leonora. (2024). Leinster Township. *The Shire of Leonora*. https://www.leonora.wa.gov.au/visitors/see-and-do/leinster-township.aspx

Tonts, M., Plummer, P., & Lawrie, M. (2012). Socioeconomic wellbeing in Australian mining towns: A comparative analysis. *Journal of Rural Studies 28*(3), 288–301. https://doi.org/10.1016/j.jrurstud.2011.10.006

Tonts, M., Martinus K., & Plummer, P. (2013). Regional development, redistribution and the extraction of mineral resources: The Western Australian Goldfields as a resource bank. *Applied Geography*, *45*(December), 365–374. https://doi.org/10.1016/j.apgeog.2013.03.004

Tunnicliffe, A. (2024, August 21). Mining equipment: Carrying the load. *Mining Technology*. https://www.mining-technology.com/features/mining-equipment-carrying-the-load/?cf-view

Western Australia. (2024). *Western Australia Mineral and Petroleum Statistics Digest 2022-2023*. Government of Western Australia, Department of Energy, Mines, Industry Regulation and Safety. https://www.dmp.wa.gov.au/Documents/About-Us-Careers/Stats_Digest_2022-23.pdf

WEF. (2017). *Digital Transformation Initiative: Mining and metals industry*. Geneva: World Economic Forum: Geneva. https://report.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/white-paper-dti-2017-mm.pdf

Young, J. (1998). Just transition: A new approach to jobs v. environment. *WorkingUSA, 2*(2):,42–48. https://doi.org/10.1111/j.1743-4580.1998.tb00090.x