Sustainable development in the mining industry: towards the development of tools for evaluating socioeconomic impact in the Canadian context

Abstract

In spite of its economic outputs, the Canadian mining sector has suffered from several setbacks that have compromised its reputation. This has led many of its stakeholders to adopt a shift towards a new paradigm focused on sustainable development.

In this review of the literature, we identify the impact that mining activities have had on various social, economic and environmental issues in Canadian society. We also survey the criteria and indicators included in various models that may be used to evaluate the adequacy of the transition of mines towards sustainable development. Finally, the strengths and weaknesses of eight tools that have been applied to the socioeconomic impact of mines are analysed.

A clear vision of prospects for promoting sustainable development in Canadian mining emerges from this survey. Our analysis reveals important factors that not given adequate consideration in the models used currently to evaluate and suggests opportunities to improve these evaluation tools through identification of more relevant criteria and indicators.

The research undertaken should incite stakeholders to develop social and economic impact evaluation tools that are better adapted to the Canadian context.

Keywords: sustainable development, evaluation tools, indicators, impact, mining industry, Canada.

1. Introduction

The Mining Association of Canada (MAC) began its transition towards sustainable development in the 1980s. At that time, the MAC was the first association in the world to introduce an environmental policy intended for the mining industry (Fitzpatrick and al. 2011).

The mining industry began to intensify its metal extraction activities in the aftermath of the Second World War. This effervescence led to numerous unfortunate events, including breakages of dykes caused by the technological limitations of the time, forcing the relocation of communities living nearby. Such events raised consciousness in the Canadian mining industry.

Since 1992, The Whitehorse Mining Initiative Leadership Council Accord has forged a key to the future of the Canadian mining industry (Government of Canada, 2017). The aim of this initiative begun in 1992 was to improve the social and economic climate as well as environmental protection in association with mining activities in Canada. Many regard this initiative as being oriented radically towards sustainable development (Fitzpatrick and al. 2011). That same year, the United Nations conference on the environment and development in Rio de Janeiro was instrumental in further focusing public attention on the environmental impact of industrial activities. During the period of 1998 to 2002, the MAC conducted several studies and met with the leaders of several communities in order to listen to their expectations with regard to the socioeconomics and environmental aspects of the mining sector. These initiatives led to the current policy entitled “Towards sustainable mining” (MAC 2004), the goal of which is to enable the industry to meet the demand for mining products and energy while applying the principles of sustainable development.

The Quebec mining industry has encountered various problems that hinder its transition towards sustainable development. The challenge is felt in the strategic and the operational aspects of complex decisions that must accommodate all interests (Petrie and al. 2007). In order to ensure a successful transition, the Quebec Government has implemented a mining strategy that includes economic and social measures (MERN 2014). The aim of the economic orientation is to accelerate the development of mining and diversify the economy of the northern sector of the province while improving competitiveness. This aspect is embodied in the Plan Nord, of which one aim is to develop the labour force and favour the participation of local communities in the development of mining.

The Quebec mining industry is evolving in a dynamic environment under permanent pressures from all parties concerned. In this climate, the advantages associated with the application of the principles of sustainable development may be overlooked. According to the Bureau de normalisation du Québec (BNQ), the social, economic and environmental benefits to be gained are considerable (BNQ 2012). For example, taking the social dimension into consideration improves company reputation and relations with local communities, allowing mining operations to evolve within a less rigid environmental regulatory framework. Integration of the principles of sustainable development also leads to better utilisation of natural resources.

In this article, we examine the social, economic and environmental impacts of mining activities in Quebec and the criteria and indicators included in various models that may be used to evaluate the adequacy of the transition towards sustainable development.

The research methodology is presented in section 2 below, followed by discussion of the results of the literature search in section 3. Our conclusions appear in section 4.

2. Research Methodology

The review of the literature was focused on six main aspects. To begin with, the concept of sustainable development is presented as well as the positioning of the mining industry in this regard. We next examine the legislation and standards applicable to the Quebec mining industry. The third aspect is a survey of mines in Canada and abroad in terms of aspects of sustainable development, with emphasis on identifying the factors that hinder the transition of the Quebec mining industry. The fourth aspect concerns guides and frames of reference for sustainable mining. By associating these with the socioeconomic impact of mines, the fifth aspect is intended as a survey of the criteria and indicators that are relevant to mining in the Quebec context. The final aspect is an overview of tools that may be used to evaluate the socioeconomic impact of this industry. Analysis of their strengths and weaknesses is provided in order to help researchers and experts develop models and tools that are reliable and better adapted to the context of mining in Quebec.

Various criteria were established in order to ensure a systematic search for documents. These concerned the databases consulted, the keywords used, the type of document and where they were published. In addition to generalities associated with sustainable development in the mining sector, we attempted to identify evaluation tools that are based on more than one method and have been applied in the mining sector at least in case studies. The selection criteria were as follows:

- Keywords: impact, sustainable development, mines, industry, criteria, indicator, principle, evaluation, method, tool, approach, measure, social, economic, local community, legislation, standard, regulation (in English and French).
- Scientific articles (international) in which the proposed tools were applied.
- Databases: ABI Inform global, Ebsco, Scopus and the publishers Elsevier, Taylor and Francis Group. The Google Scholar research platform was also used.
- The relationship between research and variables affecting the degree of sustainable development achieved.
- The existence of a mining sector application (at least one case study) allowing operationalization of the criteria and indicators identified.

In addition to the above criteria of selection, the tools considered in this review are those oriented towards evaluation of the social and economic impact of the mining industry and published since 2005. For inclusion

in this study, a document had to deal with sustainable development in relationship to a mine with some interest in the impact of mining activities. Monographs were excluded, since most of the work presented in these books has been published in scientific journals or in conference proceedings.

3. Results and discussion

3.1. Sustainable development

Sustainable development is defined in Quebec legislation *(Loi québécoise sur le développement durable, chap. I, art. 2)* as follows:

> In the context of industrial activity, development is considered sustainable if it meets present demand without compromising the capacity of future generations to meet their demand. Sustainable development is based on a long-term vision that takes into consideration the inextricably associated character of the environmental, social and economic dimensions of development activities.

Figure 1 illustrates how these three dimensions overlap.

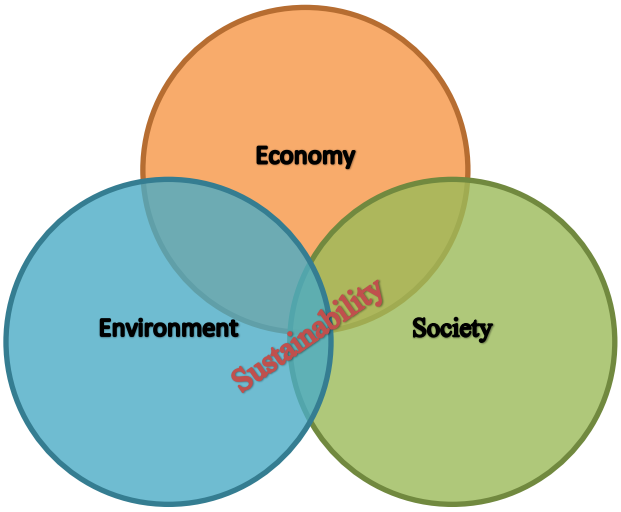

Figure 1 – Representation of the dimensions of sustainable development

The economic dimension is concerned with the manner in which organisations utilise the generally limited resources available on the planet and with the associated socio-environmental costs. These costs include regeneration of the natural capital consumed and compensation for the wealth that the environment was providing (Pawłowski 2008).

The social dimension is concerned with the value that a mining project can add to the population. According to Wilkinson and al. (2001), this dimension must take into consideration the balance between current economic pressures and the future needs of the population. According to Freeman (1984), the consideration of all interested groups in the decision-making process is essential to success in the social realm.

The environmental dimension refers to analysis of the possible impact that a mining project could have on the surrounding ecosystem and its inhabitants (Marnika and al. 2015). Depending on the nature of the project and the environment, this dimension may include aspects such as noise, water quality, impact on biodiversity and so on.

Taking these three dimensions into account ensures that all possible impact is considered during the evaluation and execution of a mining project. Other dimensions exist, although they usually can be defined in terms of interactions between economic, social and environmental factors. Pawłowski (2008) has identified some of these, including, ecological, moral, legal and political dimensions.

The possible interactions between dimensions are not considered in this article. For several reasons, this review is focused mainly on the economic and social dimensions. The literature is replete with studies of environmental impact and evaluations thereof, particularly in the mining industry. In contrast, social and economic impact is less studied and not regarded with the same urgency. With regard to sustainable development, there is no obvious reason to treat the three dimensions with the same importance (Morgan 2012). Furthermore, the social and economic impact is variable and may have several different manifestations during the life of a mining project (Poveda and Lipsett 2014). In addition, the complex challenge of identifying the intangible aspects of the socioeconomic impact is ample justification for focusing on its evaluation.

3.2. Legislative and regulatory framework peculiar to the Quebec mining sector

According to a study by the Fraser Institute, Quebec ranks sixth in the world in attractiveness to mining companies and third in Canada behind Saskatchewan and Manitoba (Jackson and Green 2017). However, the slowness of the environmental permit process and the absence of a framework for negotiations with local communities could cause this rank to slip (AMQ 2016b). According to an IRIS (*Institut de recherche et d'informations socioéconomiques*) study, the Quebec government and the communities concerned continue to have an interest in enforcing legislative rigours that annoy mining companies (Handal 2011). This study shows that loosened legislation combined with financial support from the government has not been profitable in socioeconomic terms. For example, in 2007, income from mining was taxed at half the rate that was applicable elsewhere in Canada. This was added to various allowances and incentive measures intended to maintain an attractive fiscal environment and thereby allow Quebec to reap socioeconomic benefits. During the next year, employment in the mining industry dropped by 25% and accounted for only 0.27% of industrial jobs (Handal 2011). The legislation was as flexible in the payment of income tax. For example, mining companies in the Abitibi-Témiscamingue region paid no income tax in 2015 (Belzile 2016). This suggested that the challenge of reducing unemployment and fructifying public investment in the mining sector requires more than flexible legislation and public financial support.

In Quebec, the main legislative guide for the mining sector was adopted in December of 2013. Dealing with mining rights and permits, leases and restoration, the legislation is intended to stimulate sustainable mining

activities. It specifies the rights of citizens affected by mining projects, the rights of communities and the infrastructures to be integrated into the territories being used. However, spokespersons for the citizenry are expressing reservations about this legislation. For example, the coalition *"Pour que le Québec ait meilleure mine"* points out weaknesses regarding the following points (Amos and Audoin 2009):

- Disproportionality between the economic interests of mining companies and the social rights and quality of life of the population.
- Lack of credible mediation in legal disputes between mining firms and citizens.
- No modification of the precedence of mining rights (free mining), which favour only mining firms to the detriment of citizens.
- Vagueness regarding the obligation to consult First Nations communities.
- No public access to environmental and health data on mining projects.

Another deficiency noted in the legislation is associated with the communication of information under the control of the stakeholders (Bergeron and al. 2015). Mining companies that hold the rights associated with a location are under no obligation to disclose the nature of the sought minerals. In addition, in spite of the efforts undertaken to consult with the stakeholders in a mining project, decisions are often made without considering the concerns of the local residents. For example, although the citizens' committee of the south side of the town of Malartic (Quebec) objected to the expansion of the mine, approval was granted without considering the opinions expressed by the citizens and independent organisations (QMM 2017). According to a spokesperson for the Canadian association of physicians for the environment (Dr. Isabelle Gingras), the standards are not adapted to mining projects in their current context (Shields 2014): "The current standards are not adapted to the reality of open mines and their impact on human health. We need new standards for dust, noise and the psychosocial impact of mining operations."

In Northern Canada, several types of agreements exist between the mining industry, the federal government and the local communities. Through community and socioeconomic agreements, mining companies participate in the development of local communities in several ways. These agreements deal with education, employment, development of local businesses and so on. A socioeconomic follow-up committee created for the certifications required in specific mining projects also ensures that the projects fit with pre-established socioeconomic objectives. Mechanisms of exchange between industrialists, governments (federal and provincial) and regional associations must also be created.

3.3. Impact of the mining industry from a sustainable development perspective

3.3.1. Economic dimension

In Quebec, the mining industry contributes considerably to public finances through royalties and income tax. In 2014, the mining industry paid over $120 million in royalties to the Quebec government. The economic impact of the mining sector is also felt among small businesses, which include 3,800 suppliers throughout

the province (Doumont 2015). Between 2013 and 2015, $508 million were invested in Quebec highways and roads in order to meet the demand created by mining operations (MERN 2014). Investment also accelerated research and innovation in the field of mining (MERN 2014). Through various agencies, Quebec taxpayers funded several research projects on subjects relating to the mining sector (MERN 2014).

In 2014, salaries in the mining industry were above those in forestry, manufacturing, construction and the financial sector. The average annual salary in the mining sector was over $100,000 (Marshall 2015). According to the former minister of state delegated to mining, Luc Blanchette:

> "The Quebec mining sector represents investments averaging nearly $3 billion annually, 30,000 direct, indirect and induced jobs paying annual salaries averaging over $90,000. It is an established leading industry in all regions of Quebec, its network of suppliers and equipment manufacturers including nearly 500 businesses generating $30 billion in annual income, a third of which are located in the Montreal and Montérégie regions" (MERN 2016).

The impact of mines on local communities is very diversified. The salaries earned by mine workers are superior to those of most of the remaining local jobs. In 2016, weekly earnings in Québec averaged $858.50 while the average weekly salary in the mining sector was $1261.14 (ISQ 2016). Many local residents consulted affirm that being employed in a mine equals social upward mobility (Rodon and Lévesque 2015). Indirect jobs are also created through local partners of the mining companies. In addition to tax revenues, royalties paid by mining companies also return to the communities to support various local economic and social activities. However, measuring the economic progress of certain local mining communities would provide a better evaluation of the economic impact of mining activities (Schweitzer 2014).

In spite of the economic performance of the Canadian mining industry, the fluctuations of the world economy affect this industry in several ways. At the beginning of the millennium, 60% of Canadian exports came from the manufacturing sector. During this period, the selling price of finished products fell steadily as the price of raw materials rose. By 2011, raw materials represented two thirds of Canadian exports (UQAC 2013). This phenomenon tends to squeeze the national economy into areas of specialization and may explain why Quebec industries are so sensitive to fluctuations in raw materials costs. After record investments of $5.1 billion in the Quebec mining sector in 2012, the downward trend in metal prices caused investments to drop to $3 billion in 2014 (ISQ 2015). This decline had an impact not only on the Quebec economy, but also on local communities, particularly in terms of employment.

Another negative economic impact of mines is associated with the cost of restoring the sites (Handal 2011). In Quebec, many mines have been abandoned over the years, and the state is obliged to spend large sums on the restoration of the land. The most recent survey estimates the cost of restoring 713 abandoned mines at $808 million (ISQ 2015). New legislation includes measures to ensure the restoration of mines and the surrounding lands. Once their plans for restoring and re-landscaping have been accepted by the ministry of

energy and natural resources (MERN), a mining company must provide financial guarantees corresponding to the total estimated cost.

3.3.2. Social dimension

The mining industry in Quebec accounts for 30,000 direct and indirect jobs, often held by local workers. These jobs represent $1.7 billion in salary in the production sector alone (Doumont 2015). A study conducted by the ministry of forestry, wildlife and parks (MFFP) concluded that 10 direct jobs created lead to the creation of 9 indirect jobs (MFFP 2011). The presence of a mine near a community seems to have a positive impact on education. Young people are more motivated to complete high school when there is a good chance getting a well-paid job in the mining sector (INSPQ 2015).

In Quebec, an initiative intended to facilitate collaboration between mining companies and local residents was begun in 2012. This was *Développement Rétention Emploi Autochtone Minier* or DREAM (Dansereau 2012). The aim of this project was to train First Nations persons to work in the mining sector and to encourage them to do so on the long term. DREAM was a creation of the mining sector labour committee (CSMO-Mines) in partnership with the industry and First Nations, and is considered as a model for "win-win" agreements between the different groups (Dansereau 2012).

Another social impact of this industry comes from donations to the surrounding community. Financed to the tune of $2 million entirely by the Osisko mining company, the Osisko stadium in the town of Malartic is a good example (CSMO 2014). The Fond Essor Canadian Malartic (FECM) provides $150,000 of funding annually for activities having a durable impact on the municipality. An additional donation of $325,000 is marked for community projects intended to support the local economy after the closure of the mine. Health and safety problems have also been taken into consideration in mining activities in Quebec. During the years 2010 through 2015, the workplace accident combined frequency (per 200,000 hours worked, the number necessitating compensation or temporary reassignment) fell from 4.8 to 2.2 in the mining sector (APSM 2016). According to the Commission des normes, de l'équité, de la santé et de la sécurité du travail CNESST (2016), temporary reassignment speeds up the return to regular work by allowing the worker to perform other tasks under certain conditions while healing from injury. Figure 2 shows the trend of the accident frequency in this industry for the years 2003 through 2015.

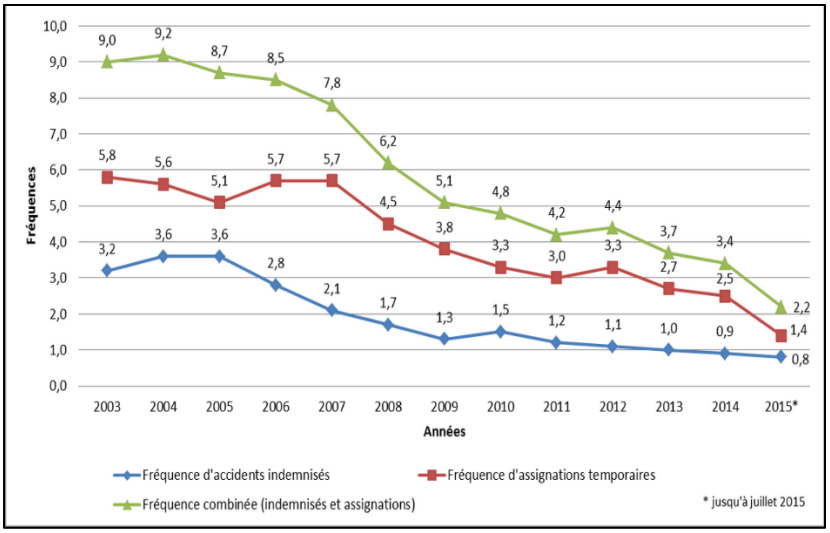

Figure 2 – Combined frequency of accidents in the Quebec mining sector (APSM 2016)

The Quebec mining association (AMQ) has put in place various mechanisms in order to decrease the frequency of workplace injuries. These include rescue activities in the event of major accidents or disaster, based on the work of an inter-mine mutual aid committee. This committee works jointly with the mining rescue crew of the CNESST (standards, equity and occupational health and safety commission). In addition, an auditing program is in place to favour proper health and safety practices. This program allows interested companies to receive professional evaluations of various aspects of their operations (compliance with standards and regulations, emergency measures plan, prevention activities, field monitoring, industrial hygiene and health). The industry also uses modular training for mineworkers (mandatory for all personnel working underground) to reduce the frequency and severity of workplace accidents.

While the jobs offered by mining companies are advantageous, they have negative effects on the social cohesion of the surrounding communities. Community services and traditional activities are sometimes abandoned over time, for example, intergenerational fraternizing and transmission of ancestral knowledge (Knotsch and al. 2010). Work schedules are another factor that affects social cohesion. The demands of mining are such that local workers go home only every two weeks. Many local residents find that this creates difficult and stressful situations (Rodon and Lévesque 2015).

Noise, vibrations and dust produced by mining make up another aspect of the challenge. The Osisko mine in Québec is only one illustration of this problem. For example,

> "Since its operations began, Osisko is finding it difficult to comply with decreed standards relative to noise, dust, vibrations and overpressure during blasting. As of July 14, 2014, the ministry of the environment has issued 131 notices of non-compliance to Osisko (since the beginning of the project) and has received 1, 275 complaints from citizens with regard to these problems" (INSPQ 2015, 5).

Noise comes primarily from engines, loading and unloading of rock into bins, electricity production and so on (ELAW 2010). Miners are exposed to various sources of noise in their work environment, which on the long term can lead to deafness. Vibrations also come from engines, but especially from blasting. The shock waves from these explosions are very powerful and can affect workers, citizens and the stability of nearby infrastructures (ELAW 2010).

Mining communities are highly intertwined with mining economic cycles, and when these are in their trough, entire towns can disappear. For example, the mining village of Joutel in Northern Quebec disappeared after four mines were shut down one after the other.

The relocation of communities near mines is another problem that has become a source of inequality between citizens and loss of confidence in authorities. In 2006, the expansion of the Canadian Malartic mine required the demolition of 246 homes on the south side of the town of Malartic, which disrupted daily life residents (INSPQ 2015). According to a survey conducted in the autumn of 2011 on the quality of life of the residents of Malartic, 19.5% of the respondents attributed the stress that they were experiencing to the Canadian Malartic mine (LeBlanc and al. 2012). This psychological distress was particularly high in the relocated families.

The migration of people towards mining areas is another source of problems for the nearby communities, especially where mining is the principal source of income. The arrivals of workers can quickly create conflicts. This combination of cohabitation and weak social bonding can cause disorganization of the society as a whole, as well as changes in the way of life of the locals (UQAC 2013).

The social acceptability of mining projects, based on the quality of relations between the different groups, has become a decisive issue (Yates and al. 2016). Local communities are becoming more and more refractory to mining projects and are manifesting their will to be more actively involved. Social acceptability plays an important role in assessing the impact of mining activities because local communities can block the implementation of a project. According to the Fraser Institute, 36% of mining companies claim that public opposition can block approval of their projects (Wilson and Green 2013) and they therefore do everything they can to avoid conflicts with the local community. According to Franks and al. (2014), interruption of exploration activities can cost as much as $10,000 US per day. In Canada, in spite of improvement in relations between mining companies and local populations, bad practices are still noted (Bergeron and al. 2015). These are mainly the result of a lack of involvement of local communities in the projects as well as the impact on existing infrastructures and the environment in general (Bergeron and al. 2015).

3.3.3. Environmental dimension

The Quebec mining sector does attempt to interact responsibly with the environment. Besides the management of mining wastes, restoring of mining sites is another field in which continual improvement is noted.

The mining industry wants to avoid abandoned mine sites. It has supported the measure making mining companies responsible for 100% in costs of the site restoration and requiring them to deposit 100% of the financial guarantee needed to cover these costs (Quebec Mining Association 2020). To minimize emissions, the mining industry in Quebec has introduced processes and programs for reduction at source, processing controls and monitoring. The compliance rate of mining operations has been 96% in Quebec over the past 20 years, even though the framework and criteria have continually tightened since 1989, including implementation of a water policy and related regulations, subjection to the Industrial Waste Reduction Program, continuous measurement requirements and increase in possible penalty amounts (Bienvenu 2015).

In order to reduce its impact on the environment, the Quebec mining industry is participating in a series of ministry initiatives such as the Mine Environment Neutral Drainage (MEND-NEDEM 2020), the Inventory of Orphaned/Abandoned Mines (NOAMI 2020) and the Towards Sustainable Mining (TSM) (AMC 2020). Through programs such as these, mining companies are improving their practices and thereby reducing their footprint in the environment.

It is important to note that the examples cited in this section show that the positive elements tend to be improvements to operations more than reductions of impact.

The negative environmental impact is varied, ranging from contamination of the water table to atmospheric pollution. Mining residues (tailings) in particular pose problems of soil and water contamination with heavy metals (cadmium, arsenic, lead, zinc, etc.), which can have adverse effects on biodiversity (Chopin and Alloway 2007). This is a major challenge in Canada. According to Farrell and Ali (2013) the problems associated with mining residues are:

- Vast expanses of land needed for the building of residue dumps and tailings ponds with secure enclosures.
- High initial cost of building secure residue and tailings holding facilities.
- Management of large quantities of contaminated water that threaten to contaminate neighbouring environments.
- Risk of failure of dykes enclosing tailings ponds caused by fluidizing of residues or failure of the drainage system.

Several failures of tailing pond dykes have been documented during recent decades (Azam and Li 2010). During the period of 2004 through 2014, four major dyke breakages occurred in Canada (Azam and Li 2010).

Besides the contaminating effects of the erosion of mining grounds on flora and fauna, disturbance of land near mines can have more far-reaching consequences. Ravines are widened and sedimentation and water runoff are accelerated, which can cause downstream flooding and in some areas even destabilize the pillars of bridges (ELAW 2010). The occurrence of such problems shows that control of soil erosion and sedimentation are major challenges for the majority of mining projects and their surroundings. Air pollution

is present in some form at each stage of the lifecycle of a mine. Singh and al. (2015) cite the emissions from engines that drive heavy machinery and generators that run continually during the processing of ores.

Finally, Table 1 summarizes the diversity of the impact of mining in terms of dimensions of sustainable development and some of the contexts in which it appears.

Table 1 – The impact of mines expressed in terms of dimensions of sustainable development

Impact	Social	Economic	Environmental[1]
Positive[1]	• Job creation • Upward mobility in mining communities • Donations and grants to local communities • Improved occupational health and safety (OHS) record	• Contributions to public finances • Investment in local and national infrastructures • Investment in scientific research and innovation • Competitive salaries • More dynamic local economy	• Reduction of emissions from mining operations • Restoration of mining sites and surroundings • Optimization of energy consumption
Negative	• Loss of community social cohesion • Occupational health and safety problems • Disappearance of towns during economic downturns in mining • Abandon of community activities • Increase in conflicts as new residents settle in the local communities • Loss of confidence in local authorities and politicians • Relocation of citizens • Modification of lifestyles	• Pressure on local resources • Cyclical economic sector • Increased dependency of the local economy because of training in mining only • High cost of restoring mining sites	• Sedimentation in waterways • Heavy metal contamination of water • Drop in biodiversity (plants and wildlife) • Impact on climate

[1] The positive elements of the environmental dimension should be viewed as improvements undertaken by the mining industry.

3.4. Guides and frames of reference for sustainable mining

Mobilizing a vast network of experts, several guides and frames of reference are developed with the intention of harmonizing concepts and systems of measurement for the purpose of evaluating sustainable development. They allow organisations to communicate openly and clearly their adequacy in this regard, using a familiar framework. The power of such guides and frames of reference resides in their credibility but also in the criteria and indicators that are used to evaluate performance (GRI 2015).

The Global Reporting Initiative (GRI) proposes criteria and a guide for the presentation of reports on business activities (GRI 2015). It may be used for reporting regardless of the size of the company, the sector of activity or the geographical location. One of its particularities is that it proposes two options (essential criteria or exhaustive criteria) for the identification of aspects that reflect impact from a sustainable development perspective.

Published in November 2010, the standard ISO 26000 – Societal responsibility defines how organizations can contribute to the sustainability of their activities (ISO 2010). This standard sets guidelines for orienting organizations towards practices that are socially responsible, ethical and transparent. These guidelines are based on criteria and indicators that operationalize the transition towards sustainable development. For example, the occupational health and safety criterion relies on several indicators, such as the number of salaried employees exposed directly and frequently to illnesses in connexion with their activity, the rate and type of work-related accidents, occupational illnesses, absenteeism, proportion of workdays lost and total number of deaths associated with the work, by geographical region, gender, and so on.

The intention of the Canadian initiative (AMC 2004) is to meet the challenge of sustainable mining through the following six protocols operationalized by indicators:

- Relations with First Nations communities and other nearby residents
- Management of energy and GHG emissions
- Management of mining residues
- Management of biodiversity conservation
- Occupational health and safety
- Planning of crisis management and communications.

The focus of the Initiative for Responsible Mining Association (IRMA) includes business integrity, social responsibility, environmental responsibility and planning and management for positive heritages.

The IRMA is implementing an accountable system of multipartite and verifiable assurances for evaluating mining companies on the basis of criteria and indicators of improved social and environmental performance. For example, equitable work and working conditions is a principle based on indicators such as respect of workers' rights to unionize and to collective bargaining, access to information essential for informed union

negotiations, neutrality of managers on efforts to unionize or organize workers, informing new workers of their rights and obligations, and so on (IRMA 2017).

The International Council for Mines and Metals (ICMM) is an industrial organization directed by company managers with interests in the issues facing the mines and metals industry. The ICMM also promotes good practices in sustainable development with its six principles based on international organisations such as the GRI. The ICMM principles of sustainable development rely on evaluation criteria based on several indicators. For example, the "ethical business practices" principle is based on a set of criteria consisting of "commitment of management to the principles of ethical practices", "implementation of policies and practices intended to prevent corruption", "respecting and doing more than required by the host country regulations". The sustainable development initiative of the ICMM focuses on environmental, social and economic aspects as well as those relating to quality, ethics and business integrity (ICMM 2016).

3.5. Summary of sustainable development social and economic criteria and indicators

A criterion is a principle or element of reference used to judge, estimate, evaluate or define something (Larousse 2017). According to the Cambridge Dictionary, a criterion is defined as "a standard by which you judge, decide about, or deal with something". Bossel (1999) adds that a criterion orients the agents of an organisation on decision-making.

Indicators "can lead to better decisions and more effective actions by simplifying, clarifying and making aggregated information available to policy makers. They can help incorporate physical and social science knowledge into decision-making, and they can help measure and calibrate progress toward sustainable development goals" (United Nation, 2007).

According to Spangenberg and al. (2002), an indicator must be:

- Indicative, that is, representative of the phenomenon being characterized
- Transparent, that is, its selection, calculation and meaning must be accessible to non-experts
- Scientifically valid, that is, recognized by the scientific community
- Robust, that is, not affected by minor modifications or improvements of the database
- Quantifiable, that is, based on accessible data that can be processed
- Independent, that is, meaningful by itself

In order to describe and evaluate the state of a system, criteria are based on a set of indicators. The above characteristics imply that a carefully chosen and rigorously justified indicator will determine the degree of impact associated with a criterion with superior accuracy and precision.

The criteria of sustainable development thus allow to favour one action, path or impact among several possibilities. Social indicators cover the demographics, social cohesion and well-being of the community, occupational health and safety, investment in the local community, cultural well-being, quality of life and so

on. Economic indicators relate to employment, labour availability and all sources of income in the region under study (Petrov and al. 2013).

Referring to the analysis in section 3.3 and to the definitions in the preceding paragraphs, we have preselected criteria and indicators relevant to the impact of Quebec mines. For each impact identified, there is at least one criterion that can be used to evaluate it. The relevance of the choice of indicators was also based on the ease of their use and guided by case studies published in scientific journal articles. For the reasons mentioned in section 3.1, the criteria and indicators retained are oriented towards the social and economic dimensions only. They are summarized in Tables 2 and 3, which include the frames of reference showing their presence in the literature. However, these frames of reference have no connexion in particular to the scientific articles, other than their mention as examples in some cases.

Table 2 – Selected economic criteria and indicators relevant to evaluating sustainable development in Quebec

Criteria	Indicators	Articles	Country	Frame of reference
Economic benefits	• Existence of donations and other investments for the communities ($ million) (qualitative) • Number of direct/indirect jobs created locally (quantitative) • Reinvestment of royalties in the locality (quantitative) • Pressure on local resources (qualitative)	Erzurumlu and Erzurumlu (2015)	USA	ISO 26000 (2010); GRI (2015); AMC (2004); ICMM (2016)
		Biggs and al. (2015)	Australia	
		Weldegiorgis and Ali (2016)	Australia	
		Tonts and al. (2012)	Australia	
Presence in the local market	• Number of local suppliers (quantitative) • Diversity of economic activities (qualitative)	Erzurumlu and Erzurumlu (2015)	USA	ISO 26000 (2010); GRI (2015)
		Biggs and al. (2015)	Australia	
		Caron and al. (2016)	Canada	

Table 3 – Selected social criteria and indicators relevant to evaluating sustainable development in Quebec

Criteria	Indicators	Articles	Country	Frame of reference
Social dialogue	• Involvement of local stakeholders in the resolution of socioeconomic problems (qualitative) • Respect of cultural heritage (qualitative) • Evidence of involvement in local communities (qualitative) • Veto for the local community (qualitative) • Proximity of the mine to residential areas (qualitative)	Craynon and al. (2016)	USA	ISO 26000 (2010); GRI (2015); AMC (2004); ICMM (2016); IRMA (2017)
		Caron and al. (2016)	Canada	
		Weldegiorgis and Ali (2016)	Rwanda	
		Craynon and al. (2016)	USA	
Vulnerability to economic downturn	• Variety of the local skill set (qualitative) • Proportion of local workers participating in job training programs (quantitative)	Weldegiorgis and Ali (2016)	Rwanda	ICMM (2016)
		Tonts and al. (2012)	Australia	

Criteria	Indicators	Articles	Country	Frame of reference
		Biggs and al. (2015)	Australia	
		Caron and al. (2016)	Canada	
Occupational health and safety	• Number of deaths and work-related injuries among local workers (quantitative)	Biggs and al. (2015)	Australia	ISO 26000 (2010); GRI (2015); AMC (2004); IRMA (2017); ICMM (2016)
		Weldegiorgis and Ali (2016)	Rwanda	
		Caron and al. (2016)	Canada	
Business ethics	• Existence of mechanisms of prevention of corruption (qualitative) • Internalisation of costs (qualitative)	Erzurumlu and Erzurumlu (2015)	USA	ICMM (2016); IRMA (2017)
Social well-being	• Conflict with new arrivals to the local community, loss of social cohesion (qualitative) • Trends in alcoholism and drug abuse (quantitative)	Poveda and Lipsett (2014)	Canada	GRI (2015); IRMA (2017)
Education	• Proportion of investment by mining companies in education (quantitative)	Yu and al. (2005)	China	ICMM (2016); GRI (2015); IRMA (2017); ISO 26000 (2010)

3.6. Tools of measurement of the social and economic impact of the mining industry

Awareness of the impact of mining projects has increased throughout society. This explains in part the increase in the number of tools available for the evaluation of sustainable development (Poveda and Lipsett 2014). Their use is becoming widespread and they are becoming indispensable for businesses (Singh and al. 2012). According to Ness and al. (2007), measurement of sustainable development allows the impact's evaluation on the short and long term in order to determine actions that lead to sustainable businesses. Evaluation tools can be used to guide the mining industry towards a proactive approach to sustainable development. Used in conjunction with economic, technological and financial models, they contribute to successful transition to sustainable practices (Petrie and al. 2007). In the past, measurement of the socioeconomic impact of mining was focused more on the economic flow of inputs and outputs in a community. Support for organizational aspects from non-governmental organisations outside of the community was also taken into consideration (Burdge and al. 1988). Today, impact evaluation methods and tools make it possible to measure sustainable development performance more directly.

In the mining sector, the goal of social and economic impact evaluation is to provide support for decisions, hence the term decision-aid tools. In some cases, these tools are used to examine subjects outside of the business per se in order to evaluate the level of sustainable development of an entire region (Su and al. 2010). The limitations of tools based on a single method of measurement have become apparent. Because of the dynamic nature of the mining industry, some of them fail to provide support for the analysis of socioeconomic problems (Govindan 2015). For example, cost-benefit analysis is more and more criticized because it considers only monetary aspects and ignores the impact of social and environmental factors (Frank 2000). The results given by tools based on a single method are also affected strongly by subjectivity and difficult to put into applications (Yu and al. 2005). In practice, various methods are often combined in order to provide more robust support for decisions.

In their review of the characteristics of the structures underlying decision processes in the mining industry, Petrie and al. (2007) points out that a decision-aid structure must not only contain a guide to approaching and solving a problem, but also built-in proactivity in the promotion of the principles of sustainable development. Based on analysis of about 50 decisional frameworks, a list of structural and analytical questions is proposed, the answers thereto orienting deciders towards a sound decision. An interesting aspect of this approach is its flexibility and adaptability to the nature of the relations between the stakeholders (collaboration or conflict). With regard to indicators of sustainable development, the authors focus on two types, corresponding to different degrees of subjectivity, namely, indicators of performance and key indicators of performances. These are grouped according to three dimensions: social, technical and environmental. However, the authors mention the widespread use of other dimensions, notably economic and political/governmental. Based on analysis of the impact evaluation reports for five mining companies, they conclude that the manner in which the indicators will be aggregated depends on the level of decision-making (strategic, tactical and operational).

They also noted a recurrent weakness in all of the evaluation tools examined, namely a lack of fit between the chosen performance indicators and the goals as defined in the evaluations. It is not clear in this study if the approach can be adjusted when the final decision is not compatible with the goal. What is clear is that no single decisional structure exists that can guide the transition towards sustainable development in the mining sector.

In a case study of sustainable development in the mining city of Hubei in China, Su and al. (2010) used a model based on a combination of three methods of analysis, namely the *analytical hierarchy process*, the *accelerated genetic algorithm* and fuzzy integrated judgment (tool 1). The model involves four steps: 1) Hierarchizing of the system composed of the objective, the criteria and the indicators, 2) Constructing the judgment matrix to rank the importance of the criteria, 3) Searching for the judgment matrix having optimal coherence and assigning weights to the criteria for each hierarchical level, and 4) application of fuzzy integrated judgment. The results were coherent with previous studies, more precise with regard to variables affecting the degree of sustainable development, and appeared to verify the reliability of this integrated evaluation method. Precision was improved by replacing the conventional judgment matrix, that is, the discrete values scale of Saaty (1980), with an interval scale. The indicators were grouped using sustainable development dimensions, namely economic, social, intelligence (level of education) and mineral resources, with weighting derived from three matrices, one for indicators, one for weights and one for judgments. The result obtained using this tool is an integrated decision in an uncertain environment influenced by several factors including unemployment, the quality of life of the local residents and the mineral reserves present in the mining area. However, the procedure for selecting the experts that will participate in the choice of criteria and indicators is not explained. This aspect is important, since the fuzzy integrated judgment process was based on their opinions, and regardless of the effectiveness of the method used, if subjectivity is not reduced at the source, the results will be biased (Kommadath and al. 2012).

In a study of the mining city of Huangshi in China, Yu and al. (2005) found that the degree of coordination of sustainable development factors has a strong influence on the long-term development of such communities. To confirm this assertion, they developed a model of systematic evaluation that considers economic, social, environmental and intellectual resources as factors (tool 2). Using the Delphi method, a system of criteria and indicators relevant to the context of the studied mining community is generated, and coordination is then evaluated using the *fuzzy integrated judgement* method. With fuzzy logic, the matching of judgments with different sustainable development factors is maximized. A clear vision of the most influential factors was thus obtained in the case of the city of Huangshi. Judgments of the relevance of the criteria were obtained simultaneously from the indicators thanks to an integrated matrix, which saved time. It can be concluded from this article that two factors had a strong influence on sustainable development in this mining city: namely, the abundance of mining resources and the conditions of their extraction. Another conclusion is that the fuzzy-logic-based method reduced considerably the subjective content of the judgments. However, the

coherence of the weights assigned to the criteria and indicators was not studied, and such a study would improve the reliability of the evaluation of sustainable development in this mining community.

Mihai and al. (2015) analyzed various alternatives for carrying out a mining project with the obligation to take into consideration the socioeconomic impact and the acceptance of the project by the surrounding society (tool 3). They also reduced the level of subjectivity by replacing the discrete values scale with an interval scale, which in addition to the advantages mentioned above, also allowed some flexibility in the judgment. At the end of the evaluation of four alternatives (updating the project, stopping the project, maintaining the project in its initial form and undertaking a tourism development project), multi-criteria analysis was used to determine the optimal decision starting from the single criterion synthesis approach with the weighted sum. Although the results showed the effectiveness and ease of use of multi-criteria analysis, certain limitations were also apparent in this study, associated with method itself and with human factors involved in the incoherence of the data gathered. The evaluation took on a hypothetical aspect, since most of the criteria were predictive, for example long-term costs and foreign investments. The limited financial resources of the evaluators created an obstacle by affecting the representativeness of the population surveyed. In addition to these limitations, use of multi-criteria analysis requires an expert in this method with vast experience in holding workshops and conducting inquiries in order to gather the most authentic information. If time becomes a constraint, workshops that often require days may be cut short, in which case subjectivity sets in reduces the quality of the evaluation (Porthin and al. 2013).

Kommadath and al. (2012) developed a tool for measuring the degree of integration of the principles of sustainable development into the mining sector using an approach based on fuzzy logic (tool 4). The authors noted that for the purpose of characterizing the relationships between the dimensions under study, input-output analysis suffered from several weaknesses. Input-output analysis requires the collection of large amounts of data and must involve several stakeholders. Limitations on data aggregation oblige the analyst to standardize the dataset with adjustments, which may reduce data quality. The particularity of this tool was the use of fuzzy logic to accommodate the subjectivity inherent in the sustainable development concept and to combine indicators that are not quantified with the same ease, for example the number of jobs created and the level of involvement of the local population. The tool was able to define sustainable development in terms of a function composed of a number of quantitative indicators derived from expert judgments (qualitative) using the Delphi method. In spite of the advantages associated with facilitating the decision process, the involvement of the stakeholders and their commitment, there was no way around the subjectivity in the definition of the membership function of the criteria. The authors suggest more in-depth study of the process of choosing the participants (stakeholder representation) in the evaluation, since the opinions of these individuals represents the principal source of subjectivity.

Poveda and Lipsett (2014) developed a tool for measuring the transition of a mining industry towards sustainable development based on the idea that continual measurement and improvement of socioeconomic performance must be ensured (tool 5). Their goal was to measure the degree of integration of the principles

of sustainable development directly in terms of the impact of mines. The tool features the subdivision of activities into fields of excellence in which the industry must improve its performance, for example education in the local community. Using the weighted sum method with an integrated approach based on continued improvement of performance and multi-criteria analysis, social, economic and environmental effects were evaluated in each phase of the mining project in terms of the chosen fields of excellence. The result was expressed as scores indicating the degree of improvement for each criterion during a given period and suggesting a basis for strategies to be developed in order to improve the transition towards sustainable development. A case study in the oil sands of Alberta revealed the shortcomings of this tool, the authors suggesting a users' guide in order to overcome the complexities of the various steps. As in any qualitative evaluation, data subjectivity remains a problem. Since the difficulties encountered in this study are not described in sufficient detail, no particular method of choosing the experts participating in the choosing and weighting of the criteria and indicators is suggested.

Erzurumlu and Erzurumlu (2015) developed a sustainable mining development evaluation tool that places the community at the centre of the process (tool 6). In a case study conducted in a mining region of Central America, it is shown that involving the community at the outset of a project leads to an increase in socioeconomic benefits for the mining company. The approach is based on two methods, namely multi-criteria analysis and a combination of intuitive and analytical thought called *design thinking*. The latter method is used to provide the criteria and the social and economic indicators on which the former is based and thereby determine the alternative most conducive to the success of the project. The *design thinking* process comprises three steps: inspiration, idea generation and implementation. Inspiration consists mainly of identifying the constraints under which the project is being carried out and of analyzing the position of the community on mines as well as its expectations. Idea generation consists of examining ideas proposed by stakeholders for improving mining activities from a sustainable development perspective. It is at this step that the social and economic indicators are selected. Implementation refers to interpreting and summarizing the results obtained in the preceding steps using the upgrading approach, for example, noting the preponderant alternatives for orienting the mining project. The advantageous feature of this tool is the iterative process used to refine the results. Ideas that are initially too vague are brought back to the first step for clarification. However, its successful use requires a change in the organizational culture of the mining company and total commitment from the stakeholders.

Craynon and al. (2016) used an approach based on a geographical information system to identify the constraints associated with the opening of a mine (tool 7). In addition to identifying the deficiencies with regard to sustainable development, this system optimizes simultaneously the social, economic and environmental aspects. Using an iterative process, the benefits of a mining project are maximized from a sustainable development perspective by mapping interactions between the project components. Experts may focus for example on the risks associated with choosing a high-potential mining zone close to a community (source of conflict). A case study conducted in the USA showed the effectiveness of this tool as means of

improving communication between stakeholders and subsequent planning of more sustainable projects. The sustainable development index was evaluated by analyzing the potential for conflict in the area proposed for the mining operations. After mapping of the conflict factors, paired comparison of the factors was performed in order to rank the potential conflicts using the AHP method. The final choice of the mining site must not only ensure the economic viability of the project but also minimize the negative effect of the mining activities on the local society and the environment. The main advantage of this tool is the ease of access to information and its flexibility. In addition, the problem source identification capability is interesting. For example, because of the weighting of the elements, the mapping indicates simultaneously the ore quality and the residence density in a given area. The main shortcoming of this tool is its reactive approach, since it is used after a site has been chosen and a mining project is well underway.

Weldegiorgis and Ali (2016) used the *Q-Sort Method* to carry out an evaluation of socioeconomic impact in localities far away from urban areas (tool 8). Applied in Rwanda, this approach was designed to provide quantitative analysis of qualitative indicators associated with the impact of a mine. Using factorial analysis, the authors analyzed the opinions, perceptions and preoccupations of several interested groups. In addition to the conventional activities of the *Q-Method* (interview, documentary analysis), the *Q-Sort Method* uses discussions with focus groups and representatives to measure the importance attributed to a mining project. This method is based on a weighting system associated with a judgment scale ranging from "agree entirely" to "disagree entirely". The use of this tool implies inter-correlation of the opinions of the various stakeholder groups. The result of this process reveals the perspective most shared by the groups on the pursuit of certain aspects of a mining project. One of the shortcomings of the tool is the difficulty of gathering the right information during interviews. Translation of the local language introduces an additional source of bias.

In summary, the list of tools mentioned in this section shows that the development of models for the evaluation of the social and economic impact of mining projects is not a novelty. However, for several reasons, the effectiveness of the models proposed so far remains questionable. One problem is the difficulty of generalizing the impact identified. Given that activity in the mining sector is subject to economic cycles, the perceived impact will vary depending on how profitable ore extraction is in any given period. This implies that evaluations must be spread over time in order to obtain an exhaustive list of the potential impact factors in a given locality. Another persistent difficulty is the control of subjectivity in the data-gathering process. As Petrov and al. (2013) mentions, several practices must be improved, especially the inclusion of the local communities in data gathering and analysis (both before a project begins and while it is in operation) and their involvement in the choice of the social and economic indicators. Furthermore, it does not suffice to evaluate impact only and propose a sustainable mining orientation. In addition to orientation, a method of follow-up is needed to provide a framework for adjustments made as function of the impact noted.

The reliability of the chosen indicators remains questionable, especially in the case of mines in Northern Canada. It is not clear that these indicators are well matched with the impact being evaluated. Some of them contribute little to the follow-up process because they were devised for other geographical areas and do not

reflect the local economy, sources of income and activities associated with the land and sea. Some are qualitative and do not lend themselves to reliable measurement of impact. More effort is needed in order to characterize relationships between qualitative and quantitative indicators. Furthermore, model development must be based on a multidisciplinary analysis that reveals all aspects of the impact (Petrov and al. 2013). For example, separating resource management from the evaluation of impact decreases the effectiveness of decisions made in the realm of social responsibility. Evaluation models must be integrated adequately into the company management system. On the other hand, indicators oriented exclusively towards the local community limit the scope of the evaluation. Mining requires interaction between stakeholders beyond the region of the mine, through the knowledge transfer, exporting, and so on. This aspect must be taken into consideration, since the external parameters and the impact measured locally are interacting variables. The analysis of the tools is summarized in Table 4.

Table 4 – Summary of the eight models of evaluation of the impact of mining activities on sustainability

N°	Authors	Method/approach used	Country	Advantages	Shortcomings
1	Su and al. (2010)	*Analytical hierarchy process* (AHP) *Accelerated genetic* algorithm (AGA) *Fuzzy Integrated Judgement* (FIJ)	China	• Three methods integrated • Precision of the variables affecting the sustainability of mining in a given city • Improved precision of the expert judgments • Improved coherence ratio of the AHP method	• Absence of criteria for choosing the experts participating in the evaluation • Uncontrolled interference between social and economic indicators
2	Yu and al. (2005)	Delphi *Fuzzy integrated judgement* (FIJ)	China	• Combination of methods • Combination of qualitative and quantitative indicators • Subjectivity well controlled • Simultaneous presentation of results when several dimensions and criteria are considered	• Uncontrolled interference between social and economic indicators • Absence of a procedure for the selection of criteria and indicators of sustainable development.
3	Mihai and al. (2015)	Weighted sum method	Romania	• Improved precision of the expert judgments • Ease of association of the quantitative and qualitative indicators in the weighting process	• Evaluation is hypothetical • Criteria and indicators are predictive • Requires consideration of a large population • To be useful, the evaluation requires expertise in multi-criteria analysis
4	Kommadath and al. (2012)	FIJ Delphi method	India	• Sustainable development concept adapted to the specific mine by consensus • Distinguishes between sustainable and non-sustainable activity	• Subjectivity in the definition of the membership function of the criteria and indicators • Level of expertise required of the participants
5	Poveda and Lipsett (2014)	Continued improvement of performance	Italy	• Evaluation of impacts at each phase of a mining project • Diversification of sources of criteria and indicators	• Complex process: several steps; requires a users' guide • Uncontrolled subjectivity

N°	Authors	Method/approach used	Country	Advantages	Shortcomings
		Weighted sum method		• Elaboration of a sustainable development improvement strategy	
6	Erzurumlu and Erzurumlu (2015)	Upgrading approach *Design Thinking*	Central America	• Human-oriented approach • Process is iterative and transparent	• Requires a change in organizational culture in the mining company • Requires total commitment from the stakeholders
7	Craynon and al. (2016)	Geographical information system	USA	• Maximises the net benefits present in a mining project • Maps interactions between system components • Analysis and spatial interpretation of conflicts in relation to sustainability • Social acceptability is favoured • National and local regulations are supported	• Reactive approach applied after the mining site is chosen and the project is underway
8	Ali and Weldegiorgis (2016)	Functional analysis Q-methodology	Rwanda	• Effective for fast evaluation of situations involving several stakeholders • Suitable for participatory processes • Uses simple data collection techniques that stimulate thought processes • Determines and defines the main ideas in a vast population being considered • Approach is mature and applied in several fields	• Risk of censure associated with culture and hierarchy in the mining community

4. Conclusion

The present review of the literature has shown that sustainable development is a strategic lever for improving the long-term viability of the mining sector. Compliance with the principles of sustainable development is profitable because it can be used to create advantageous conditions. The review also shows that legislation plays an important role in the transition of the Quebec mining industry towards sustainable development. Although this region of the globe is already one of the most attractive for mining, the socioeconomic climate still has considerable room for improvement.

The socioeconomic impact of the Canadian mining sector varies considerably and is influenced by several factors, in particular current mining legislation and social acceptability.

The survey of tools that have been applied to the evaluation of the social and economic impact of the mining sector from the perspective of sustainable development revealed various deficiencies. In summary, only one of these tools would be suitably adapted to mining in Quebec and Canada. It is also noted that the tools based on a single method of evaluation appear to be less effective than the more integrated tools.

In spite of the limitations on the conclusions that can be drawn from this study, our findings should incite professionals to develop tools that are better adapted to evaluating specific aspects of the social and economic impact of mining in Canada.

Conflicts of interest

None declared.

Ethical statement

The authors state that the research was conducted according to ethical standards.

Funding

The authors thank the Natural Sciences and Engineering Research Council of Canada (NSERC) for financial support through the Discovery Grants Program.

References

Association minière du Canada (AMC). (2004). Vers le développement minier durable. http://mining.ca/fr/vers-le-d%C3%A9veloppement-minier-durable Accessed 28 November 2016

Association minière du Canada (AMC). (2020). Towards Sustainable Mining (TSM). https://mining.ca/towards-sustainable-mining/how-tsm-works/ Accessed 16 June 2020

Amos, W., & Audoin, A. (2009). Réforme en profondeur de la loi sur les mines du Québec. http://www.quebecmeilleuremine.org/sites/default/files/RapportEcojustice&Coalition.pdf Accessed 28 November 2016

Association minière du Québec (AMQ). (2016a). Enquête mondiale annuelle de l'institut fraser sur le secteur minier : Le québec perd deux positions, rien pour rassurer l'association minière du québec. *Communiqué de presse.* http://www.amq-inc.com/actualites/posts/enquete-mondiale-annuelle-de-l-institut-fraser-sur-le-secteur-minier-le-quebec-perd-deux-positions-rien-pour-rassurer-l-association-miniere-du-quebec Accessed 28 November 2016

Association minière du Québec (AMQ). (2016b). Un suivi environnemental serré permet de limiter l'impact de l'activité minière. *Environnement.* http://www.amq-inc.com/pages/environnement Accessed 13 July 2016

Association paritaire pour la santé et la sécurité du travail du secteur minier (APSM). (2016). Évolution des heures travaillées, de la fréquence et de la gravité des accidents et des maladies. *Info Statistiques.* http://aspmines.qc.ca/info-statistiques/ Accessed 28 November 2016

Azam, S., & Li, Q. (2010). Tailings dam failures: a review of the last one hundred years. *Geotechnical News, 28* (4), 50-54.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorising tools for sustainability assessment. Ecological economics, 60 (3), 498-508.

Belzile, J.-M. (2016). Mines en Abitibi-Témiscamingue : 35 millions $ en redevances, aucun impôt payé en 2015. http://ici.radio-canada.ca/nouvelle/802601/mines-abitibi-temiscamingue-impots-redevances-2015 Accessed 12 September 2016

Bergeron, K. M., Jébrak, M., Yates, S., Séguin, C., Lehmann, V., Le Meur, P. Y. & Gendron, C. (2015). Mesurer l'acceptabilité sociale d'un projet minier : essai de modélisation du risque social en contexte québécois. VertigO-la revue électronique en sciences de l'environnement. 15 (3), Page 14.

Bienvenu, L. (2015). Overview of environmental compliance in Québec's mining industry. https://mern.gouv.qc.ca/english/mines/quebec-mines/2015-04/portrait-environnementale.asp Accessed 16 June 2016

Biggs, M., Bruce, E., Boruff, B., Duncan, J. M., Horsley, J., Pauli, N., & Curnow, J. (2015). Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy, 54*, 389-397.

Bureau de normalisation du Québec (BNQ). (2012). Développement durable-Guide d'application des principes dans la gestion des enteprises et des autres organisations. Québec. https://www-secur.criq.qc.ca/bnq/documents/enquetes_publiques/9700-021_dpfr.pdf. Accessed 28 November 2016

Bossel, H. (1999). Indicators for sustainable development: theory, method, applications. *International institute for sustainable development.* http://www.ulb.ac.be/ceese/STAFF/Tom/bossel.pdf Accessed 28 November 2016

Burdge, R. J., Field, D. R., & Wells, S. R. (1988). Utilizing social history to identify impacts of resource development on isolated communities: The case of Skagway, Alaska. *Impact Assessment, 6*(2), 37-54.

Caron, J., Durand, S., & Asselin, H. (2016). Principles and criteria of sustainable development for the mineral exploration industry. *Journal of Cleaner Production, 119*, 215-222.

Chopin, E.I.B., Alloway, B.J. (2007). Distribution and Mobility of Trace Elements in Soils and Vegetation Around the Mining and Smelting Areas of Tharsis, Ríotinto and Huelva, Iberian Pyrite Belt, SW Spain. *Water Air Soil Pollut* 182, 245–261 (2007) doi:10.1007/s11270-007-9336-x

Comité sectoriel de main-d'œuvre de l'industrie des mines (CSMO). (2014). Le Stade Osisko deviendra un levier économique. Abitibi Express. http://explorelesmines.com/fr/nouvelles/bons-coups/651-le-stade-osisko-deviendra-un-levier-économique.html Accessed 15 August 2016

Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST), (2016). Assignation temporaire. *Sante et sécurité au travail*. http://www.csst.qc.ca/travailleurs/assignation-temporaire/Pages/travailleur-assignation temporaire.aspx? Accessed 28 November 2016

Craynon, J. R., Sarver, E. A., Ripepi, N. S., & Karmis, M. E. (2016). A GIS-based methodology for identifying sustainability conflict areas in mine design–a case study from a surface coal mine in the USA. International Journal of Mining, Reclamation and Environment, 30 (3), 197-208.

Dansereau, S. (2012). Les minières ont un dream pour former les Autochtones. *Les affaires.* http://www.lesaffaires.com/archives/generale/les-minieres-ont-un-dream-pour-former-les-autochtones/549801 Accessed 13 September 2016

Doumont, J.-L. (2015). Plus de 120 M$ de redevances au gouvernement du québec par l'industrie minière en 2014 *Informeaffaires.* https://informeaffaires.com/regional/mines/plus-de-120-m-de-redevances-au-gouvernement-du-quebec-par-lindustrie-miniere-en-2014 Accessed 28 November 2016

Université du Québec à Chicoutimi (UQAC). (2013). L'industrie minière et le développement durable. (Document de travail), Chaire de recherche et d'intervention en éco-conseil, Québec. Pages 5 and 7

Environmental Law Alliance Worldwide (ELAW). (2010). Guide pour l'évaluation des EIE de projets miniers *1. Généralité sur l'exploitation minière et ses impacts*. Etats-Unis d'Amérique : Environmental Law Alliance Worldwide.

Erzurumlu, S. S., & Erzurumlu, Y. O. (2015). Sustainable mining development with community using design thinking and multi-criteria decision analysis. *Resources Policy, 46*, 6-14.

Farrell, J., & Ali, M. (2013). Environmental Analysis of the Mining Industry in Canada. http://www.cmic-ccim.org/wp-content/uploads/2013/07/HatchScopingReport.pdf Accessed 28 November 2016

Fitzpatrick, P., Fonseca, A., & McAllister, M. L. (2011). From the Whitehorse Mining Initiative Towards Sustainable Mining: lessons learned. *Journal of Cleaner Production, 19* (4), 376-384. doi: http://dx.doi.org/10.1016/j.jclepro.2010.10.013

Frank, R. H. (2000). Why is cost-benefit analysis so controversial? *The Journal of Legal Studies, 29* (S2), 913-930.

Franks, D. M., Davis, R., Bebbington, A. J., Ali, S. H., Kemp, D., & Scurrah, M. (2014). Conflict translates environmental and social risk into business costs. *Proceedings of the National Academy of Sciences, 111*(21), 7576-7581. doi: 10.1073/pnas.1405135111

Freeman, R. E. (1984). Strategic management. A stakeholder-approach. *Press Universitaire de Cambridge*.

Global Reporting Initiative (GRI). (2015). Lignes directrices pour le reporting développement durable. https://www.globalreporting.org/resourcelibrary/French-G4-Part-One.pdf Accessed 28 November 2016

Government of Canada. (2017). Whitehorse Mining Initiative. https://www.nrcan.gc.ca/mining-materials/mining/minerals-and-metals-policy/whitehorse-mining-initiative/8698. Accessed 16 June 2020

Govindan, K. (2015). Application of multi-criteria decision making/operations research techniques for sustainable management in mining and minerals. *Resources Policy, 46, Part 1*, 1-5. doi: http://dx.doi.org/10.1016/j.resourpol.2015.07.006

Handal, L. (2011). Le soutien à l'industrie minière : quels bénéfices pour les contribuables? http://www.iris-recherche.qc.ca/wpcontentluploads/2012/04/Etude-Mines-web.pdf Accessed 9 September 2016

Initiative for responsible mining assurance (IRMA), (2017), Principe et objectifs. http://www.responsiblemining.net/irma-standard/principles-and-objectives/ Accessed 28 November 2016

Institut national de santé publique du Québec (INSPQ). (2015). Effets individuels et sociaux des changements liés à la reprise des activités minières à Malartic : période 2006-2013. https://www.inspq.qc.ca/pdf/publications/1959_Effets_Changements_Activites_Minieres_Malartic.pdf Accessed 28 November 2016

Institut de la statistique du Québec (ISQ). (2015). L'investissement minier au Québec en 2014. Mines en chiffres. http://www.stat.gouv.qc.ca/statistiques/mines/mines-chiffres-2015.pdf Accessed 2 January 2017

Institut de la statistique du Québec (ISQ). (2016). Rémunération hebdomadaire et horaire des employés, régions administratives et ensemble du Québec, 2012-2016. Statistiques et publications. http://www.stat.gouv.qc.ca/statistiques/profils/comp_interreg/tableaux/tra_remuneration.htm Accessed 15 November 2016

International Council of Mining and Metal (ICMM). (2016). Community development toolkit. https://www.icmm.com/website/publications/pdfs/4080.pdf Accessed 28 November 2016

International Organization for Standardization (ISO). (2010). ISO 26000-Lignes directrices relatives à la responsabilité sociétale. site https://www.iso.org/fr/standard/42546.html Accessed 16 September 2016

Jackson, T., & Green, K. P. (2017). Le Québec monte au 6e rang du classement mondial des endroits les plus attrayants pour l'investissement minier. https://www.fraserinstitute.org/fr/%C3%A9tudes/annual-survey-of-mining-companies-2016-fr. Accessed 12 April 2017

Knotsch, C., Bradshaw, B., Okalik, M., & Peterson, K. (2010). Research and information needs concerning community health impacts and benefits from mining–A 2010 community visit report. https://ruor.uottawa.ca/bitstream/10393/30213/1/2011_Research-Needs-Mining-Community-Health.pdf. Accessed 2 February 2017

Kommadath, B., Sarkar, R., & Rath, B. (2012). A fuzzy logic based approach to assess sustainable development of the mining and minerals sector. Sustainable Development, 20 (6), 386-399.

Larousse. (2017). Le grand larousse illustré. http://www.larousse.fr/dictionnaires/francais Accessed 28 November 2016

Marnika, E., Christodoulou, E., & Xenidis, A. (2015). Sustainable development indicators for mining sites in protected areas: Tool development, ranking and scoring of potential environmental impacts and assessment of management scenarios. Journal of Cleaner Production, 101, 1-12.

Marshall, B. (2015). Faits et Chiffres de l'Industrie Minière Canadienne. West Coast Editorial Associates Wet Frog Studios. http://minesqc.com/app/uploads/Faits-et-chiffres-2015.pdf Accessed 15 November 2016

Mine Environment Neutral Drainage (MEND-NEDEM). (2020). Mine Environment Neutral Drainage Program. http://mend-nedem.org/default/?lang=en Accessed 16 June 2020

Ministère de l'Énergie et des Ressources Naturelles (MERN). (2014). Bilan de la stratégie minérale du Québec et des actions du gouvernement du Québec dans le secteur minier. Mines. https://www.mern.gouv.qc.ca/publications/mines/strategie/MS01-01-1409_Strategie_minerale.pdf Accessed 28 November 2016

Ministère de l'Énergie et des Ressources Naturelles (MERN). (2016). Québec Mines 2016 – Le ministre Pierre Arcand accueille les acteurs du secteur minier québécois. https://mern.gouv.qc.ca/2016-11-21-quebec-mines-2016-ministre-pierre-arcand-accueille-acteurs-secteur-minier-quebecois/ Accessed 7 February 2017

Ministère des fôrets, de la faune et des parcs (MFFP). (2011). Profil des retombées économiques des activités et des investissements du secteur minier au Québec. Ministère des fôrets, de la faune et des parcs. Québec. http://mern.gouv.qc.ca/publications/mines/statistiques/etude-impact-économique-secteur-minier.pdf Accessed 28 November 2016

Mihai, A., Marincea, A., & Ekenberg, L. (2015). A MCDM Analysis of the Roşia Montană Gold Mining Project. Sustainability, 7 (6), 7261-7288.

Morgan, R. K. (2012). Environmental impact assessment: the state of the art. Impact Assessment and Project Appraisal, 30 (1), 5-14.

National Orphaned/Abandoned Mines Initiative (NOAMI). (2020). Inventory of Orphaned/Abandoned Mines. http://www.noami.org/choosemap_e.php?language=English Accessed 16 June 2020

LeBlanc, P., Asselin, H., Bussière, B., Demers, I., Ependa, A., Gagnon, A., & Pelletier, L. (2012). Transformations et bouleversements d'un territoire : le cas de la municpalité de Malartic. Chaire Desjardins en développement des petites collectivités de l'Université du Québec en Abitibi-Témiscamingue. Rouyn-Noranda. https://depot.erudit.org/id/003725dd Accessed 15 November 2016

Pawłowski, A. (2008). How many dimensions does sustainable development have? Sustainable Development, 16 (2), 81-90.

Petrie, J., Cohen, B., & Stewart, M. (2007). Decision support frameworks and metrics for sustainable development of minerals and metals. Clean Technologies and Environmental Policy, 9 (2), 133-145.

Petrov, A., Cavin, P., & Heleniak, T. (2013). Measuring Impacts: A Review of Frameworks, Methodologies and Indicators for Assessing Socio-Economic Impacts of Resource Activity in the Arctic. http://yukonresearch.yukoncollege.yk.ca/wpmu/wp-content/uploads/sites/2/2013/09/Petrov-et-al_final-Gap-analysis-report.pdf Accessed 28 November 2016

Porthin, M., Rosqvist, T., Perrels, A., & Molarius, R. (2013). Multi-criteria decision analysis in adaptation decision-making: a flood case study in Finland. Regional environmental change, 13 (6), 1171-1180.

Poveda, C. A., & Lipsett, M. G. (2014). The Wa-Pa-Su Project Sustainability Rating System: A Simulated Case Study of Implementation and Sustainability Assessment. Environmental Management and Sustainable Development, 3(1). doi : http://dx.doi.org/10.5296/emsd.v3i1.4613

Québec meilleure mine (QMM). (2017). Malartic : des citoyens en colère dénoncent les conditions du décret gouvernemental autorisant l'agrandissement de la mine. http://www.quebecmeilleuremine.org/communique/malartic-des-citoyens-en-col-re-d-noncent-les-conditions-du-d-cret-gouvernemental-autoris Accessed 15 July 2016

Quebec Mining Association. (2020). Close environmental monitoring: Allows to limit impact of mining. https://www.amq-inc.com/en/mining-industry/environment

Rodon, T., et Lévesque, F. (2015). Understanding the Social and Economic Impacts of Mining Development in Inuit Communities: Experiences with Past and Present Mines in Inuit Nunangat. Northern Review(41), 13.

Saaty. (1980). The analytic hierarchy process: planning. Priority Setting. Resource Allocation, MacGraw-Hill, New York International Book Company, (pp. 287).

Schweitzer, P. (2014). Gap Analysis: Impacts of Resource Development on indigenous communities in Alaska and Greenland. Resources and Sustainable Development in the Arctic.

Shields, A. (2014). Mines à ciel ouvert : des impacts négligés. Le Devoir. http://www.ledevoir.com/environnement/actualites-sur-l-environnement/421525/mines-a-ciel-ouvert-des-impacts-negliges Accessed 7 May 2017

Singh, Murty, Gupta, & Dikshit. (2012). An overview of sustainability assessment methodologies. Ecological Indicators, 15(1), 281-299. doi: http://dx.doi.org/10.1016/j.ecolind.2011.01.007

Singh, Srinivas, M., & Naik, B. N. (2015). Forcasting the Impact of Surface Mining on Surroundingusing Cloud Computing. Journal of Computer Sciences and Applications, 3 (6), 118-122.

Spangenberg, J. H., Pfahl, S., & Deller, K. (2002). Towards indicators for institutional sustainability: lessons from an analysis of Agenda 21. Ecological Indicators, 2(1-2), 61-77. doi: http://dx.doi.org/10.1016/S1470-160X(02)00050-X

Su, S., Yu, J., & Zhang, J. (2010). Measurements study on sustainability of China's mining cities. Expert Systems with Applications, 37 (8), 6028-6035.

Tonts, M., Plummer, P., & Lawrie, M. (2012). Socio-economic well-being in Australian mining towns: A comparative analusis. Rural Studies, 28, 288-301.

United Nations. (2007). Indicators of Sustainable Development: Guidelines and Methodologies. United Nations publication, New York. Page 3.

Weldegiorgis, F. S., & Ali, S. H. (2016). Mineral resources and localised development: Q-methodology for rapid assessment of socioeconomic impacts in Rwanda. Resources Policy, 49, 1-11. doi: http://dx.doi.org/10.1016/j.resourpol.2016.03.006

Wilkinson, A., Hill, M., & Gollan, P. (2001). The sustainability debate. International Journal of Operations & Production Management, 21 (12), 1492-1502.

Wilson, A., & Green, K. P. (2013). Quebec's mining policy performance: Greater uncertainty and lost advantage. Institut Fraser. Canada. https://www.fraserinstitute.org/studies/quebecs-mining-policy-performance-greater-uncertainty-and-lost-advantage Accessed 5 July 2017

Yates, S., Bergeron, K.-M., Jébrak, M., Angers, P., Lehmann, V., Séguin, C., et al. (2016). Indice du risque social : un outil pour mieux saisir les enjeux, risques et opportunités des projets miniers. Éthique publique. Revue internationale d'éthique sociétale et gouvernementale, 18 (1).

Yu, J., Yao, S., Chen, R., Zhu, K., & Yu, L. (2005). A quantitative integrated evaluation of sustainable development of mineral resources of a mining city: a case study of Huangshi, Eastern China. Resources Policy, 30 (1), 7-19.