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A sustainable Arctic: Making hard decisions

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ABSTRACT

The Arctic is experiencing substantial increases in human activity in areas ranging from fossil fuel and mineral extraction to transport along Arctic waterways. Such actions may yield new sources of economic benefits and further objectives to promote national defense, yet they may also generate potential risks to the Arctic environment. As such, concerns from various stakeholders have been raised regarding how to make Arctic operations better meet sustainability goals and balance defense and economic objectives with environmental degradation. This article describes how decision analytical tools, such as multicriteria decision analysis (MCDA), may help identify policies and project proposals that minimize the potential for environmental degradation within a framework of maximizing economic, industrial, and defense objectives. Specifically, MCDA conducts value tradeoffs to assess the utility of various decision alternatives against disparate criteria; for this case, this includes the evaluation of Arctic operation sustainability. This article demonstrates through an example of industrial mining in Greenland how MCDA might serve as a tool to guide uncertain decisions for various Arctic projects, and potentially indicate opportunities to structure such projects to provide greater sustainability for their longer-term operations.

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Arctic sustainability; multicriteria decision analysis; Arctic environment

Introduction

The Arctic is currently experiencing an unprecedented level of economic, industrial, and military activity. Economically, the U.S. Energy Information Administration (Conley et al. 2012) estimated that the Arctic holds 13 percent of the world's oil reserves, 30 percent of undiscovered gases, and substantial deposits of metals such as palladium, nickel, iron ore, and many others. Private companies, such as the Shell Corporation, have already begun to exploit offshore Arctic oil reserves, while Russia's Arctic mining efforts account for roughly 50 percent of the global supply of palladium, and 20 percent of the global supply of nickel. Driven by a range of factors, such as receding sea ice, improvements in sea and air transport, and a desire to obtain resources within Arctic lands and waters, increased human activity in the area is contributing to sustainability concerns pertaining to environmental health, the social well-being of native communities, and economic development for both local communities and international companies (Avango, Hacquebord, and Wråkberg 2014; Becker and Pollard 2016; Borgerson 2013).

A broader question raised by the Arctic Council centers on the sustainability of increased operations in Arctic lands and waterways, where certain economic and industrial activities pose short-term benefits that may not yield longer-term economic, environmental, or social benefits to local and regional communities (Mikkelsen and Langhelle 2008). Economically, industrial operations and economic activity are often framed as temporary, where any financial or vocational opportunities to local communities may disappear without replacement at some point in the future (Mikkelsen and Langhelle 2008). Environmentally, the persistence of pollutants in Arctic lands and waters remains problematic because of the fragility of local ecosystems and the limited opportunities for the natural bioremediation of hazardous contaminants, exacerbating the effects of pollutants and toxins ranging from plastic debris to chemical mine drainage (Barbante et al. 2017; Cózar et al. 2017). Such pollution can have lasting environmental uptake and can yield unsustainable damages to Arctic flora and fauna (Barry and Price 2015). Socially, the Arctic Council has noted that increased defense-, industry-, and transportation-based activities pose risks to the social cohesion and well-being of local indigenous communities, including exposure to noxious pollutants as well as economic legacy issues should industrial or commercial projects

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cease operation, which halts the generation of economic benefits to local populations after years of profitable activity (Axworthy and Dean 2013).

Recognizing the environmental, social, and economic sustainability challenges posed by increased human activity in the Arctic, national and international governance regimes have been established to monitor and govern human activity within the Arctic region (Berkman and Young 2009; Koivurova 2010). Internationally, examples include the Arctic Council and the Conference of Parliamentarians of the Arctic Region (CPAR), which establish shared norms for Arctic governance yet are limited in their capacity to enforce violations of said norms (Koivurova 2010). On a national level, U.S. policy is driven by various sources, such as the National Security Presidential Directive (NSPD)-66 on Arctic Region Policy, as well as various federal groups, such as the interagency U.S. Arctic Policy Group, to research and monitor U.S. Arctic interests in land and natural-resources management, environmental protection, human health, and transportation.

Given increasing industrial and military activity in the Arctic, and the inevitable sustainability challenges that such activity incurs, guidance is necessary to holistically evaluate policy proposals and industrial projects within the greater Arctic region. Specifically, such guidance should comparatively review strategic sustainability concerns regarding the economic, social, and environmental consequences posed across the lifetime of a proposed project. This viewpoint is further described in NSPD 66, where then-President Barack Obama instructed the Secretaries of State, Defense, Transportation, Commerce, and Homeland Security to "establish a risk-based capability to address hazards in the Arctic environment," which would seek to "advance work on pollution prevention and response standards" (Jordan 2013; Office of the President 2009). However, such risk-based approaches might be complicated by differing decision criteria ranging from economic and military objectives to environmental sustainability, ethical concerns for indigenous populations, and other socioeconomic implications. Tools of decision analysis may serve as one option to comparatively review various disparate criteria, and may ultimately help evaluate Arctic sustainability concerns from various projects and other human activity (Cole et al. 2016; Dawson et al. 2016; Guerra and Jenssen 2014).

In this vein, this article demonstrates how one form of decision analysis (multicriteria decision analysis [MCDA]) can be used to inform decisions based on disparate criteria related to Arctic sustainability. Specifically, MCDA allows users to assess value tradeoffs and review multiple project proposals based on various disparate criteria, and ultimately indicate which policy or project may be ideal under given circumstances and evidence. Relative to project sustainability within fragile ecosystems and at-risk communities, MCDA has been applied to environmental policy and sustainability applications in a variety of environmental settings (Linkov and Moberg 2011). Case-specific applications include terrestrial remediation (Linkov et al. 2014; Yatsalo et al. 2016) and aquatic remediation (Jaglal 2008), where decision support can help identify options to remediate contaminated sites or identify the optimal policy options to have a minimal environmental footprint for a fragile ecosystem (Bates et al. 2015). As such, MCDA has natural applications to the evaluation of a project's potential sustainability challenges by integrating disparate sources of information, such as with objective data and subject-expert opinion, to evaluate various alternatives that meet a similar goal. We explore the use of MCDA through a case application of industrial mining in Greenland, where a decision analytical approach can help improve and identify strategies that balance industrial goals with sustainability concerns for local and regional communities.

Case study: Isua mine, Greenland

Similar to other regions of the Arctic, Greenland has received global awareness in recent years because of its potential for commercial, industrial, and transportation development opportunities. Specifically, Greenland is being positioned and represented as a major new frontier for the exploration and exploitation of mineral and hydrocarbon resources (Nuttall 2012a, 2013). Further, resource extraction has been posited as a potential boon for Greenland's economic prospects and labor force, which are otherwise largely dependent on limited-growth opportunities in commercial fishing (Økonomisk Råd 2012). This sentiment is recognized by the government of Greenland, which acknowledges that a developed mining industry might contribute to beneficial economic development and societal gains (Government of Greenland 2014; Ministry of Foreign Affairs 2011). However, the government of Greenland has also argued that such industrial developments must be met by equal consideration to environmental pollution and sustainability concerns, alongside legacy issues to indigenous populations (Government of Greenland 2014; Ministry of Foreign Affairs 2011).

The mining industry is associated with sustainable-development challenges. Environmentally, this includes acid-mine drainage (Søndergaard, Elberling, and Asmund 2008), persistent chemical pollution of Arctic waters and lands (Norstrom et al. 1998), and toxic gas and aerosol concentrations that contribute to so-called Arctic haze (Shindell et al. 2008). Economic issues are related to economic benefits to society, including employment, business creation, multiplier effects, and tax and revenue distribution (Kadenic 2015; McMahon and Remy 2001). Social issues associated with mining include occupational health and safety and the wider social disturbance of the host community (Carvalho 2017; Kristoffersen and Langhelle 2017; McMahon and Remy 2001). Nevertheless, the industry can also be a key driver of the socioeconomic development of local communities, representing a driver of growth for a community's economy if done responsibly and with the direct participation and permission of local leaders (McMahon and Remy 2001).

Within the mining industry, there is limited consensus on how a sustainability assessment should be conducted (Fonseca, McAllister, and Fitzpatrick 2013). While sustainability-assessment frameworks vary in approach and scope, they have a shared purpose of informing decision makers about the effects of mining on the environment and on society. Assessments can guide decision makers about strategies to secure long-term economic benefits of mining, including environmental conservation programs, investment in social development, diversification of skills, and growth of other industrial sectors (Lederwasch and Mukheibir 2013). Fonseca, McAllister, and Fitzpatrick (2013) categorize various frameworks for sustainability assessments, which are proposed to or applied by mining companies and industry associations (Hacking and Guthrie 2008; Ness et al. 2007).

Isua is the first large-scale mining project granted in Greenland. It is located 150 km northeast of Nuuk on the edge of the inland ice and is partially covered by glacier ice. An exploitation license has been granted to London Mining Greenland A/S (previously owned by the British company London Mining Plc., who suspended its payments in 2014; London Mining Greenland A/S is now owned by the Hong Kong–based company General Nice Development Limited) for an area covering 290 km^2 at Isukasia (Isua) in West Greenland, with a license period from 2013 to 2042 (Government of Greenland 2014, 2015). After three years of construction, the mine is expected to operate for fifteen years and process and export fifteen million tons of iron concentrate per year. The proposed operation is an open-pit mine, because the ore body is close to the surface in one large formation (EIA of the Isua Iron Ore Project 2013), and will consist of a mine pit 1,800 m long, 800 m wide, and 400 m deep.

The main components of mine infrastructure include a processing plant, slurry pipeline, dewatering and storage facility, deep-water port site, fuel storage and pipeline, a small plant near the mine for explosives used in blasting, administrative facilities, worker accommodation, a potential airstrip, and a 105-km access road. Excavated ice and waste rock will be hauled to deposit areas. The tailings will be pumped to a deep glacier meltwater lake, which will contain all the tailings during the fifteen years of operation (EIA of the Isua Iron Ore Project 2013). The iron concentrate slurry is pumped through a 104-km pipeline from the processing plant to the dewatering plant at the port site. The dry iron concentrate is stored and eventually shipped away from Greenland. During the three-year construction phase, the workforce requirement is 1,500–2,000 employees, with a peak of as much as 3,300 employees, which will mainly consist of foreign workers (SIA of the Isua Iron Ore Project 2013). The accommodations and service facilities during the operation phase are provided for 465 employees at the process plant and 165 employees in the port area. The government of Greenland expects the mining project to have significant effects on the local businesses and on development in the municipality, which can extend to the surrounding municipalities (Government of Greenland 2014).

The environmental impact assessment (EIA) undertaken for the Isua project was carried out from 2008 to 2011 (EIA of the Isua Iron Ore Project 2013). The major impacts will be the result of landscape alterations, which will imply visual disturbance in the surrounding area; hydrological consequences in the tailings pond because of gradual filling with tailings; noise disturbance; disturbance and displacement of caribou; and increased CO_2 emission (EIA of the Isua Iron Ore Project 2013). The social impact assessment (SIA) for the Isua project commenced in 2009 and was completed in 2012 (SIA of the Isua Iron Ore Project 2013). The major challenges addressed by the SIA include pressure on public services, social conflicts with international workers, and health and safety conditions at the mine site. The major contributions from the project are increased public revenue through fees and taxes, direct and indirect local employment, and education and training opportunities (SIA of the Isua Iron Ore Project 2013). However, because of the lack of previous experience with projects of this magnitude in Greenland, there are uncertainties related to the multiplier factor and limited availability of local labor. The positive impacts on the local business community depend on the capacity of local businesses to provide services and products that meet the required quality at competitive prices (SIA of the Isua Iron Ore Project 2013).

Methodology

Multicriteria decision analysis refers to a class of structured methods used to evaluate alternatives that must be compared against several criteria (Linkov et al. 2012a, 2014). Most MCDA methods include the construction of a decision matrix that lists each alternative and criterion in a grid-based format, yet different methods of MCDA may utilize different weighting and evaluation algorithms (Linkov et al. 2012b). For example, multiattribute value theory and multiattribute utility theory (MAVT/MAUT) are commonly used optimization techniques. Numerical scores are assigned to each alternative with respect to its performance on individual, weighted criteria, and scores are aggregated for each alternative (Trump et al. 2017a). The purpose of this exercise is to allow decision makers to structure decision problems in a transparent and scientifically defensible manner.

Alternatives

For the case of industrial mining in West Greenland, an MCDA method is applied for analytically comparing the total identified impacts for the two alternatives: Isua-mine and zero-mine. This article applies the weighted sum method (WSM), the most commonly applied MCDA approach for single-dimensional problems for evaluating *M* alternatives in terms of *N* criteria (Mateo 2012). Via WSM, all criteria are normalized for standardization and cross-comparison of alternative performance across various criteria (Pohekar and Ramachandran 2004). This may be formally represented as:

$$A_i = Max \sum_{j=1} a_{ij} w_j$$

Criteria identification and selection

The context-specific impacts identified by both the EIA and SIA for the Isua-mine form the criteria for the MCDA-based assessment. The impacts are grouped according to environmental, economic, and social dimensions. Some impacts are identified in both the EIA and the SIA. Within the theme "Human presence and use of the environment" in the EIA, impacts relevant to *(1) hindrance of other land use (hunting and fishing)* and *(2) disturbance of culturally significant sites* are addressed. The same impacts are addressed within the theme "Cultural and natural values" in the SIA. This displays interdependency and interconnection between the biophysical environment and the human environment, where environmental changes may cause social impacts (Hacking and Guthrie 2008; Hansen and Mortensen 2013; Trump et al. 2017b; Vanclay 2004). A central feature of the indigenous peoples' culture is an inseparable relationship with the land and its resources (Sejersen 2004). For the structure of the assessment, these particular impacts are only mentioned within the environmental dimension. Impacts related to *(3) education and training* are categorized within the economic dimension. Education and training are prerequisites for realizing the full potential of the positive effects related to direct employment in the mine, which is an economic issue. However, it is highly recognized that education and training also have a great impact on the social dimension, which again displays the interconnection among impacts (Palma-Oliveira et al. 2017).

Criteria scoring

In the EIA and SIA, the identified impacts have been originally scored by their respective authors as either negative or positive and low, medium, and high. These terms of performance measures can be represented with numbers (Wibowo 2013). Hence, they are converted into values from 1 to 10, where 1 is a very high negative impact and 10 is a very high positive impact. The conversion of the impacts is important in order to conduct a measurable and quantitative assessment. The economic and social impacts are assessed throughout the entire scale, while the environmental impacts are assessed within the negative range of the scale. The impacts of the zero-mine alternative are assigned the equal opposite value of the scale. If an impact is assessed as high positive in the Isua-mine alternative, then it will be equally assessed as high negative in a zero-mine alternative, since the potential of a highly positive impact will be absent in a zero-mine alternative. Impacts that are assessed as being not relevant or not significant will not be included in the model.

Stakeholders and value weighting

Azapagic (2004) suggests a comprehensive list of stakeholders relevant to the mining industry. The industry stakeholders include local communities, authorities, governments, employees, trade unions, nongovernmental organizations (NGOs), contractors and suppliers, shareholders, customers, creditors, and insurers. The complexity arises from multiple stakeholder values and perspectives combined with impacts on communities, economics, and ecosystems across institutional and geographical scale (Giurco and Cooper 2012).

Based on Azapagic's (2004) stakeholder list, four key stakeholder profiles are selected to illustrate this assessment. These are *community*, which includes people, employees, and trade unions; *government*, which includes the government of Greenland; *business*, which includes local companies, local suppliers, and contractors to the mine; and *NGOs*. The *community* is directly affected by neighboring mines, because those community members that comprise the employees of the industry are particularly interested in a healthy working environment, training, job creation, and derived business opportunities (Azapagic 2004; Loe and Kelman 2016). The local population has strong interest in preserving traditional livelihoods, including hunting and fishing, because indigenous identities, societies, and economies are inseparably tied to their traditional land and resources (Sejersen 2004). However, the nearest settlement, Nuuk, is located 150 km from the mine site. Trade unions are mainly interested in issues related to health, safety, equal opportunities, and fair treatment (Azapagic 2004).

Government has a strong interest in the economic dimension (Bjørst 2016; Tiainen 2016) as well as the social and environmental dimensions, because it implements and enforces laws and regulations, distributes wealth, protects the rights of the local communities, provides health services, and develops initiatives to mitigate social issues and strengthen local communities' economic, environmental, and social well-being (Azapagic 2004). *Business* is mainly interested in economic issues with no or some interest in environmental and social issues (Azapagic 2004). However, because they consist of potential local suppliers and contractors to the mine, it must be assumed that local businesses have some interest in social and environmental issues (Sejersen 2004), because they are a part of the local community as well. *NGOs* are mainly concerned with protecting the environment and securing a socially responsible and inclusive approach to mining (Azapagic 2004; Bjørst 2016).

The interests of each stakeholder group are used to weight the criteria against which the alternatives are assessed. Similar to Azapagic (2004), levels of interest are assigned on the metrics of strong (++), some (+), and none (-), and are subsequently converted into quantitative values, where a strong interest level receives the value of 5, some interest receives the value of 3, and no interest or very low interest receives the value of 1. Weights are derived from general interests and awareness areas as described by Azapagic (2004) and are supported by other contributions about Greenland and Arctic communities (Bjørst 2016; The Committee for Greenlandic Mineral Resources to the Benefit of Society 2014; Copenhagen Economics 2012; Loe and Kelman 2016; Økonomisk Råd 2012; Sejersen 2004; Tiainen 2016) with the purpose of providing illustrative examples of how various interests can be considered in the assessment.

Results and discussion

The holistic assessment of the Isua-mine as compared to a zero-mine alternative based on WSM is presented in Table 1. The table shows how the two alternatives perform on each dimension according to each stakeholder group's weight and impact level. As an example, "caribou" is an identified impact in EIA for the Isua-mine, which deals with *"disturbance and noise by the presence of vehicles, machines, buildings, personnel and other project infrastructure, which might cause displacement of caribou"* (EIA of the Isua Iron Ore Project 2013). This particular impact is assessed according to the EIA as medium-negative (-M), which is converted to a value of 3 for the Isua-mine alternative. The weight of the "caribou" impact according to the stakeholder group *community* is assessed as very important (Sejersen 2004) and is converted to a value of 5. The score of the impact "caribou" according to the stakeholder group *community* is 0.105 ($C_x \times W_{Cx}$ (stakeholder weight is normalized) = 3 × 0.035). Criteria weights will differ across studies, depending on the specific context and relevant stakeholders, and result in different outcomes for the most suitable alternatives of a decision analysis. Therefore, this assessment also includes a combined weight of all four key stakeholder groups. An equal-weighted result for both alternatives is also presented.

Figure 1 illustrates the performance of the two alternatives based on an equal-weighted score. Initially, the results indicate that Isua-mine only outperforms the zero-mine alternative on the economic dimension,

Table 1. Total sum of impacts for the Isua-mine and zero-mine alternatives.

	Key Stakeholder Profile	Isua-mine	Zero-mine
Environmental	Equal score	86	145
	Community	1.594	2.713
	Government	1.561	2.643
	Business	1.084	1.874
	NGOs	2.625	4.446
	All stakeholder groups	1.687	2.87
Economic	Equal score	104.5	60.5
	Community	3.129	1.563
	Government	3.169	1.736
	Business	4.197	2.366
	NGOs	1.085	0.585
	All stakeholder groups	2.949	1.588
Social	Equal score	37.5	50.5
	Community	0.853	1.147
	Government	0.828	1.064
	Business	0.664	0.815
	NGOs	0.951	1.308
	All stakeholder groups	0.824	1.308
Total WSM	Equal score	228	256
	Community	5.577	5.423
	Government	5.557	5.443
	Business	5.945	5.055
	NGOs	4.661	6.339
	All stakeholder groups	5.460	5.766

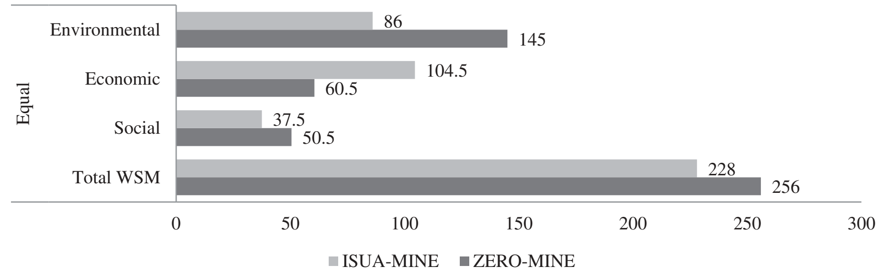

Figure 1. Equal-weighted results.

and the total sum of impacts combining all three dimensions is higher for the zero-mine alternative.

A similar distribution of performance between the two alternatives across the three dimensions is traceable throughout all stakeholder variations in Figure 2 as the equal-weighted result in Figure 1. While Isua-mine only outperforms the zero-mine alternative on the economic dimension, the performance of the environmental and social dimensions is in favor of the zero-mine alternative across all stakeholder groups.

Local community stakeholders have an interest across all dimensions, because they are most likely to experience impacts in each (EIA of the Isua Iron Ore Project 2013; SIA of the Isua Iron Ore Project 2013). Community stakeholders are directly affected by potential environmental damages and possible social consequences (Nuttall 2012b); however, they also face opportunities for employment and economic prosperity resulting from a large-scale mine. The government too has a broad interest in all three dimensions. It will need to be

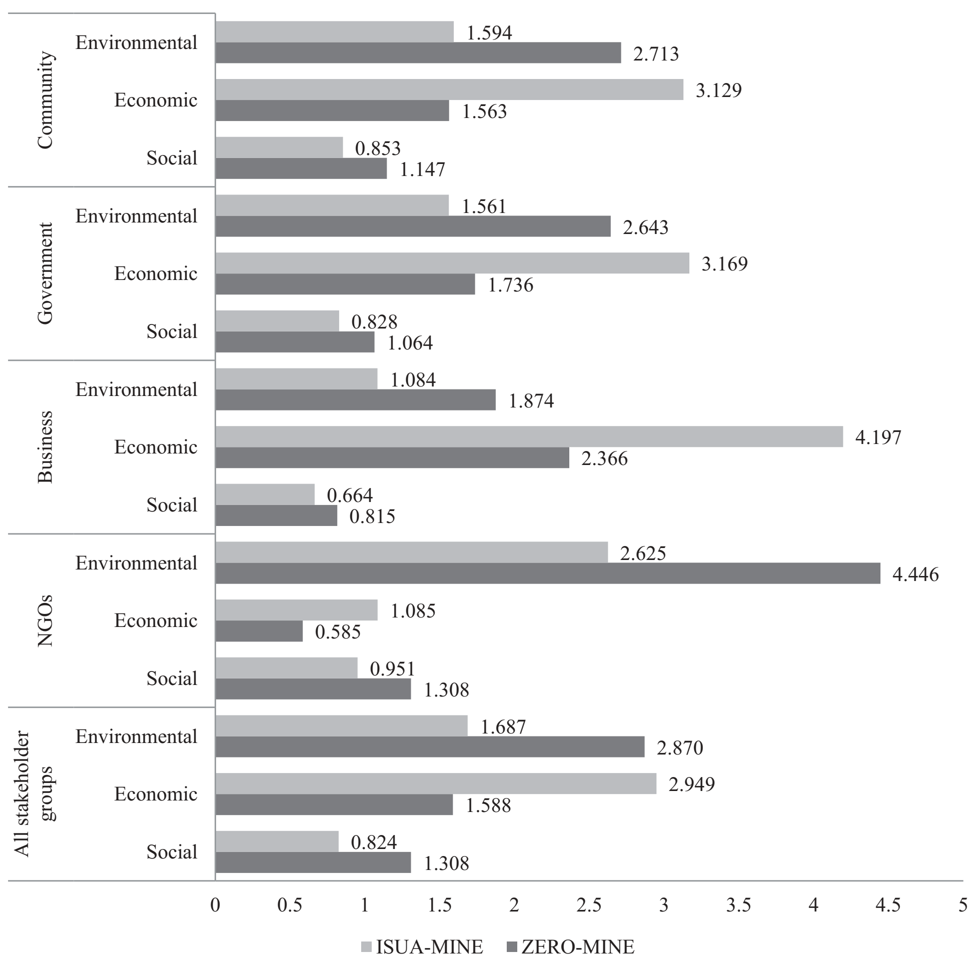

Figure 2. Key stakeholder groups results.

concerned with potential environmental impacts because they have consequences for citizens' well-being, for which authorities are accountable. Similarly, the authorities will eventually have to deal with and provide solutions for any social problems that may be caused by the mine (Azapagic 2004). Potential macroeconomic growth based on taxes and revenues from the mine because of employment opportunities at the mine is also a key interest of government, because it can lead to overall economic improvement and improved social services for the citizens (Government of Greenland 2014).

Community and government stakeholders have a similar score distribution between the two alternatives across all three dimensions. Likewise, business stakeholders expressed interest within new business opportunities for providing supply and services to the mine, contract packages, and employment (Aurora, 2012). They have some interest in the environmental and social dimensions, because they are local businesses. The business viewpoint represents the highest gap in the performance of the alternatives on the economic dimension, favoring the Isua-mine. Finally, NGOs expressed concern regarding a range of sustainability issues regarding environmental pollution and negative impacts to social well-being (Azapagic 2004; Bjørst 2016), with economic aspects being of minimal interest. The NGOs' viewpoint represents the highest gap between the two alternatives on the environmental dimension among the stakeholder groups, favoring the zero-mine alternative.

Figure 3 shows that Isua-mine outperforms the zero-mine alternative from community, government, and business viewpoints, whereas according to the equal-weighted result the zero-mine outperforms the Isua-mine alternative. This demonstrates that the evaluation of the two alternatives strongly depends on different stakeholders' perceptions of importance relative to each identified impact. While the performance gap between the alternatives from community and government perspectives is relatively similar, the gap is comparatively large from the business perspective. The combined stakeholder viewpoint indicates an outperformance by the zero-mine alternative opposed to the Isua-mine, which most likely can be explained by the relatively large gap in favor of the zero-mine alternative from the NGOs' perspective.

Even though the Isua-mine is only preferable to the zero-mine alternative on the economic dimension, the total sum of impacts favors the Isua-mine because of the perceived importance of the economic impacts combined with the potential positive economic impacts caused by the mine. While the Isua-mine may bring economic prosperity to Greenlandic society, it does not necessarily follow that these potential impacts will become a certain reality. Ultimately, it depends on the extent to which society is capable of realizing these potential economic opportunities. Studies of other Arctic communities (Iceland and Faroe Islands) and the extractive industries emphasize that human capital development plays an important role in securing and maximizing local socioeconomic benefits (Smits, Justinussen, and Bertelsen 2016). Others propose that an inclusive business approach can deliver socioeconomic development and improve sustainability (Virah-Sawmy 2015). However, Greenland faces several uncertainties associated with appropriate competencies and the experience required for the mining industry (The Committee for Greenlandic Mineral Resources to the Benefit of Society 2014; Copenhagen Economics 2012; Økonomisk Råd 2012), a workforce of sufficient scale (Statistics Greenland 2016a), and a business community dominated by small- to medium-sized enterprises (Statistics Greenland 2016b). Hence, collaborative strategies are considered beneficial for the business community to increase business potential (The Committee for Greenlandic Mineral Resources to the Benefit of Society 2014) and a focus on human capital development is essential (Smits, Justinussen, and Bertelsen 2016) in order to overcome these uncertainties as an emerging resource economy. Economic growth,

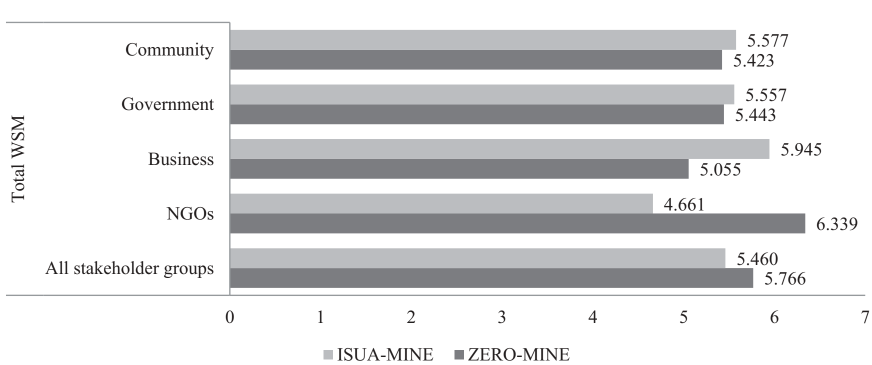

Figure 3. Total WSM results.

employment, and skills development derived from the development of the mining industry in Greenland are perceived as contributors to social sustainability, provided that local communities are included in the decision-making process and their wishes are respected (Tiainen 2016). Lack of realization of potential benefits might offset the difference between the alternatives. This is evidence of the necessity of making trade-offs among the environmental, economic, and social dimensions when considering socio-economic value creation and the sustainability of a large-scale mining project.

Conclusion

Resource extraction and geographic exploitation of the Arctic is likely to grow in the coming decades, largely driven by greater access to a previously inhospitable climate and year-round sea ice. Such opportunities also drive new challenges associated with environmental sustainability and social implications, and warrant consideration for any project in the Arctic region. Given such a motivation, this article presented a holistic assessment framework and method that includes environmental, economic, and social dimensions for the case of a project evaluation for a mine in Greenland.

Additionally, this article focused on one of many growing case applications of increasing human activity in Arctic lands and waters. An example of nonindustrial commercial activity includes transportation in increasingly ice-free Arctic sea lanes such as the Northwest Passages; for example, in 2011 Russian icebreakers delivered 820,000 tons of cargo along the Northern Sea Route in two-thirds of the time it would have taken along the Suez Canal (Conley et al. 2012). Additional travel in previously unnavigable Arctic waters will likely also include tourist travel via cruise ships, and similar economic-development projects such as with port building (Luck et al. 2010; Stewart et al. 2007). Similar to the sustainability challenges posed by industrial mining, these commercial activities will likely pose a variety of opportunities and challenges to the environmental, social, and economic well-being of local communities, and would benefit from a decision analytic approach to evaluate such activities against noted sustainability concerns.

The case outcome serves as an illustrative example of method application, which shows that the total sum of impacts, consisting of the environmental, economic, and social dimensions, results in the Isua-mine being favored by community, government, and business stakeholder groups. The evaluation of alternatives strongly depends on various stakeholders' perceptions of what is important to them. While these results are only applicable to the Isua-mine and the selected key stakeholder groups, the MCDA method can be applied to EIAs and SIAs regardless of the location or magnitude of similar Arctic development and transportation efforts. Overall, methods of decision analysis offer analytical capacity to compare various disparate criteria and sustainability concerns related to potential environmental, social, and economic consequences incurred by a growing number of Arctic projects.

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