AN ANALYTIC HIERARCHY PROCESS APPLICATION TO OIL SANDS ENVIRONMENTAL COMPLIANCE RISK MANAGEMENT

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ABSTRACT

In 2013, oil companies in Alberta, Canada invested $32 billion in new oil-sands projects. Despite the size of this investment, there is a demonstrable deficiency in the uniformity and understanding of environmental legislation requirements that translate into increased project compliance risks. In this paper, we applied the Analytic Hierarchy Process (AHP) to develop a priority list of environmental regulatory compliance risk criteria for oil-sands projects. AHP belongs to the family of multicriteria decision-making (MCDM) techniques that utilizes a pairwise comparison matrix solicited from subject matter experts (SMEs) in the field as input. The overall methodology itself consisted of 4 phases: (1) identification of the initial list of N potential environmental compliance risk criteria and verification of these criteria via a pilot survey; (2) formation of a pairwise comparison survey in the form of an N(N-1)/2 comparison matrix based on the verified criteria; (3) administration of the pairwise comparison matrix to a sample of 16 industry-specific SME's; and (4) the application of the AHP method using SuperDecisions as a tool on the collected sample to rank the identified risk criteria. Our demonstrated results can potentially inform Alberta oil sands industry leaders about the ranking and utility of specific compliance risks as understood by experts and enable a more focused environmental compliance action to help increase legislative and public trust.

Keywords: AHP; Alberta; oil sands; environment; regulatory compliance; risk criteria

1. Introduction

In the last decade, there has been an increased investment in in-situ oil sands extraction in Alberta, Canada with more than $32 billion invested in 2013 in new oil-sands projects. Recent oil price decreases have exerted pressures on oil sands projects, but the roughly $155 billion capital investments in the last 10 years or so in these projects makes it just too difficult to switch them off. Many of these projects have only recently moved into production, thus oil sands companies continue to pump oil to recover these investments by curtailing costs and production in anticipation of competitive pricing beyond 2016.

Despite current price pressures, Canadian oil sands constitute by far the largest region of oil sands in the world. This region covers an area of 140,000 sq km, an area larger than England. In situ oil sands extraction is technically complex. For example, the extraction of oil deposits residing in deep sand deposits requires the application of underground steam in large quantities to increase the viscosity and pump the oil (bitumen) to a processing plant on the surface. The industry employs highly specialized engineers and scientists with expensive equipment resources.

In addition and specific to Alberta oil sands, project engineers and executives have to achieve required levels of environmental regulatory compliance and sustainability throughout a project's lifecycle. The successful deployment of new projects depends heavily on past regulatory compliance and risk management successes (Rasmussen, 2009). In general, there are hefty public demands for environmental oversight for Alberta's oil sands developments. For example, the environmental compliance risk for oil companies may be higher in Alberta than in the Gulf of Mexico according to a Ceres report, a nonprofit environmental organization in the US (Nicholls, 2010). Other researchers such as Briggs, Tolliver, and Szmerekovsky (2012) reviewed the supply chain risks in a related industry, the upstream crude oil industry. These authors identified environmental and regulatory compliance as one of the six high-risk criteria.

During a project's lifecycle, environmental requirements may change significantly with new regulatory requirements added after project definition which pose a potential risk to the sustainability of a project. The in-situ oil plant may not be able to meet new regulatory compliance within an economic framework. For example, Pollard (2009) analyzed environmental risk management and concluded management should pay attention to changes in environmental regulations and possess a sound understanding of environmental risk. Resolving environmental problems and reducing risks as well as liability are all positive reasons for implementing a risk management system even before the start of construction (Jafari, Khorasani, & Danehkar, 2010).

In summary, the identification and prioritization of risks for in-situ oil sands projects requires a more focused, justified, and rigorous approach. In this paper, we expose the core environmental compliance criteria essential to environmental risk management of in-situ oil sands projects. The work is significant from two points of view. First, the use of a systematic approach rather than anecdotal evidence was applied to identify the importance of compliance risk criteria using a cross-sectional sample of SMEs deeply rooted in the Alberta oil sands industry. And second, the exposure of such ranked compliance criteria to the general public increases the level of public trust and the view that the industry is indeed cognizant about such priorities and the need to manage associated risk.

2. Literature review

2.1 Background to the oil sands

The business environment has changed in the last decade. Shareholders expect better financial performance from companies while adhering to an environmental management plan (Flammer, 2012). As global environmental requirements for oil sands increase and as the technology for extracting the oil changes, project engineers and company executives need to understand and support the environmental functions. Such an understanding helps ensure that Alberta oil sands projects will be compliant with the provincial government regulations.

The biggest concentration of oil sand deposits in the world is situated in Canada. There is an equivalent of 950 to 1,600 billion barrels of oil in these oil sands of which about 175 billion barrels of oil are recoverable (Owen, Inderwildi, & King, 2010). Great Canadian Oil Sands Ltd (later Suncor) began production of the oil sands north of Fort McMurray, Alberta, Canada in 1967 (George, 2012). The oil sands are uncovered in open pit mines; however, the oil sands (80%) in northeastern Alberta are at depths of more than 150m, too deep for open pit mining and suitable for in situ extraction (George, 2012).

In-situ oil sands extraction is technically complex and involves highly specialized individuals, expensive equipment resources, and registered patents according to the Canadian Association of Petroleum Producers (CAPP, 2010). The in-situ process used by most companies is the Steam Assisted Gravity Drainage (SAGD) process. Butler was the first to introduce steam as a method to move bitumen to a production well (Mohebati, Maini, & Harding, 2010). Butler's steam process developed into the modern SAGD process (Coskuner, 2009). The main advantages of the SAGD process are the use of gravity to drain the oil, lower energy consumption, and relative high recovery efficiency (between 70-75%) (CAPP, 2010; Mohebati et al., 2010). In-situ plants have a small land footprint similar to the footprint of conventional oil well operations, and in-situ plants have no need for tailings ponds. For in-situ projects, the steam-to-oil ratio (SOR) is a measure of the energy efficiency of bitumen recovery.

According to the ERCB report ST98-2011, the Alberta oil sands industry produced 1.613 million barrels per day (Mb/d) of crude bitumen in 2010 (ERCB, 2011). The oil sands crude production represents 0.857 Mb/d from surface mining and 0.756 Mb/d from in situ projects (ERCB, 2011). The total crude bitumen production from the Alberta oil sands will more than double by 2020, an increase from 1.6 Mb/d in 2010 to about 3.3 Mb/d (ERCB, 2011). The production from in situ projects will exceed production from mining projects within the next few years. Doubling production of the oil sands will increase the need for better environmental risk mitigation planning to avoid the potential negative environmental impact.

An oil sands project can end in financial disaster if the local jurisdiction deems the project as non-compliant with local regulations. A non-compliant project will not receive a license to start producing. An oil company may spend $500 million on a pilot in-situ project before the start of production and up to $1.5 billion on a commercial project (Government of Alberta, 2010). Coupled with these high capital investments are environmental risks due to the fact that Alberta's oil sands are situated in an environmentally sensitive part of the province. In 2008, ducks (1,600) drowned in the

Syncrude Aurora tailings pond and Syncrude, a leading Alberta oil sands producing company, paid $3M in penalties, and much more in loss of image since the unfortunate incident gave the company a reputation for producing dirty oil and reminded all oil sands executives that the preservation of the environment is a serious issue (Stewart, Archer, & Trynacity, 2010; Stewart et al., 2010). As such, managers of future oil sands projects must consider the environment during project execution.

2.2 Environmental compliance regulations

The government of Alberta measures the environmental impact of the oil sands in terms of several factors or indicators which are as follows (Government of Alberta, 2009):

1. Land use or footprint – The area of boreal forest cleared for operations, all affected land shall be reclaimed and biodiversity shall be maintained (regulated by Alberta Environment).
2. Air pollution – Greenhouse gas (GHG) emissions from the oil sands totaled 45 million tons in 2009 (McCarthy, 2010), and these GHG emissions represented 6% of Canada's GHG emissions and 0.1% of global emissions. The Alberta provincial government introduced, in 2007, a 12% mandatory reduction in GHG emissions for all large industrial facilities, including oil sands (Alberta Environment, 2008).
3. Water use – The Alberta government regulates all fresh water resources in the province. In 2009, irrigation and agriculture represented 44% of the total provincial water usage allocations; the provincial regulator allocated 7% of the water usage to oil sands industry. In-situ projects require about 0.5 barrels of fresh water per barrel of oil, and 80-90% of water used in SAGD is recycled (CAPP, 2010).
4. Water quality – The Alberta Environment Regulator regulates the release and the quality of all water. All water must conform to the water quality standards of Alberta environment (Hurley, Sadiq, & Mazumder, 2012).
5. People – The oil sands developments have an effect on the communities. Consulting with local stakeholders and communities is a regulatory requirement (Government of Alberta, 2009).

Project engineers do consider these five environmental indicators because the Alberta government constantly monitors these same environmental indicators ensuring proof of compliance by the project owner throughout the project construction and production phases.

2.3 Risk management

Arimura, Hibiki, and Katayama (2008) explained that an environmental risk management system such as International Environmental Risk Management system (ISO 14000), helped companies identify and resolve environmental impact in areas such as natural resources and solid waste generation. Edwards and Darnall (2010) identified that the implementation of an environmental risk management plan improves the possibility of an organization complying with environmental regulations. Therefore, the success of the project and the future sustainability of an oil sands project will depend on the environmental risk management strategy followed by decision makers.

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2.4 Risk management of in situ oil sands projects

The BP Deepwater Horizon oil spill in the Gulf of Mexico that happened in April 2010 demonstrated how a company with a long-term environmental strategy could still have an environmental incident that was catastrophic to the company's image (Cherry & Sneirson, 2011). Oil company executives need to ensure an environmental risk management process is in place, and that the company complies with the environmental, health and safety regulations.

Regulatory compliance risk management is the process of establishing mitigation actions that will help to: (a) protect the company image, (b) protect the company wealth, (c) execute successful oil sands projects, (d) ensure a safe workplace, (e) protect the environment, and (f) maintain close relationships with local communities. In the case of new oil sands projects, engineers will have to work towards regulatory compliance.

Regulatory compliance is possible when project engineers manage the identified risk criteria. These risk criteria include (a) operational risk, (b) compliance and legal risk, (c) reputation risk, (d) social risk, (e) environment, health, and safety or EHS risk, (f) geologic risk, (g) political risk, (h) financial risk, and (i) economic risk (Andersen & Mostue, 2012; Wagner & Armstrong, 2010). Briggs et al. (2012) reviewed risk criteria in the oil industry's supply chain, and they recognized social risk, economic risk, financial risk, technological risk, and environmental and regulatory compliance risk as high-level risk criteria. These risks focus on the business, the public, and the environment. Another oil industry study by Enyinda, Briggs, Obuah, and Mbah (2012) identified the primary risk criteria as geological and production risks, environmental and regulatory risk, transportation risk, oil availability risk, geopolitical risk, and reputation risk.

2.5 Influence of Alberta environmental policies on risk management

The influence that regulations and government actions have on the risk level of new projects may determine the final compliance of the project. Compliance requirements and their influence on projects could have a significant influence on how executives see the future compliance issues and corporate social responsibility as measures of project success (Wagner & Armstrong, 2010).

El-Fadel, Abi-Esber, and Ayash (2009) examined the use of regulatory and compliance-based modeling as applied to air quality assessment. El-Fadel et al. (2009) stated that environmental regulatory compliance based on science works to a point, and then it becomes a political decision-making situation. The political decision-making is outside the influence sphere of the project engineer or oil company executive. However, it is the regulator and politicians that need to take action based on this scientific evidence.

2.6 The need to apply an MCDM technique

The environmental policy uncertainty in the oil and gas industry in Alberta influences the decision-making in this industry and the framework most suitable for decision-making. In light of this paper's focus on identifying and ranking the environmental risk criteria and the fact that such multiple criteria cannot be defined as a monetary value or added together, attention was turned to multi-criteria decision making (MCDM) models. Rasmussen (2009) was a key reference who investigated the decision-making process under risk and compliance and proposed a holistic process to decision-making. An

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MCDM process that considers or manages the human aspect of decision-making is beneficial. An understanding of the openness and endless approach that is qualitative research may also help to get a better understanding of decision-making.

A number of MCDM techniques could potentially be applied to rank the environmental risk criteria associated with oil sands extraction projects. The premise was based on a study by Huang, Keisler, and Linkov (2011) who reviewed more than 300 environmental project papers and concluded that there is an increase in the application of MCDM. In addition, Huang et al. determined that the methods used the most in environmental analysis included AHP (Saaty, 2006), MAUT (Beccacece & Borgonovo, 2011), and outranking (Jajimoggala & Karri 2013). Similarly, Geng and Wardlaw (2013) identified the MCDM methods most used in environmental management included compromise programming, goal programming, as well as AHP.

Decision-making is a broad subject that influences the project, project executives, project engineers, and the organization (Akdere, 2011). It is essential to identify typical decision-making models used for multicriteria decisions-making (MCDM particularly for environmental decision-making). A review of the literature regarding the decision-making process used in other industries where most of these risks occur found that the AHP is often used as an MCDM. AHP is an MCDM methodology suitable for complex systems that allow for the interpretation of both qualitative and quantitative aspects of decisions (Saaty & Sagir, 2009). Saaty (2006) has used AHP since its introduction in 1980 for a large number of MCDM projects within various industries, and it has been applied in areas such as setting priorities, risk management, quality management, project management, and strategic decision-making. Lastly, it is well-known that AHP is preferred over traditional methods such as a multiple-choice survey as it provides superior measurement or discrimination of a participant’s perceptions (Estévez, Walshe, & Burgman, 2013).

Therefore, AHP is a preferred MCDM framework by many practitioners (Aydin & Arslan; 2010; Podvezko, Mitkus & Trinkūnienė, 2010). At the end of the process, AHP not only allows the researcher to manage different types of data but also evaluate the consistency of the inputs from decision makers (Stoklasa, Jandová, & Talasová, 2013). Following this overall guidance, we also opted to apply AHP.

3. Methodology

The applied research methodology is in compliance with the following principles: (a) a valid research purpose, (b) an appropriate methodology for data collection and analysis, (c) a manageable research scope and effort, and (d) the researcher’s perception of the real-word problem to be researched (Cooper & Schindler, 2013).

The purpose was to (a) identify the environmental compliance risk criteria, and (b) assess the contributions these risk criteria make to regulatory compliance of in-situ oil sands projects in Alberta. The adopted data collection and analysis methodology is based on AHP and consisted of a number of steps beginning with the identification of the initial list of N potential environmental compliance risk criteria using the Alberta Energy Regulator (AER) database, verification of this list of N criteria with five SMEs, the formation of a pairwise comparison survey in the form of an N(N-1)/2 comparison matrix, the administration of the pairwise comparison matrix to a sample of 16 industry-specific subject matter experts (SMEs) to solicit their individual pairwise priorities among the identified N risk criteria and the application of the AHP method using SuperDecisions as a tool on the collected sample to rank each of the N risk criteria. A summary of these steps is shown in Figure 1.

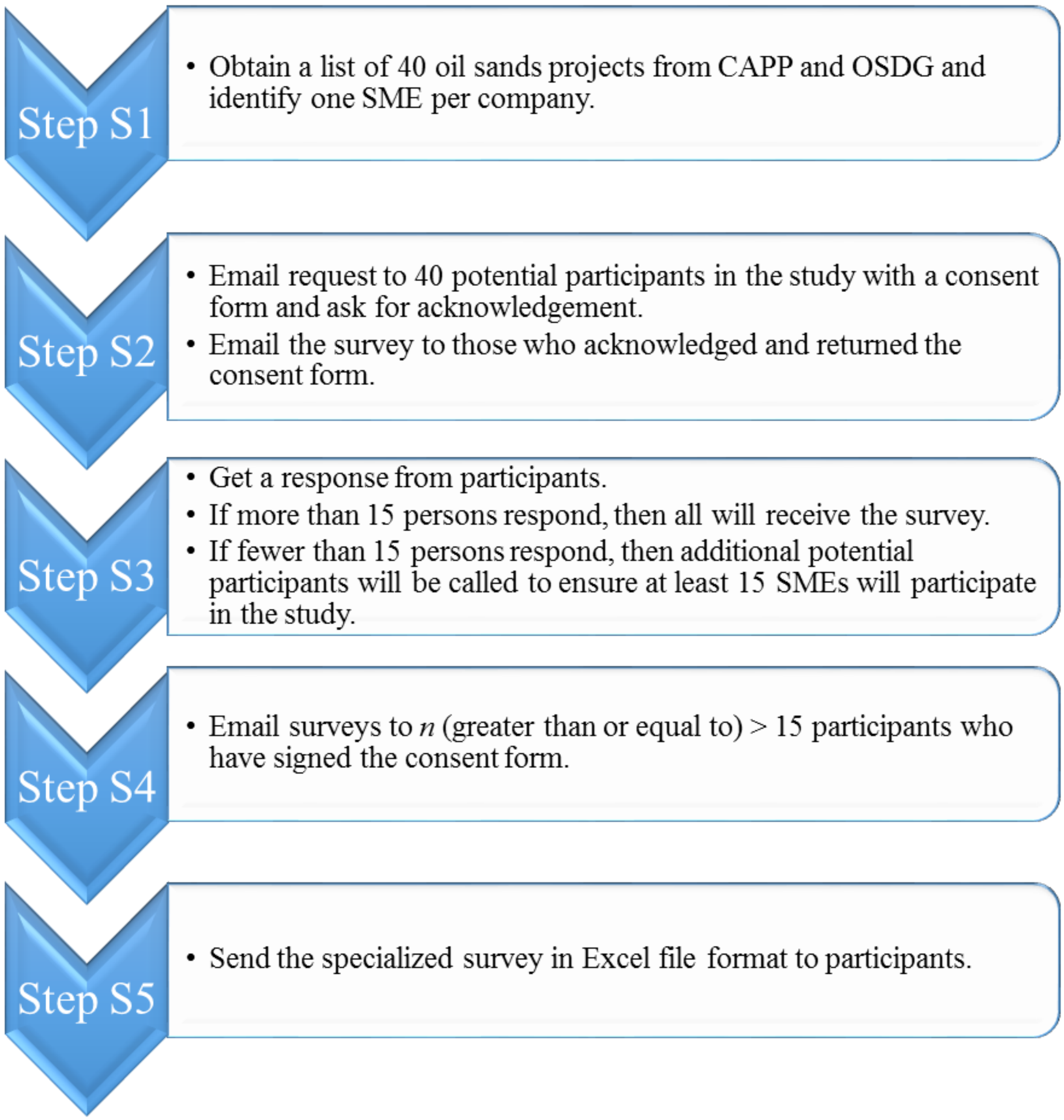

Figure 1. Execution steps for specialized survey

3.1 Identification of potential risk criteria

The study began with the identification of a list of environmental compliance risk criteria. These criteria were identified from past literature and a key database called the AER archival database encompassing all reports filed for regulatory compliance of oil sands projects (ERCB, 2008). These reports were self-disclosure reports and were a result of past project engineer- and project manager-identified regulatory compliance issues as reported to the AER.

3.2 Formation of the pairwise comparison survey

The formation of the pairwise comparison survey required two steps. First, a pilot survey was formed utilizing the list of the identified N potential risk criteria. This survey was administered to five SMEs before adopting the list for forming the final pairwise comparison survey. It is important to note that the five SMEs who were consulted in the pilot survey step were members of CAPP, a recognized association of petroleum producers. In addition, the primary author's personal engineering work in the oil sands field was put to use in encapsulating the relevant regulatory risks and in soliciting the sample through business contacts.

The pilot survey administered to the set of 5 SMEs was analyzed to determine the final list of N risk criteria. Once this list of N criteria was finalized, these N criteria were converted to an N(N-1)/2 pairwise comparison matrix or survey and administered at a later point in time to a separate set of 16 SME's.

The sample of SMEs involved in the research is drawn from the population of risk management SMEs involved in Alberta in-situ oil sands projects. The population was selected because of the high concentration of in-situ oil sands projects in the province. In 2010 there were more than 87 oil sands projects in Alberta in various stages of execution (Government of Alberta, 2010).

A targeted or purposeful sample of SMEs was sought to ensure that these SMEs took an active involvement in the decision-making process and that they were directly involved in risk management or environment, health, and safety (EH&S) management. Eligibility depended on the participant's organizational function and subject knowledge. The knowledge of individual group members in the AHP decision group is a main concern (Saaty, 2006). Additionally, individual decision makers with subject expertise and experience can provide valid inputs and be representative of the subject matter (Huang, Chen, & Chang, 2009). Therefore, the expert knowledge and experience of the SMEs recruited contributed to the success of the survey.

The sample size of 16 SMEs was based on Firestone (2006) who recommended 15 SMEs in a decision-making panel, Goepel (2011) who recommended using a group of at least five SMEs for AHP, and the key papers by Goepel (2011) as well as Saaty (2006) who both concluded that the background and experience of the SME's were more valuable to the success of AHP than the number of SME's in the decision-making panel. In this research, the guidelines from Firestone and Goepel were followed in order to recruit a purposeful sample of 15 SMEs from the frame.

The criteria resulting from execution of the pilot survey are shown by level in Figure 2 below. The initial list of criteria used in the pilot survey were close to the final list shown in Figure 2 and only included an item called "Human compliance" that was deemed not important by the pilot SMEs.

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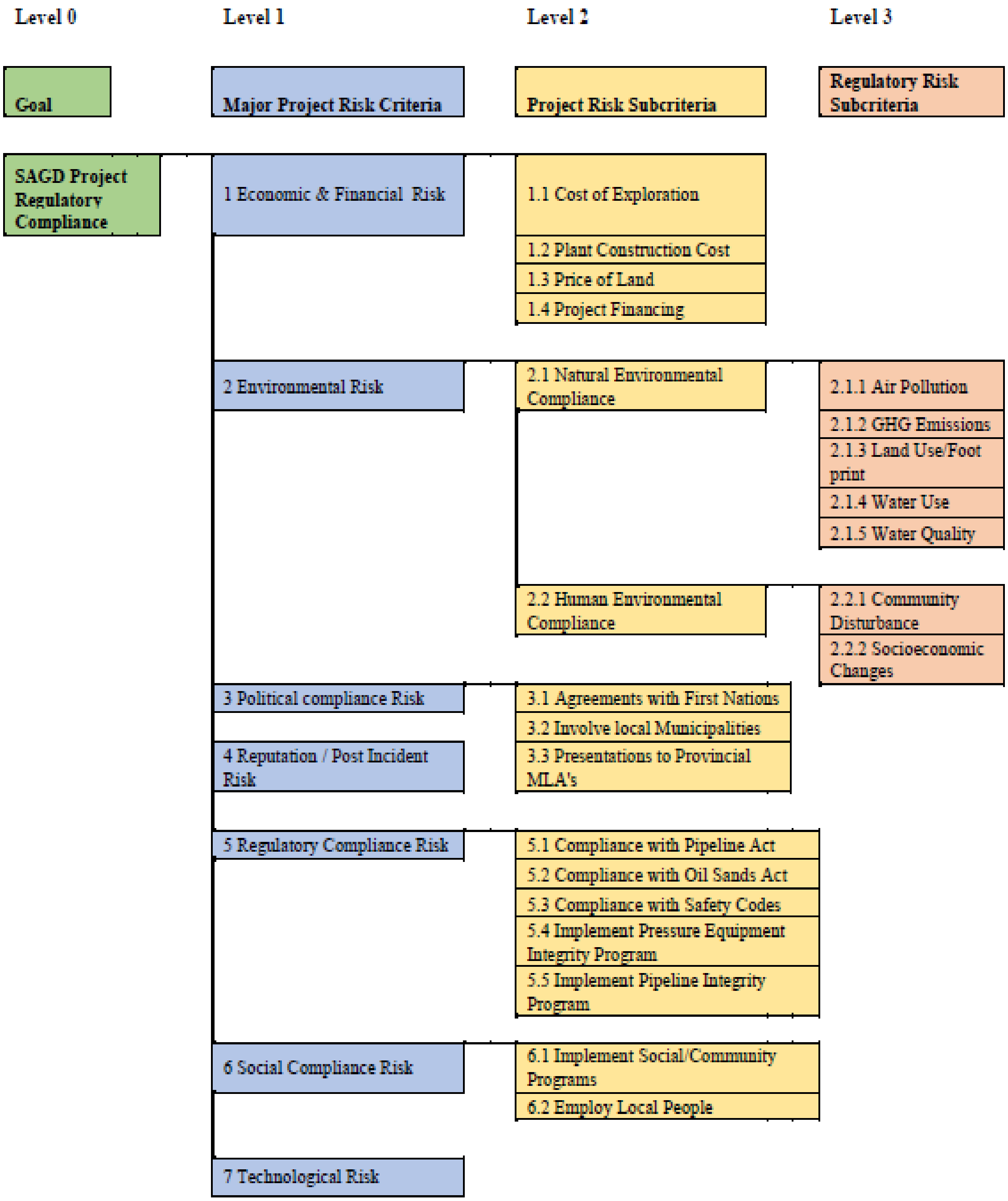

Figure 2. Risk Management hierarchy validated in a pilot study

Given the resulting set of criteria and their levels, a pairwise comparison survey was defined capturing the risk criteria as a matrix using an Excel spreadsheet. A portion of this matrix is shown in Table 1 below.

Table 1
A sample of the pairwise comparison survey matrix

2.1. Natural Environmental Risk Factors																		
2.1.1 Air Pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.2 GHG Emissions
2.1.1 Air Pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.3 Land Use/Foot print
2.1.1 Air Pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.4 Water use
2.1.1 Air Pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.5 Water Quality
2.1.2 GHG Emissions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.3 Land Use/Foot print
2.1.2 GHG Emissions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.4 Water use
2.1.2 GHG Emissions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.5 Water Quality
2.1.3 Land Use/Foot print	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.4 Water use
2.1.3 Land Use/Foot print	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.5 Water Quality
2.1.4 Water use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	2.1.5 Water Quality

Next, we included the pairwise comparison survey in an Excel spreadsheet for portability and distributability and administered the pairwise comparison survey to 16 SMEs comprised of senior executives and project engineers of in-situ oil sands companies in Alberta, Canada. One specialized survey was collected per oil sands company, with the exception of three companies from which two SMEs participated to check for inter-rater reliability. The purposive sample of project engineers and company executives provided the best possible data since these engineers and executives were directly responsible for the risk management process during SAGD project planning and implementation.

3.3 Application of the AHP method

The pairwise comparison matrix scores from each participant's Excel spreadsheet were then imported in the SuperDecisions AHP software and AHP was executed to determine the ranking of the risk criteria at each level as detailed in the steps of Figure 3 (Saaty, 2003). Following the AHP run, the ranking of the risk criteria was triangulated with a small group of five oil executives and project engineers. They indicated their acceptance of the final rankings assigned to the risk criteria.

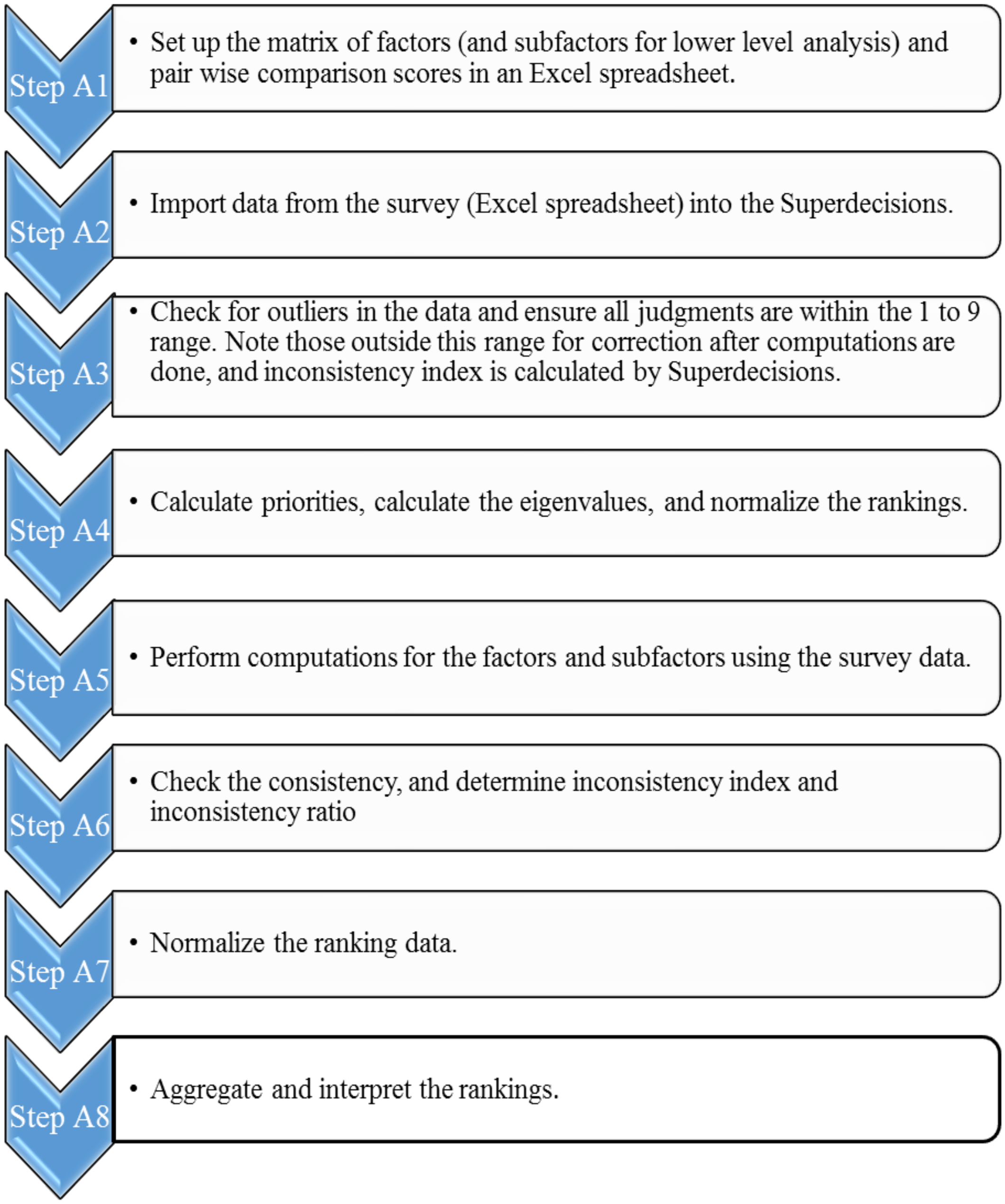

Figure 3. AHP analysis steps

The AHP has the advantage of permitting a hierarchical structure of the criteria and subcriteria, which provides users with a better focus on specific criteria when doing a pairwise comparison. Figure 4 shows the hierarchy as it was inserted in SuperDecisions in order to perform the AHP analyses. The hierarchy contained four levels: the goal (Level 0), the risk level (Level 1) supporting the goal, Level 2 defining or supporting the risk level, and Level 3 defining sub-criteria supporting Level 2. These four levels were entered in SuperDecisions.

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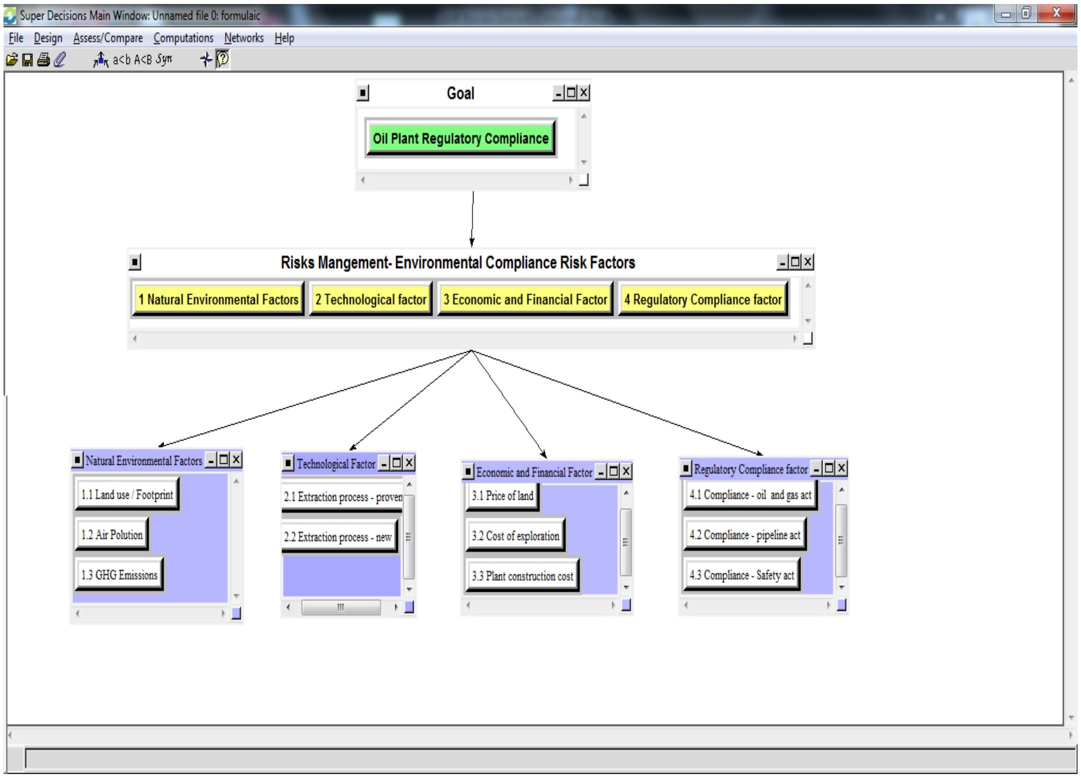

Figure 4. Risk management hierarchy as shown in SuperDecisions

4. Results

Following the AHP analysis, the risk rankings were aggregated for *N*=16 surveys to obtain the final rankings for the compliance risks. For the aggregation of AHP rankings, the AHP practitioner may use either the arithmetic mean or the geometric mean. Saaty (2006) proposed the geometric mean rather than the arithmetic mean as the proper way to aggregate judgments by more than one judge. Aczel and Saaty (as cited by Saaty, 2006) proved Saaty's theorem using the geometric mean if all participants have equal importance in the aggregated result. For this study, all SMEs had equal importance.

Table 2 shows the ranking of all risks based on the surveys of 16 SMEs and aggregated using the geometric mean. Table 3 shows the overall ranking of all risks.

Table 2
Aggregated risk ranking per level using geometric mean

Ranking	Criteria / subcriteria	Geometric Mean Weight (%)	Weight Normalized (%)
1	5 Regulatory compliance	19.28	22.78
2	4 Reputation/Post incident	15.15	17.90
3	2 Environmental Compliance	14.35	16.95
4	1 Economics and financial	13.01	15.37
5	7 Technological	11.92	14.08
6	6 Social compliance	6.66	7.87
7	3 Political	4.27	5.04
	Level 1 Project Risks Total	84.64	100.00
1	12 Plant construction cost	28.07	36.10
2	14 Project financing	24.47	31.47
3	11 Cost of exploration	16.76	21.56
4	13 Price of land	8.45	10.87
	Level 2 Economics & Financial total	77.75	100.00
1	22 Human Environmental Compliance	48.11	55.64
2	21 Natural Environmental Compliance	38.35	44.36
	Level 2 Environmental Compliance Total	86.46	100.00
1	31Agreements with First Nations	55.87	57.75
2	33 Involve local municipality	26.84	27.74
3	32 Presentations to provincial MLAs	14.04	14.51
	Level 2 Political Total	96.75	100.00
1	53 Comply with the Safety Codes Act	23.07	26.71
2	54 Implement a Pressure Equipment Integrity Program	20.63	23.89
3	52 Comply with the Oil Sands Act	15.93	18.44
4	55 Implement a Pipeline Integrity Management Program	13.40	15.51
5	51 Comply with the Pipeline Act	13.34	15.45
	Level 2 Regulatory Compliance Total	86.37	100.00
1	62 Employ local people	71.71	74.43
2	61 Implement social/community programs	24.64	25.57
	Level 2 Social Compliance Total	96.35	100.00

Ranking	Criteria / subcriteria	Geometric Mean Weight (%)	Weight Normalized (%)
1	215 Water quality	27.85	32.37
2	214 Water use	23.51	27.32
3	211 Air pollution	15.02	17.46
4	212 GHG emissions	10.16	11.81
5	213 Land use/Footprint	9.50	11.04
	Level 3 Natural Environmental Compliance Total	86.04	100.00
1	221 Community disturbance	59.05	65.34
2	222 Socioeconomic changes	31.33	34.66
	Level 3 Human Environmental Compliance Total	90.38	100.00

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Table 3
Overall ranking of risks, highest to lowest

Ranking	Criteria/Subcriteria	Geometric Mean Weight (%)	Weight Normalized (%)
1	5 Regulatory compliance	9.17	12.37
2	2 Environmental risks	7.78	10.50
3	1 Economics & financial	7.25	9.78
4	4 Reputation/Post incident	6.84	9.23
5	7 Technological	5.52	7.45
6	22 Human environmental compliance	3.45	4.66
7	21 Natural environmental compliance	3.23	4.36
8	6 Social compliance	3.11	4.20
9	3 Political	2.51	3.39
10	53 Comply to the Safety Codes Act	2.46	3.32
11	62 Employ local people	2.28	3.08
12	12 Plant construction cost	2.08	2.81
13	14 Project financing	1.86	2.51
14	54 Implement a Pressure Equipment Integrity Program	1.81	2.44
15	221 Community disturbance	1.59	2.15
16	31Agreements with First Nations	1.43	1.93
17	52 Comply to the Oil Sands Act	1.38	1.86
18	222 Socioeconomic changes	1.38	1.86
19	51 Comply to the Pipeline Act	1.35	1.82
20	11 Cost of exploration	1.32	1.78
21	55 Implement a Pipeline Integrity Management Program	1.16	1.57
22	215 Water quality	1.00	1.35
23	61 Implement social/community programs	0.74	1.00
24	33 Involve local municipality	0.63	0.86
25	214 Water use	0.60	0.81
26	13 Price of land	0.58	0.79
27	211 Air pollution	0.49	0.67
28	212 GHG emissions	0.38	0.52
29	32 Presentations to provincial MLA's	0.36	0.49
30	213 Land use/Footprint	0.32	0.44
		74.14	100.00

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5. Conclusions

In summary, the AHP allowed for the definition of a complex problem in terms of criteria and subcriteria, using a top-down breakdown that allows for a bottom-up generation of the relative importance using a pairwise comparison. The ranking of risk criteria applicable to in situ oil sands projects was, in order from highest to lowest, (a) Regulatory Compliance, (b) Company Reputations/Post Incident, (c) Environmental Compliance, and (e) Economics and Financials. There was a clear indication of a long-term sustainable approach to in situ oil sands projects with an understanding of the relationship between regulatory compliance, environment, economics, and the public (company reputation/post incident). The identified environmental compliance risks in the oil sands industry in Alberta could be applicable to other provinces in Canada and the USA. However, applying the environmental compliance risk and mitigation strategy rankings to other provinces and states might need further research that considers unique provincial or USA regulatory requirements.

A summary of conclusions of this research is as follows:

- Risk management of environmental regulatory compliance of oil sands projects should be a primary strategy.
- AHP was an ideal MCDM method applied to the ranking of risks in the oil sands industry.
- Understanding and ranking risks should improve environmental compliance.
- Regulatory compliance would lead to an improved socioeconomic environment.
- A sustainable environment in the oil sands should increase public confidence.
- Environmental compliance of oil sands projects should be a global business requirement.

With future research based on the outcome of this work, the hope is for project engineers and executives to manage their oil sands projects successfully. To be truly successful, oil sands projects should not only be economically successful but also successful in the management of environmental compliance risks. Project engineers should implement risk mitigation strategies that would inspire public confidence in the sustainable future of oil sands extraction.

The application of AHP shortened the time needed to identify and prioritize risks, and helped participants deeply involved in the oil sands industry avoid confusion in answering survey questions as explained by similar AHP applications (Ishizaka, 2012; Ishizaka & Labib, 2011). It is for these same reasons that researchers and practitioners have applied AHP in such fields as environmental management, forest management, water resource management, energy management, and renewable energy planning. This paper ranked environmental compliance risks in the oil sands industry and showed that AHP is an effective method to gain SME consensus in terms of rankings in a practical setting.

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