Impact Assessment, Risk Assessment and Artificial Intelligence

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Abstract

The topic of the risk derived from the uncertainty in environmental and social impact assessments is receiving increased attention. This is presumably because of cases where the residual impacts of large-scale projects are not manifesting themselves as described in the technical studies that supported their permits.

Predicting environmental and social impacts carries varying levels of uncertainty; but no examples have been found of the risks associated to these uncertainties being assessed in a structured manner. However, uncertainty has been used as an argument for projects being denied permits.

This paper presents a novel framework for assessing risks derived from uncertainty in impact assessment; employing basic Artificial Intelligence tools to develop this framework in practice. It proposes a method for the determination of the consequence associated to a risk; using algorithms that combine Uncertainty with the main attributes of residual effects, which are Magnitude, Geographic Extent and Duration.

The complexity of environmental and social systems, together with the multiple attributes used to characterize residual effects, invite using Artificial Intelligence tools for assessing risk.

Introduction

The development of large-scale projects carries different types of risks; varying from technological, financial, environmental and social. A recent study (Collard, 2024) reveals that in British Columbia (BC), Canada, between 1995 and 2022, only 50% of projects that received environmental certification were built; and only 25% were built on time. The takeaway is that environmental and social risks are not the only factors preventing or delaying large-scale projects from happening in BC; but that financial and technological challenges are also important factors.

The Environmental Assessment Act (EAA) of BC (BC, 2018) requires under Section 25 (2)(b) that effects assessments consider risks and uncertainties associated with the residual effects and cumulative effects anticipated by a project. The BC Environmental Assessment Office (EAO) Effects Assessment Policy instructs proponents to assess risk and uncertainty "separately" (EAO, 2020); which is problematic because uncertainty should be an input to the characterization of risk.

Environmental Management Systems by the International Organization for Standardization (ISO 14001) define "Risk" as the "Effect of Uncertainty on Objectives;" which in the context of an environmental assessment can be interpreted as the ***effect of uncertainty on a project achieving the goal of preventing significant residual environmental and social impacts***. This definition implies that the risk assessment should consider uncertainty as an input.

The need to assess risk associated with high levels of uncertainty has been previously acknowledged (Howarth, 2013). Also, the need to increase transparency is considered a key element for the next generation of impact assessment (Sinclair et.al.) This paper presents a novel framework for the assessment of risks derived from the uncertainties inherent to impact assessments; one that addresses this need for greater transparency by showing clear criteria and decision rules using decision trees.

Embedding Uncertainty in Risk Assessment

Uncertainty is not a new topic in impact assessment, and it has been argued that it requires more communication and transparency (Tennoy et.al., 2012). Uncertainty is acknowledged in most technical reports but is not discussed or analyzed in-depth in most impact assessment statements and final determinations (Duncan, 2012).

Global trends such as Climate Change — which contributes to uncertainty in impact assessment — have been widely considered, but approaches are not systematic (Byer et.al., 2011; Byer et.al., 2012). Efforts have been documented proposing methods for dealing with uncertainties derived from Climate Change to support decision making (Colombo et.al., 2012). These methods differ from the framework proposed in this paper, because they are aimed at identifying design options that generate the highest financial returns under different Climate Change scenarios.

Impact assessments are focused on the characterization of residual environmental and social impacts; meaning the impacts that remain after the application of mitigation measures. The significance of residual impacts is driven mainly by their Magnitude, Geographic Extent and Duration (Paredes, 2022). The main characteristics of residual impacts, Magnitude, Geographic Extent and Duration can be combined with Uncertainty to derive the Consequence of a residual impact not manifesting itself as predicted. Consequence is one of the two factors considered in risk assessment; the second one being Probability (see Figure 1).

Because earlier in the assessment process, project and environmental interactions not expected to generate impacts are not warranted further consideration (EAO 2020); for the purposes of the risk assessment, residual impacts are considered to have a high probability of occurrence. This means that in practice, consequence rankings are the key determinants of risk levels; meaning that high, moderate and low levels of consequence correspond to relatively high, moderate and low levels of risk, respectively. This rationale ultimately implies that ***higher levels of uncertainty generate higher levels of risk***.

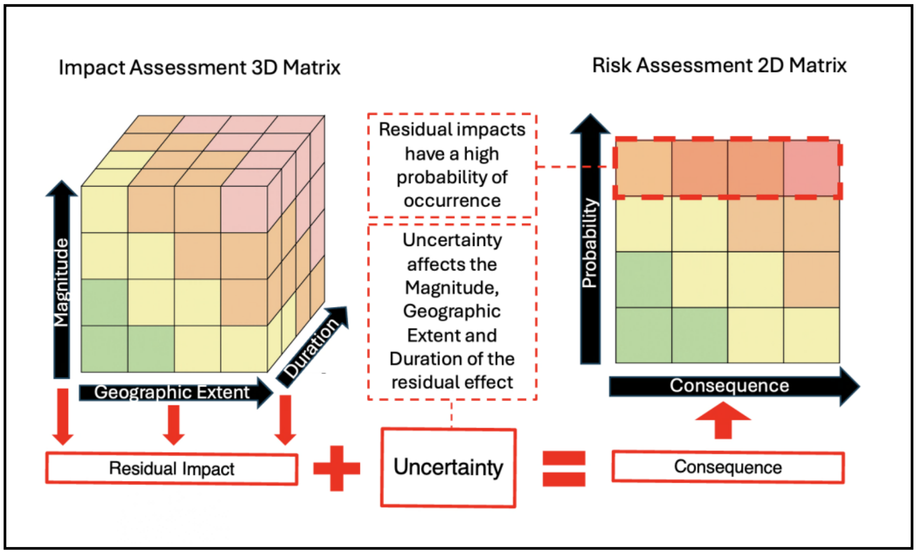

Figure 1 - Impact Assessment and Risk Assessment Factors

Uncertainty in the assessment of residual effects can be influenced by different factors. Guidance from EAO is to assess uncertainty considering the five factors presented in Figure 2 (EAO, 2020). Mitigation effectiveness is a key factor in determining the Magnitude of residual impacts; but it remains difficult to characterize. Mining projects occur in a variety of environmental settings, which makes mitigation effectiveness site-specific, particularly on impacts occurring in sub-surface conditions. It is noted that mitigation effectiveness is to be reported by the holder of Environmental Assessment Certificates in BC; as stated under Section 30 of the EAA.

Factors Influencing Uncertainty	Sources of Uncertainty
Knowledge of the Valued Component	Limitations in the understanding of processes, interactions or behaviour. Uncertainty is reduced when studies have been conducted during several years to understand the behavious of the VC
Mitigation Effectiveness	Mitigation effectiveness is difficult to predict because of complex systems or human behaviour. The uncertainty is reduced when the results of monitoring programs demonstrate that mitigation measures are producing predicted results or achieving expected outcomes on the VC.
Modelling of the Effect	Inadequate, over-simplification, omission of processes. Uncertainty is reduced when appropriate models are chosen to predict the behaviour of the VC and/or conservative assumptions are used to set up modelling scenarios. Uncertainty is also reduced when models are calibrated using information collected in the field. Further, uncertainty is mitigated when sensitivity analysis are conducted for modelling scenarios.
Data Used to Feed Models	Limitation is data availability or quality, spatial or temporal resoulution challenges, poorly known model parameters. Uncertainty is reduced when conservative assumptions are used to deal with information gaps
Interpretation of Results	Values or terms are interpreted differently by different people. Uncertainty is reduced with Peer Review or Senior Review of the results of the assessment

Source: BC EAO Effects Assessment Policy, 2020

Figure 2 - Sources of Uncertainty in Impact Assessment

Decision Trees for Classifications of Consequence

A Decision Tree is proposed as the tool used to predict the value of a target variable (i.e. Consequence) by learning simple decision rules inferred from the data features (i.e. Levels of Uncertainty, Magnitude, Geographic Extent and Duration). Decision trees are widely used in the field of environmental impact assessment; and they are considered a supervised learning algorithm, which is a type of machine learning algorithm employed in the development of artificial intelligence.

In the proposed framework, decision trees facilitate the classification of “Consequence;” with the root node being “Uncertainty," the intermediate nodes being “Magnitude,” “Extent” and “Duration,” and the terminal node being “Consequence.” Uncertainty is proposed as the root node because it is the factor that has the potential to influence Magnitude, Geographic Extent and Duration.

The framework also assumes that Uncertainty opens the door for residual effects manifesting themselves with higher levels of Magnitude, Geographic Extent and Duration; not the opposite. The rationale behind this assumption is that mitigation measures are designed to reduce of the Magnitude, Geographic Extent and Duration of potential effects; and Uncertainty related to mitigation effectiveness or effects modelling works against this objective.

Artificial Intelligence (AI) is helpful to navigate the multiple options that a decision tree will include; which could range from 81 possibilities (i.e. 3^4 when factors are ranked under 3 levels such as Low, Moderate and High) up to 625 possibilities (i.e. 5^4 when factors are ranked under 5 levels such as Negligible, Low, Moderate, High and Extreme).

For this proposal, decision trees with 3 level rankings were prepared. Numerical values were assigned to each level (1 for Low, 2 for Moderate and 3 for High) and algorithms composed of a formula and numerical criteria were used to rank the resulting value for “Consequence” as Low, Moderate or High. Numerical criteria were developed to represent scenarios applying Balanced Risk Tolerance, Favourable Risk Tolerance and Adverse Risk Tolerance. Figure 3 shows a decision tree for which numerical criteria representing a balanced risk tolerance were applied and Figure 4 includes a visual representation of the different types of criteria applied.

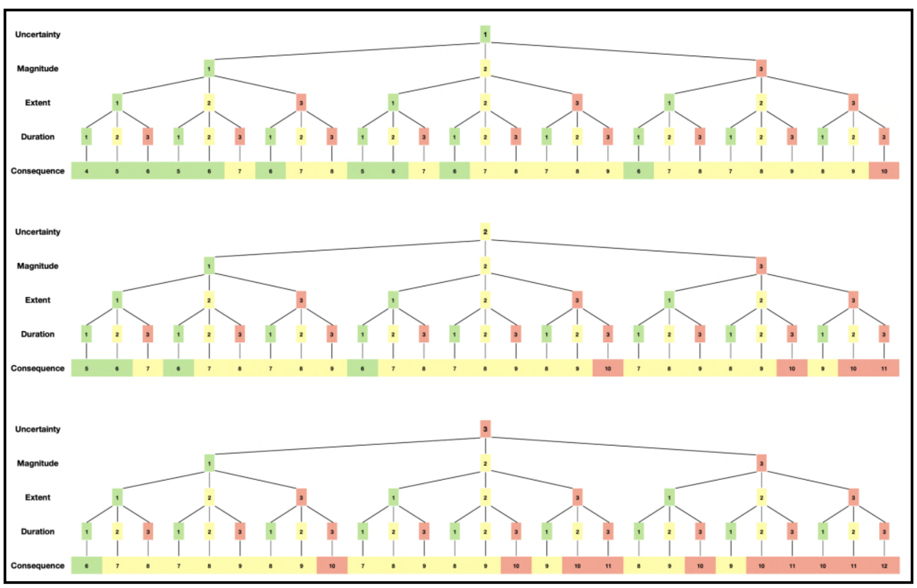

Figure 3 - Decision Tree with 3 Level Rankings and Risk Balanced Criteria

Consequence = U+M+G+D									Types of Criteria	Legend	
4	5	6	7	8	9	10	11	12	<- Balanced Risk Tolerance		High Risk
4	5	6	7	8	9	10	11	12	<- Favourable Risk Tolerance		Moderate Risk
4	5	6	7	8	9	10	11	12	<- Adverse Risk Tolerance		Low Risk

Figure 4 - Visual Representation of Balanced, Adverse and Favourable Risk Criteria

Human Analysis vs AI Analysis

The proposed framework was applied to three cases documented in Assessment Reports prepared by EAO, to compare the results of the framework with that of real-world human analysis. These cases correspond to two mining projects and one energy project in BC which applied for Environmental Certification under Section 27 of the EAA (BC, 2018), as follows:

- Highland Valley Copper Mine Life Extension, Open Pit Mining (Brownfield) with 40 Valued Components (EAO, 2024a)
- Caribou Gold Project, Underground Mining (Greenfield) with 47 Valued Components (EAO, 2023)
- Ksi Lisims LNG (Greenfield), with 56 Valued Components (EAO, 2024b)

Assessment Reports were reviewed to identify the classifications of Magnitude, Geographic Extent and Duration for residual impacts, and the separate determinations of uncertainty and risk for each of the residual impacts on Valued Components. EAO guidance is that Consequence can be assessed as Minor, Moderate or Major based on the combination of Magnitude and Geographic Extent (BC EAO 2023). It is noted that Uncertainty and Duration are not considered in the determinations of consequence in the Assessment Reports.

Determinations of Magnitude, Geographic Extent, Duration and Uncertainty from the Assessment Reports were used as inputs to six algorithms; and the resulting risk classifications were compared with the ones presented in the Assessment Reports. The six algorithms were developed using two equations and three sets of criteria, described as follows:

- Equations to estimate Consequence as a function of Uncertainty (U), Magnitude (M), Geographic Extent (E) and Duration (D):
  - (A1) $C = \sum(U,M,E,D)$ (all factors carry the same weight)
  - (A2) $C = \sum(4xU,3xM,2xE,D)$ (Uncertainty carries the highest weight, followed by Magnitude, then Geographic Extent, with Duration carrying the lowest weight)
- Criteria were applied to the scores resulting from the equations listed above to rank Consequence:
  - (C1) Balanced Risk Tolerance (i.e. range of scores for a Low, Moderate or High are equal)
  - (C2) Favourable Risk Tolerance (i.e. range of scores for a Low is larger than for Moderate or High)
  - (C3) Adverse Risk Tolerance (i.e. range of scores for a High is larger than for Moderate or Low)

Comparing Results from Human and AI Analysis

Figure 5 presents the results of the risk classifications obtained by human analysis and the six algorithms developed. Results were normalized as percentages for the purposes of comparison because the three cases have different numbers of Valued Components. Figure 6 presents a correlation analysis between each of the six algorithms used and the results from the human analysis.

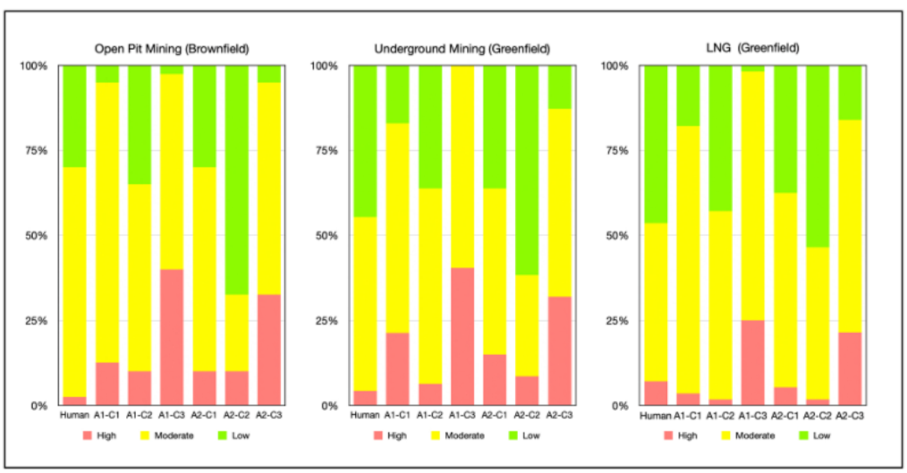

Figure 5 - Risk Classifications from Human and AI Analysis

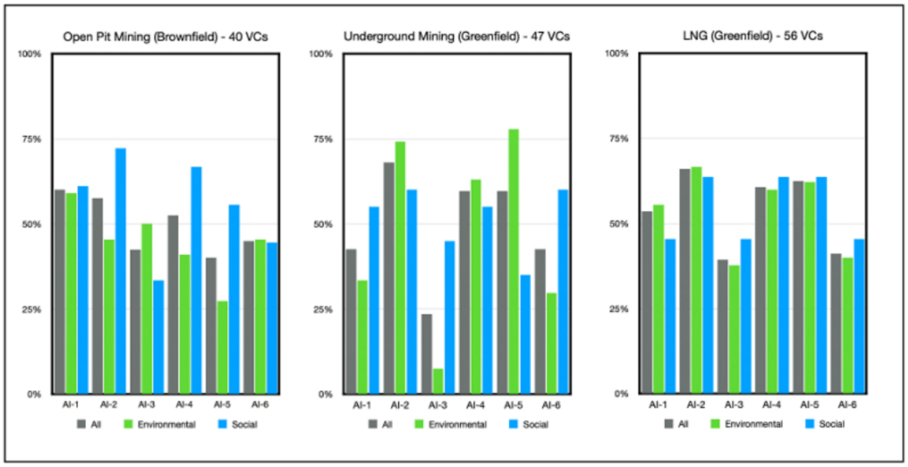

Figure 6 - Correlation between Human and AI Analysis

Comparing the results of human and AI analysis leads to the following main observations:

- For the two mining cases, the percentage of High risks increased under the AI analysis, and for the energy case the percentage of High risks diminished; which is evidence that different criteria were applied for risk classifications in the Assessment Reports.
- For the Open Pit Mining case, AI classified four additional High risks associated with impacts to surface and groundwater resources.
- For the Underground Mining case, AI identified eight additional High risks; linked to Air Quality, Surface and Groundwater Resources, Caribou, Health Infrastructure and Services, Human Health and Aboriginal Language and Culture. AI reclassified the High risk to impacts to Housing and Accommodation as Moderate.
- For both mining cases, the drivers for AI to classify risks associated with impacts to surface and groundwater resources as High were the long-term duration and the moderate to high uncertainty in the assessment.
- For the Energy case, AI reclassified two risks associated to impacts of Invasive Species and Community Health from High to Moderate; and the main drivers for this were the medium magnitude and local geographic extent. The risks that remained classified as High were associated to impacts to wetlands and lichen; which had high levels of uncertainty.
- Correlations between human and AI analyses vary substantially depending mainly on the criteria. Overall, highest levels of correlation were achieved with algorithms that apply high risk tolerance criteria.

Conclusions

- Classifications of Uncertainty found in the Assessment Reports are mainly subjective and not systematic; particularly in relation to the effectiveness of mitigation. This represents an obstacle for assessing the risk derived from uncertainty.
- Human analysis can be subject to inconsistencies when multiple variables are to be considered combining impact and risk assessment. The ability of the practitioner to apply professional discretion is also a source of potential inconsistency.
- AI has the potential to assist in human analysis by removing inconsistencies; but AI will be subject to the same biases used by professionals when setting up the criteria for the classification of all variables involved in the risk assessment.
- Current practice doesn't satisfy requirements under Section 25 of BC EAA 2018; mainly because uncertainty is not included as an input to risk classification.

Recommendations

- Develop site-specific knowledge from active operations to quantify "Mitigation Effectiveness." Reports from active mine sites on "Mitigation Effectiveness" can be used as evidence for the classification of uncertainty related to proposed mitigation measures.
- Building off of the framework presented in this paper, develop AI tools to support the assessment of the risk derived from the uncertainty embedded in the assessment of the residual impacts of projects.
- For transparency, include in environmental assessment reports the criteria applied for ranking the risk derived from residual effects not manifesting themselves as predicted.

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