AHP/ANP IMPLEMENTATION FOR ADJUDICATING ENVIRONMENTAL TORT CLAIMS

ABSTRACT

We present here an AHP/ANP implementation to address the challenges of measuring the quality expert judgment regarding uncertain evidence of environmental tortious conduct. Through the AHP/ANP, the approach combines two decision theory techniques, Weight of Evidence (WoE) and Clairvoyance Analysis (CA), to enable abductive reasoning and determine the best explanation of the observed environmental damage.

Keywords: Weight of Evidence, Information value, expert judgment, Bayesian reasoning, environmental justice.

1. Introduction

A rising number of tort claims are being filed in the pursuit of environmental justice regarding large-scale infrastructure investments. Adjudication of such claims requires ascertaining the available evidence of environmental damage allegedly caused by tortious conduct. Experts are requested to issue judgments about the truth of environmental tort claims. One primary question in environmental litigation concerns the extent to which the courts should rely on expert judgment for adjudicating environmental torts.

2. Literature Review

Our approach supports abductive reasoning and counterfactual analysis to test hypotheses of causal mechanisms that explain evidence of environmental damage. Abductive reasoning is a form of logical inference also known as "inference to the best explanation;" counterfactual analysis uses logical conditionals of the form "If A had not occurred, C would not have occurred" to explain causal claims. Weight of Evidence (WoE) is a Bayesian method in which evidence is used to update prior information; clairvoyance analysis (CA) is a method to determine the information value or worth of expert judgment (Good 1991; Howard 1966, Suter and Cormier 2011).

3. Objective

Our objective is to present a decision model that addresses the challenges of measuring the quality of expert judgment in assessing evidence. Expert judgment is defined as skilled opinion regarding possible causal mechanisms linking evidence of environmental damage and an alleged tortious conduct. The approach thus accommodates scientific uncertainty into the rules governing evidence and legal procedure

4. Methodology

WoE entails Bayesian analysis in which the prior probabilities are obtained using the AHP and the posterior probabilities using the ANP. The Bayes factor is used to calculate the odds of correctly linking evidence and the causal agent by a given mechanism:

$$W(H|E\&M) = \log_{10}\left(\frac{Pr(H|E\&M)Pr(\neg H)}{Pr(\neg H|E\&M)Pr(H)}\right)$$

where $Pr(H)$ is the prior probability, $\neg H$ is the negation of H, $Pr(\neg H) = 1 - Pr(H)$, $Pr(H|E\&M)$ is the probability E is true if H and M are true, and $Pr(E|\neg H\&M)$ is the probability of evidence E if H and $M$are false.

WoE involves the concepts of *confidence* and *plausibility* (subjective probabilities about the link between the causal agent and environmental harm). It entails implementing the matrix form of the Bayes theorem (Saaty and Vargas 1998). Solving the principal eigenvector of the AHP 2×2 pairwise comparison matrix **A** generates the subjective probabilities for confidence, $\boldsymbol{P}(\boldsymbol{\Theta})^{\boldsymbol{T}} = [Pr(H), Pr(\neg H)]$, and plausibility $\boldsymbol{P}(\mathbf{X}|\boldsymbol{\Theta})^{\boldsymbol{T}} = [Pr(E|H\&M), Pr(E|\neg H\&M)]$, respectively. CA is the information value of expert judgment using the probabilities of type-I (the risk of false positives, FPR) and type-II errors (the risk of false negatives FNR):

$$IV(H|E\&M) = \frac{(FPR - FNR)W(H|E\&M)}{\max\big((FPR - FNR)W(H|E\&M)\big)}$$

5. Model Analysis

Consider an expert judging confidence *preponderant*, thus $\alpha_c = 7$, $Pr(H) = 0.88$, and plausibility *convincing*, thus $\alpha_p = 5$, $Pr(E|H\&M) = 0.83$ (see Table 1). The prior and likelihood subjective probabilities are arranged in matrices:

$$\boldsymbol{P}(\boldsymbol{\Theta})^{\boldsymbol{T}} = [Pr(H), Pr(\neg H)] = [0.88, 0.12]$$

$$\boldsymbol{\Delta P}(\boldsymbol{\Theta}) = \begin{bmatrix} Pr(H) & 0 \\ 0 & Pr(\neg H) \end{bmatrix} = \begin{bmatrix} 0.88 & 0 \\ 0 & 0.12 \end{bmatrix},$$

$$\boldsymbol{P}(\mathbf{X}|\boldsymbol{\Theta}) = \begin{bmatrix} Pr(E|H\&M) & Pr(\neg E|H\&M) \\ Pr(\neg E|H\&M) & Pr(E|H\&M) \end{bmatrix} = \begin{bmatrix} 0.83 & 0.17 \\ 0.17 & 0.83 \end{bmatrix},$$

so that the conditional probabilities are:

$$\boldsymbol{P}(\mathbf{X}) = \boldsymbol{P}(\mathbf{X}|\boldsymbol{\Theta})\boldsymbol{P}(\boldsymbol{\Theta}) = \begin{bmatrix} 0.83 & 0.17 \\ 0.17 & 0.83 \end{bmatrix}\begin{bmatrix} 0.88 \\ 0.12 \end{bmatrix} = \begin{bmatrix} 0.75 \\ 0.25 \end{bmatrix},$$

and the posterior probabilities are:

$$\boldsymbol{P}(\boldsymbol{\Theta}|\mathbf{X}) = \boldsymbol{\Delta P}(\boldsymbol{\Theta})\boldsymbol{P}(\mathbf{X}|\boldsymbol{\Theta})\boldsymbol{\Delta P}(\mathbf{X})^{-\mathbf{1}} = \begin{bmatrix} 0.88 & 0 \\ 0 & 0.12 \end{bmatrix}\begin{bmatrix} 0.83 & 0.17 \\ 0.17 & 0.83 \end{bmatrix}\begin{bmatrix} 1/0.75 & 0 \\ 0 & 1/0.25 \end{bmatrix} = \begin{bmatrix} 0.97 & 0.58 \\ 0.03 & 0.42 \end{bmatrix}$$

Thus, sensibility is 0.97, specificity is 0.42, type-I error is 0.58 and type-II error is 0.03. Next, WoE and CA values are obtained:

$$W(H|E\&M)_{ik} = \log_{10}\left(\frac{Pr(H|E\&M)Pr(\neg H)}{Pr(\neg H|E\&M)Pr(H)}\right) = \log_{10}\left(\frac{0.97 \cdot 0.12}{0.03 \cdot 0.88}\right) = 0.70$$

$$IV(H|E\&M) = \frac{(FPR - FNR)W(H|E\&M)}{\max\big((FPR - FNR)W(H|E\&M)\big)} = \frac{(0.58 - 0.03) \cdot 0.70}{0.465} = 0.83$$

where $\max\big((FPR - FNR)W(H|E\&M)\big)$ is computed using $\alpha_c = \alpha_p = 9$.

Thus, H should be accepted.

6. Limitations

Our approach is an exploratory tool that focuses on how well the experts explicitly state candidate hypothesis and mechanisms linking the causal agent to environmental damage, and to acknowledge the tolerable degree of scientific uncertainty applicable to the rebuttable legal presumptions of said mechanisms.

7. Conclusions

Adjudication of environmental torts requires the evaluation of the expert judgment used in supporting hypothesis of causation. Our approach enables the implementation of abductive reasoning to ascertain the truth of claims regarding the liability of an agent. The use ANP in the form of the matrix form of Bayesian inference, along with the use of AHP to derive subjective prior probabilities, provides a means for the implementation of WoE and CA a rigorous and systematic way.

8. Key References

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