Grant: AFC618-53

Title: Innovations in Applied Decision Theory for Mine Surveillance and Health And Safety Efforts

Organization: University of North Carolina

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Focus Area: Heart disease and malignant and non-malignant lung disease

Project Summary: Miners are exposed to a complex mix of airborne hazards that can lead to chronic respiratory and cardiovascular diseases. Decisions about potential interventions to improve health and safety for miners require reasonable estimates of a potential intervention's impact. Health and safety professionals require a clear idea of where impact can be made, and how big of an impact an intervention may have in terms of disease, disability, and mortality. While there are well- established methods for the analysis of epidemiologic data to estimate parameters that may be well-suited to etiological research and communication among academics, for example estimation of covariate-adjusted hazard ratios or rate ratios, the development of epidemiological methods suited to decision-makers who evaluate policy choices is less well developed, particularly as it relates to the conditions encountered in miner populations.

The goal of the proposed work is to develop innovative methods for leveraging applied decision theory to improve mine health and safety. Applied decision theory, which has rapidly progressed in the last several years thanks to computational gains and theoretical progress, brings together two fields. The first focuses on theoretical developments regarding how to help a person make decisions in the face of uncertainty. This work was begun in the 18th century by Bernoulli, and subsequently Bayes, but this line of research has developed substantially in the last thirty years with the increasing access to computational methods for implementing Bayesian statistics. The second field, which matured during World War II, is control and systems engineering and its application to practical problems faced by decision makers. The field of decision analysis provides a formal, systematic way to analyze decisions and communicate between decision makers and those who advise them.

We have recently illustrated that the difference between the parameters typically quantified by epidemiologists (such as rate ratios) and the quantities desired in an applied decision-making context (such a counterfactual risk differences) can be large. Moreover, when epidemiological parameters are inappropriately used in a decision-making context, poor decisions can result. For example, we showed that the standardized mortality ratio method that epidemiologists use to report observed and expected numbers of deaths in occupational cohort studies may appear to a decision maker to be the basis for a counterfactual risk difference (i.e., the difference between the number of observed deaths and the number expected if the cohort had not been exposed). However, it is no such thing; only the ratio of the observed to expected has a counterfactual interpretation (as an estimate of a rate ratio); and, the difference between these values may give a highly-distorted picture to a decision-maker if he or she uses the observed and expected quantities typically reported by an epidemiologist as an indication of the number, or distribution, of excess cases due to exposure. Building upon that work, we propose to strengthen methods for valid decision- making in occupational settings where the work environment poses a range of hazards, such as mining.

We also propose work engaging stakeholders and communication as well, drawing on work in decision theory about presentation of information in ways that fosters clear communication as well as encourages novel thinking about alternatives and creative problem solving. The methods we propose will improve the validity of information used in decision making and improve the clarity in communication with decision makers. We will demonstrate how to derive valid estimates of quantities that a policy-maker requires in an applied decision making framework.

Building upon our prior research, we propose a set of aims that draw upon decision theory and will develop tools for better decision-making, including estimates of the impact of different policy choices in a contemporary framework informed by decision-theory and statistics for causal inference. The tools we develop will be tailored to the types of data and policy choices faced by health and safety professionals in the mining industry. We propose to extend methods for miner disease and mortality surveillance and hazard detection. We will focus on plausible interventions (rather than complete elimination of a hazardous agent); and, we will consider impacts on a wide range of diseases while accounting for competing risks (rather than focusing on one disease-at-a-time).

These methods will be developed and illustrated using data for a large, recently updated cohort of Ontario miners. The methods and results we propose are highly-relevant to US miners, as the methods are general and the working conditions and experiences of these Ontario miners are highly relevant to US miners. The aims build upon each other, addressing increasingly complex questions to inform policy choices.

Aim 1. *Methods to rank order the occupationally-associated health problems of miners*. Valid information that allows health and safety professionals to accurately rank-order excess disease or death, by category of disease, may inform specific interventions or serve as a basis for framing future intervention efforts. We propose to develop and illustrate methods for calculation and ranking of cause-specific excess disease in a contemporary framework for valid decision-making; this aim includes development of tools for communication in graphical as well as tabular formats of cases of disease and disease-free life.

Aim 2. *Methods to improve decision making about hazards in the mine environment that may affect multiple diseases*. We extend the framework to estimate joint models for diseases potentially affected by the work environment. Here we target estimation of quantities to inform a policy maker about potential impacts on a range of disease endpoints of interventions that effect occupational exposure. This approach offers a simple solution to interpretation of competing risks. We focus on joint models for diseases of the heart and lung.

Aim 3. *Methods to improve decision making in a setting with multiple hazards*. We will consider how intervening on exposure to one agent may have spillover effects. Standard analyses often do a poor job because the focus in on estimation of the independent effect of each agent. Policy evaluation, however, emphasizes the fact that interactions (e.g., departures from additivity of effects) are central to decision making and identification of where the greatest impact of policy choices occur. We will extend the use of Markov chain Monte Carlo methods in a Bayesian analysis to estimate joint models for disease affected by multiple exposures. This approach offers a framework for addressing uncertainty in decision analysis while leveraging external information.