

# Identifying Antecedent Conditions Responsible for the High Rate of Mining Injuries in Zambia

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The incident rates of mining-related accidents and injuries in developing countries exceed those of developed nations. Interventions by international organizations routinely fail to produce appreciable long-term improvement. One major reason is the inability to identify and analyze the underlying factors responsible for creating unsafe working conditions. Understanding these antecedent conditions is necessary to formulate effective intervention strategies and prioritize the use of limited resources. This study utilized a logic model approach to determine the root causes and broad categories of potential interventions for mining accidents and injuries in Zambia. Results showed that policy interventions have the greatest potential for substantive change. A process of educating officials from government and mining companies about the economic and social merits of health and safety programs and extensive changes in regulatory structure and enforcement are needed. *Key words:* mining health and safety; logic modeling; developing countries.

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One of the challenges facing organizations seeking to administer assistance and technical program support in developing countries is the formulation of practical interventions that will have positive sustainable impact and successfully achieve their intended objectives. This is particularly true when the objective of an intervention involves highly complicated issues that are heavily influenced by social, cultural, and economic considerations. Such is the case

with regard to efforts to reduce the prevalence of mining-related injuries and fatalities in African countries such as Zambia, which are heavily dependent upon mining and mineral development. While numerous international humanitarian and aid organizations have attempted to intervene on behalf of mine workers by providing training and educational support and through technical and economic assistance, these interventions rarely produce any appreciable long-term improvement in the health and welfare of the targeted populations. While it may seem appropriate to attribute these negative outcomes to a lack of social and cultural understanding, poor project management and planning, or ill-conceived strategies, this is not necessarily the case. Well-managed programs utilizing highly competent personnel who are intimately knowledgeable about the social and political conditions of a given area still fail with some regularity.

One major contributing factor is that it can be difficult to ascertain the antecedent conditions (i.e., root causes) that contribute to the high rates of occurrence associated with accidents and occupational illnesses in these indigenous mining operations. The ability to identify and evaluate root causes responsible for creating unsafe working conditions is a prerequisite to formulating effective intervention strategies and prioritizing the use of limited resources. Logic modeling is a process through which practitioners and researchers can understand the link between program strategies, the conditions they are attempting to change, and the expected outcomes.<sup>1-3</sup>

## *Mining Health and Safety in Developing Countries*

Sub-Saharan Africa has a long and distinguished mining history. The extraction of natural resources accounts for substantial proportions of the region's gross domestic product, employment, and export earnings. In Zambia, for example, the mining sector contributed approximately 64% of the country's foreign exchange earnings and 18% of the gross domestic product in 2004.<sup>4</sup> Furthermore, the mining sector comprises 15% of the formal employment in Zambia, not including the more than 30,000 workers engaged in unlicensed and artisanal mining activities annually.<sup>5</sup>

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Despite the importance of mining to the region and the economic opportunities it imparts to individual countries, the incidence rates of accidents and occupational injuries attributed to this industry are dismal.<sup>6</sup> Furthermore, we previously documented a high occurrence of tuberculosis and silicosis in Zambian miners.<sup>7</sup> With the addition of occupational illnesses and disease, as well as their synergistic effects, the combined impact has far-reaching social and economic implications.<sup>8</sup> Viewed by many mining and health professionals as a crisis, the magnitude of this situation has drawn the attention of the international community. Of particular concern are mines and mineral-processing facilities operated by indigenous companies, as well as those individuals engaged in small-scale and artisanal mining. Due to their nature, there is little in the way of quantitative information or statistical data that describe the poor safety record of this sector of the mining industry.<sup>9</sup> Throughout Africa, these small operations are typically under-capitalized, dependent upon dangerous, labor-intensive mining methods, and constrained by antiquated equipment and operating systems. While skilled in the unit activities inherent to their individual operations, the workers normally have little to no formal training in issues related to mine safety and occupational health. This situation is compounded by the mobility and turnover of the workforce, the social, political, and community health challenges prevalent to the region, and the fact that workers have few employment alternatives, where mining is a means of escaping poverty. In the absence of a strong regulatory environment, the culmination of these factors has created a climate where safety and health have low priority despite the high frequency of accidents and injuries. As a consequence, regional capacity in the fields of occupational health, mine safety engineering, and health and safety management is exceptionally limited.

Efforts to reduce mining-related injuries and fatalities using a variety of interventions have met with varying degrees of success. In most cases, such efforts have focused on the introduction of training programs, the transfer of technology, capital investment, and professional exchanges, partnerships, and collaborations with in-country universities and government agencies. While the interest of international groups and aid organizations on the health and safety of indigenous miners has unquestionably improved work environments for many, their efforts and the resources they represent are often wasted through unproductive and/or ineffective activities that fail to produce appreciable long-term improvements. Such failures stem from numerous sources, including duplication of program objectives and lack of coordination between groups, production of unexpected detrimental consequences, and the inability to gain social acceptance and provide a sustainable basis for the programs.

### *Identifying Antecedent Conditions*

A major factor in this lack of program success is the difficulty of ascertaining the antecedent conditions that contribute to accidents and occupational illnesses in indigenous mining operations. The ability to identify underlying safety and health hazards is a prerequisite to formulation of effective intervention strategies and prioritizing the use of limited resources. While U.S. mining companies must adhere to rigorous health and safety standards that require them to anticipate, identify, evaluate, and control potential hazards, the processes and methods employed at modern operations have serious deficiencies when used as assessment tools in small-scale, labor-intensive operations. In addition to the physical and social characteristics of work in small-scale indigenous mines, the prevalence of poverty, corruption, and political unrest, as well as the social complexities and tremendous community health crises facing many countries, complicate the ability to explicitly understand the linkages between accident causes and effects and predict the repercussions of specific interventions.

### *The Logic-modeling Approach*

Many approaches within the field of logic modeling have been successfully employed in a wide variety of health-related applications, including social behavior, substance abuse, and program planning/assessment.<sup>2,10-18</sup> The ATM approach, described by Renger and Titcomb,<sup>3,19</sup> is a three-step process that begins with an understanding of the **A**ntecedent conditions of the problem. The first step is akin to the RCA, or root-cause analysis, and is the focus of this paper. The second step, **T**argeting, requires that components of proposed strategies be meaningfully linked to antecedent conditions over which an agency has control to change. The final step is **M**easurement, in which the effect of intervention strategies on targeted antecedent conditions is assessed.

The advantage of the ATM approach is that it results in a visual representation of program elements useful in program planning and evaluation and gives program planners, evaluators, and stakeholders a strong understanding of the rationales behind program elements. Users can explicitly state why certain activities are being performed, *why* certain outcomes are expected, and *how* these outcomes are to be accomplished.<sup>3</sup> As our purpose was to make explicit the issues related to mining accidents, the ATM approach seemed ideal to meet this need.

The first step of the ATM approach is to define the problem of interest. In the current context, the problem is defined as worker injuries and fatalities incurred as a direct consequence of mining accidents. Most problems are influenced by behavioral, environmental, social, and biological conditions, where these antecedent condi-

tions must be identified and understood in order to know where to focus intervention efforts effectively.<sup>20</sup> This is accomplished by conducting interviews with individuals who have content expertise in the area of the problem. In the current context, content experts to be interviewed might include mining engineers, production supervisors, lead miners, labor representatives, government regulators, and academic researchers from the mining and health sector. These interviews do not stop with the primary conditions leading to the problem; instead, interviewers explore secondary, tertiary, and even more removed conditions to understand how these factors relate to one another. Each expert is interviewed individually and is asked a series of questions using the format "Why does this condition occur?" Throughout each interview, a visual map of the relationship of antecedent conditions to the problem is developed. Individual interview maps are then integrated into a single summary map, which provides a comprehensive view of all the antecedent conditions at play.

While most planning models include a similar stage of identifying risk factors and conditions (i.e., PRECEDE-PROCEED, MATCH, CDCynergy), this information is not provided in many logic models. The ATM approach differs in that these antecedent conditions are explicitly shown in the resulting visual map. The visual map stimulates creative thinking about program planning and improvement; seeing previously unidentified antecedent conditions may lead an agency to better understand how best to intervene.

### *Research Objectives*

Once identified through the use of the logic model, the antecedent conditions responsible for mining-related accidents and injuries can be prioritized and cost-effective intervention strategies can be formulated.

This work is predicated on research and training activities conducted in Zambia through a collaboration between the University of Arizona and the University of Zambia over five years, sponsored by the U.S. National Institutes of Health, Fogarty International Program. While specifically oriented towards Zambia, the proposed method is applicable to other mineral-rich countries within the region. It is hoped that the information in this paper will provide a sound scientific basis for international organizations and in-country professionals to construct cost-efficient interventions to improve the health and welfare of miners in the developing world.

## **METHODS**

Two evaluators from the University of Arizona College of Public Health conducted a two-session training course for three University of Zambia Mining Engineering faculty members in Lusaka, Zambia, to provide them with the skills and understanding necessary to

conduct systematic interviews as part of the first step of the ATM approach. The training included both didactic and hands-on components. The selection of these faculty members as interviewers was predicated upon their intimate knowledge of the Zambian mining industry, access to industry and government experts, and ability to be socially accepted and trusted by those being interviewed.

Following the training, each faculty member became responsible for identifying and interviewing at least three individuals who were indisputable experts on the Zambian mining industry. The 16 experts interviewed included representatives from government, industry, labor, and academia. Before each interview, these experts were briefed as to why they were chosen (i.e., having a special understanding of the dynamic conditions believed to be responsible for the high incidence of mining-related accidents). They experts were also assured that their responses would be held in strict confidence. Each interview lasted approximately 45 minutes.

Following each interview, a member check was completed.<sup>21</sup> This consisted of a one- to two-page summary containing a visual map of the identified antecedent conditions, accompanied by written text highlighting the most salient aspects of the interview. Each expert was then asked to review the summary of the interview for accuracy and make any necessary changes or modifications.

Once the member check was completed, the results of individual interviews were combined into a single summary map. This summary map was then sent to all three interviewers for their comments regarding accuracy and completeness.

Three professionals were then chosen to independently categorize the antecedent conditions by the most effective intervention. Separate from the experts and interviewers previously discussed, these professionals were chosen based upon their expertise as well as knowledge of the Zambian mining industry. Each possessed an inherent understanding of the major occupational and labor-related challenges facing the country's mining industry, yet their perspectives differed based upon their professional experiences. Each professional was given the list of antecedent conditions and asked to denote whether change in a specific condition could best be achieved through infrastructure support, the implementation of training programs, or amendments to existing policies. Where it could be reasoned that an antecedent condition could be targeted using more than intervention, these professionals were forced to select the single approach that they felt would be best suited to effect change. The categories were mutually exclusive.

## **RESULTS**

As shown in the summary map (Figure 1), the experts identified 51 antecedent conditions that affect mine

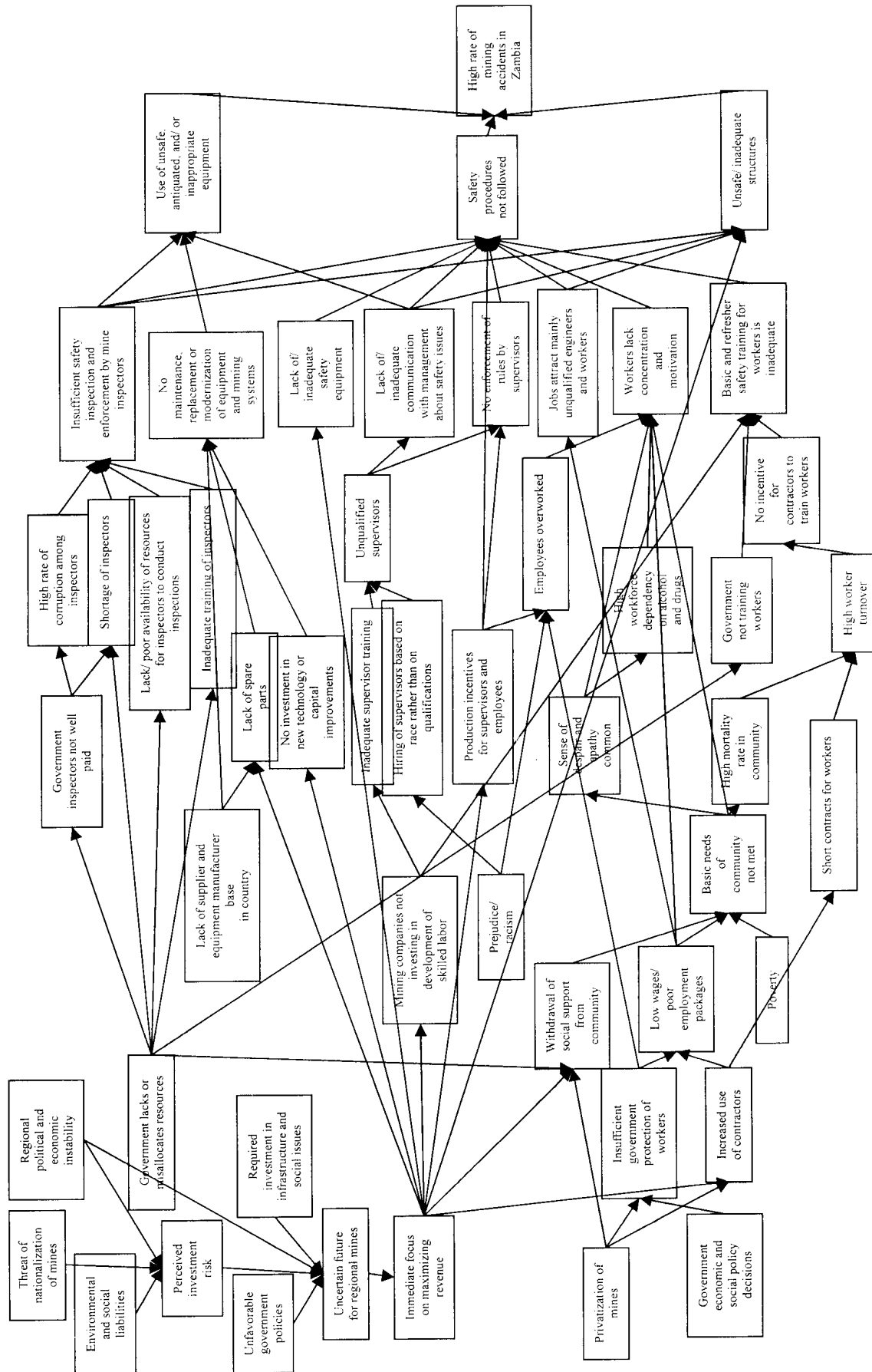


Figure 1—Summary map.

**TABLE 1 Antecedent Conditions by Intervention Category\***

Antecedent Conditions	Intervention Category		
	Training	Policy	Infrastructure
Use of unsafe, antiquated, and/ or inappropriate equipment		X	XX
Safety procedures not followed	XX	X	
Unsafe/inadequate structures		X	XX
Insufficient safety inspection and enforcement by mine inspectors		XXX	
High rate of corruption among inspectors		XXX	
Shortage of inspectors		XXX	
Lack/poor availability of resources for inspectors to conduct inspections		XX	X
Inadequate training of inspectors	XX	X	
Government inspectors not well paid		XXX	
Government lacks or misallocates resources		XXX	
No maintenance, replacement or modernization of equipment and mining systems		XX	X
Lack of spare parts		X	XX
Lack of supplier and equipment manufacturer base in-country		X	XX
No investment in new technology or capital improvements		XX	X
Lack of/inadequate safety equipment		XX	X
Lack of/inadequate communication with management about safety issues	XX	X	
No enforcement of rules by supervisors	X	XX	
Unqualified supervisors	XX	X	
Inadequate supervisor training	X	XX	
Hiring of supervisors based on race rather than on qualifications		XXX	

X denotes intervention selection by individual reviewer.

safety and contribute to accidents. Given the sheer number of factors, any attempt to effectively address possible strategies for each individual antecedent condition would have become a daunting task. Therefore, in the interest of parsimony, these antecedent conditions were sorted into three broad categories, corresponding to three intervention strategies, training, policy, and infrastructure. These categories were chosen based upon previous research experience in the region and the input of in-country partners.

The training intervention category includes both train-the-trainer and direct delivery (worker-oriented) training, focusing primarily on traditional subjects related to mine and plant safety, occupational health and industrial hygiene, hazard recognition, and task training. The policy category encompasses antecedent conditions that could best be addressed through interventions that encourage and facilitate changes in government and/or company policies. In the context of this research, the term “company” generically refers to mining companies operating within Zambia whose management and administrative control are indigenous. While this includes both artisanal and small-scale mining, it also incorporates several medium to large companies. The infrastructure category includes interventions that attempt to improve and modernize the infrastructure and physical resources of the country.

An analysis of the results of this survey found surprisingly good agreement between how the three professionals categorized the 51 identified antecedent conditions relative to the specific interventions (Table 1);

63% ( $n = 32$ ) of the responses were consistent for all three individuals. 37% ( $n = 19$ ) were consistent for at least two of the respondents. No antecedent condition in this survey received a split endorsement in each of the three intervention categories. An interesting and unexpected outcome from this analysis was the extreme dominance of the policy intervention for the antecedent conditions identified. At least two of the respondents chose the policy intervention of a specific condition 84% of the time ( $n = 43$ ). Even more intriguing was that the policy intervention was a unanimous choice in nearly 65% of the cases ( $n = 33$ ). The overwhelming frequency of this outcome proved to have significant ramifications with regard to how these interventions were to be scrutinized and the types of additional analyses to be performed.

To effectively visualize the relationships between different antecedent conditions, the summary map was divided into three smaller maps relative to individual intervention categories (Figures 2–4). This visual approach greatly enhanced the ability to scrutinize each category and depict the perceived role and inter-relationships that exist between different conditions.

## DISCUSSION

The study findings contradicted some previously held assumptions that influenced strategic planning of earlier in-country interventions. As identified by the Zambian mining experts, the breadth of the antecedent conditions believed to be responsible for mining-



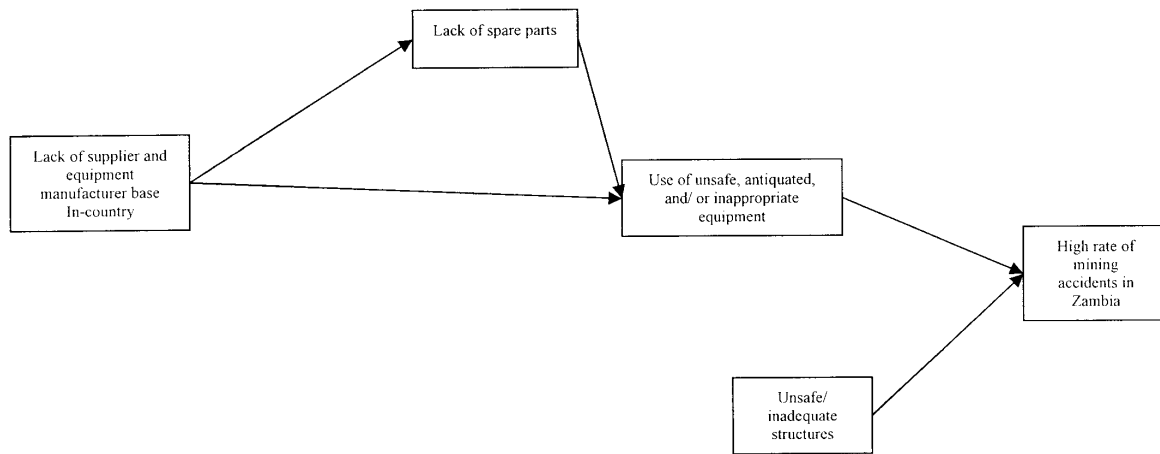


Figure 3—Infrastructure intervention map.

related accidents and injuries was exceptionally broad and incorporated a number of complex, interdependent social and economic factors. While it was anticipated that the scope of these conditions would be large and focus heavily upon perceived deficiencies in economic and human resources, the high percentage of social and political factors was somewhat surprising. In addition, the mapping of the inter-relationships (Figure 1) between the various antecedent conditions proved to be extremely beneficial and facilitated discussion regarding how individual conditions influence others and how to qualitatively determine the most significant of these conditions in terms of worker risk factors. Of particular interest, the mapping discussion occurred over a period of months and solicited the inputs of several health and mining professionals from both Zambia and the United States. Differences in perspectives and expertise helped serve as a catalyst for this discussion and enabled a much more robust analysis. The ability to identify such antecedent conditions and establish relationships between the factors is a major strength of the logic-modeling process.

The sorting of the antecedent conditions into three possible intervention categories by independent resource professionals also produced interesting results. As shown in Table 1, there was relatively good agreement between the responses given by the three reviewers. The high percentage of antecedent conditions that fell into the policy intervention category, however, was somewhat unexpected. Post-survey discussions with the reviewers indicated very similar points of view, i.e., a majority of the antecedent conditions identified by in-country experts required policy interventions, on the part of the Zambian government, private industry, and/or community leaders, as a prerequisite for achieving sustainable improvements. Based upon their experiences and knowledge of Zambia, it was their feeling that the country possesses sufficient mineral wealth and revenue-generating capacity to adequately invest in tech-

nology and infrastructure, as well as properly fund health and safety training programs, regulatory agencies, and academic programs related to mineral resources and occupational health. The experts believed that rather than reinvesting a large percentage of the substantial revenue generated by domestic mineral production to finance such activities, the government has instead elected to utilize these revenues for other purposes. As such, many of the antecedent conditions responsible for the poor health and safety record of the mining industry can be addressed only through a genuine mining commitment by the government. In addition to the reallocation of economic resources, this commitment must include policy mandates towards the enforcement of existing mining-, health-, and labor-related regulations and the development of incentives and penalties to encourage industry compliance with these regulations and accountability.

As with changes in government policies, it was the premise of the reviewers that interventions intended to change the operating and management policies of individual mining companies were also necessary. There was a shared belief that health and safety programs are a management function and are successful only if there is a steadfast commitment on behalf of company executives, managers, and supervisors. This concept translates to the basic tenet that accidents, injuries, and occupational illnesses are indicative of systemic problems within a company and can be rectified only through direct involvement of company officials. The repercussions of this involvement ideally spawn changes in company policy regarding expectations, responsibilities, and accountability of all workers with regard to safety, as well as encourage scrutiny of operating practices, training activities, and regulatory compliance.

It seems only prudent that current interventions should focus on educating policymakers and leaders in government and industry about the economic and social ramifications of mine accidents and occupational

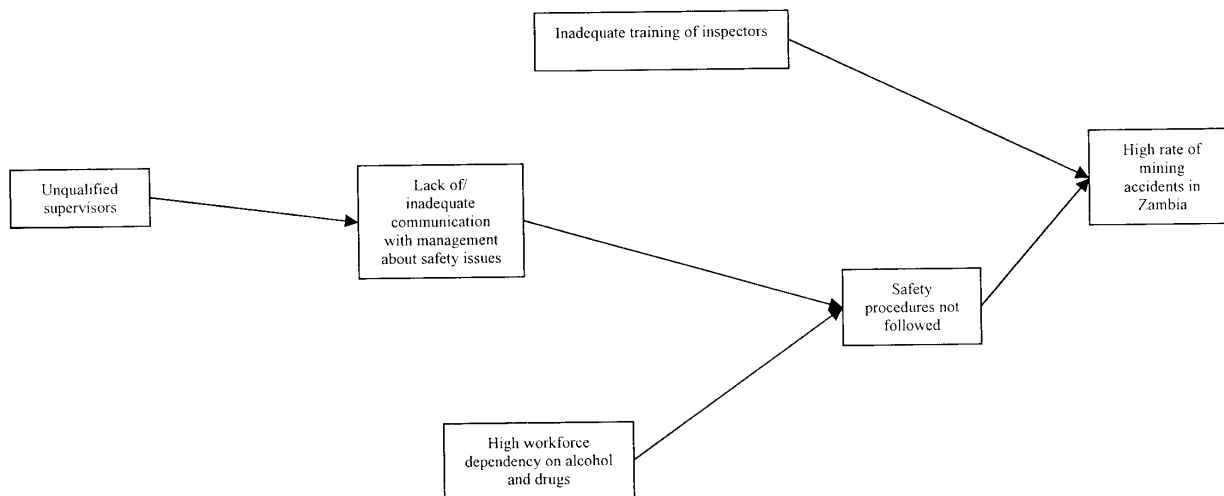


Figure 4—Training intervention map.

illnesses. While this process might appear ambiguous and difficult to facilitate, it represents one of the few interventions capable of instigating the policy changes necessary to encourage long-term, sustainable improvement in worker health and safety. This educational program would likely address many of the conditions identified in the summary maps and emphasize topic areas related to economic loss and opportunity costs related to accidents, the social and economic repercussions of worker injuries and fatalities, and issues associated with labor efficiency and productivity. A review of the summary map for policy interventions (Figure 2) also shows a need to provide assistance to government entities responsible for mine safety and health enforcement. This assistance could include everything from structural reorganization and implementation of new operating standards/regulations to the development of training programs and establishing mine rescue capabilities. Once these policy-related interventions have been initiated, other interventions associated with conventional training and infrastructure will follow.

The results of this study can be contrasted with mining health and safety approaches in developed countries. In modern mines, operating systems and production equipment are complex and highly sophisticated. As such, employees are required to interface with these complicated systems and machines in operating environments that can be extremely inhospitable (i.e., temperature, dust, fumes, darkness, confined space). Besides the large cognitive load placed upon miners as a consequence of this technology, they must also maintain an awareness of changing rock and environmental conditions, interactions with other pieces of equipment, and the dynamic unit operations that comprise the mining sequence.<sup>22</sup> Given these challenges, the foundations of most health and safety programs reside upon employee development, training, and edu-

cation, as well as the integration of these concepts into every operational process throughout an organization.<sup>23</sup> In the vast majority of U.S. mines, employee training and education programs normally emphasize the process of continuous learning and tend to focus on issues associated with employees' attitudes, knowledge, and skills.<sup>24</sup> Under this philosophical approach, key elements such as worker behavior, motivation, understanding, and accountability become primary indicators of program success.

Without regard to moral and ethical responsibilities, the economic, legal, and political ramifications that stem from injuries, fatalities, and accidents are major motivating factors that encourage companies to develop comprehensive training and educational programs that usually exceed regulatory compliance standards whenever possible. The process of constructing a successful health and safety program is not a trivial exercise. While it begins with a visible, concrete commitment from management and a strategic plan that promotes concise objectives and measurable outcomes, such a program is site-specific and necessitates a thorough understanding of the workforce, the operation, and the social, regulatory, and political context surrounding the mine. The essential foundation for constructing these training and education programs can be characterized by the questions: Why, Who, When, Where, What, and How.<sup>23</sup> For example, "What" implies the types of education, training, and development that a given class or group of employees need to undertake in order to keep them safe and productive while performing their job responsibilities in a specific work environment. This includes an understanding of the potential hazards associated with the general work environment, in addition to those risks linked to performing specific tasks or job assignments. An integral component of this process is identifying what these potential hazards are, assessing the associated risks inherent to individual hazards, and for-



mulating an appropriate intervention strategy that seeks to mitigate these hazards. Beyond regulatory compliance, there are numerous tools available, including logic modeling, to assist safety and health professionals in identifying what topic areas, skills, and knowledge must be addressed as part of an operation's training and education program.

While dominant in modern mining operations, this strategic and philosophical approach toward employee health and safety training is often severely flawed when applied to small-scale and indigenous mining companies operating in the developing world. The inherent challenges associated with the social, economic, and political conditions found in many of these countries adversely affect the ability to design and implement viable safety programs. This is particularly true in places with no effective regulatory oversight or where cultural and political barriers exist. The complexity and variability of this situation can make it extremely difficult to adapt conventional training approaches and interventions that will gain workforce acceptance or have any significant impact towards improving worker safety.

For the purposes of this discussion, it is important to differentiate between small-scale and artisanal mining and medium-sized to large indigenous operations. In a conventional sense, safety training is essentially nonexistent for most small-scale and artisanal miners. In this industry sector, miners usually learn how to perform individual tasks and operate equipment through informal mentoring, observation, and hands-on trial and error. While an argument can be made that these activities inevitably possess elements related to safety, the connection is rudimentary. Preliminary research indicates that fatal accidents occur in this group 6 or 7 times more often than in workers in larger mines.<sup>9</sup> While numerous other social and economic factors play significant roles in why these accidents occur, the lack of formalized training, the apparent inability of these miners to recognize hazards, and the cultural acceptance of these risks profoundly contribute to this situation.

Conversely, the safety programs commonly advocated by medium-sized to large indigenous mines and mining companies possess many of the same fundamental components seen in programs employed in modern operations by multinational mining companies. Unfortunately, as observed in many mines throughout the developing world, these similarities are sometimes limited to paper and fail to either become properly implemented or maintained. Despite potential differences in technology, infrastructure, and economic capacity, the biggest factor that differentiates the safety records of mines operated by multinational and indigenous companies is the corporate commitment that has been made to safety.<sup>25</sup> This is particularly evident in developing countries with weak or limited regulatory enforcement and where labor is readily available. In many of these countries, the absence of



*Research team members*

potentially severe repercussions stemming from fatal accidents and injuries mitigate the inherent incentives for indigenous companies to view safety as a priority. In stark contrast, U.S. publicly-traded companies possess numerous economic and legal incentives that motivate their commitment to employee safety and health regardless of the regulatory structures of the countries in which they operate. A similar and often more egregious situation is sometimes seen in countries with nationalized resource (mining and petroleum) industries or where political agendas place irrational demands on resource development and utilization. In such instances, policies related to employment, mineral production, revenue, or some other political mandate often supersede considerations regarding worker safety and health. As with indigenous companies, there are few substantive repercussions to the government and policymakers as a consequence of this stance. Short of labor unrest or strikes, there are few motivating factors to facilitate change.

When faced with a problem of this magnitude, especially one in which human life is involved; there is a natural tendency to want to intervene quickly. Often such haste results in activity traps.<sup>3</sup> Activity traps are well-intended strategies that on the surface appear to be addressing the problem, but upon closer inspection do not target its antecedent conditions.<sup>19</sup> For example, the 9-11 commission report identified American foreign policy, cultural differences, economic disparities, and so forth as antecedent conditions of terrorist attacks.<sup>26</sup> However, the strategies endorsed by the administration are primarily containment such as reinforcing cockpit doors, increasing airport security, better baggage screening, and so forth. Clearly, these strategies are not targeting the identified antecedent conditions, and hence constitute an activity trap. There are numerous other examples of activity traps,<sup>19</sup> all of which have the

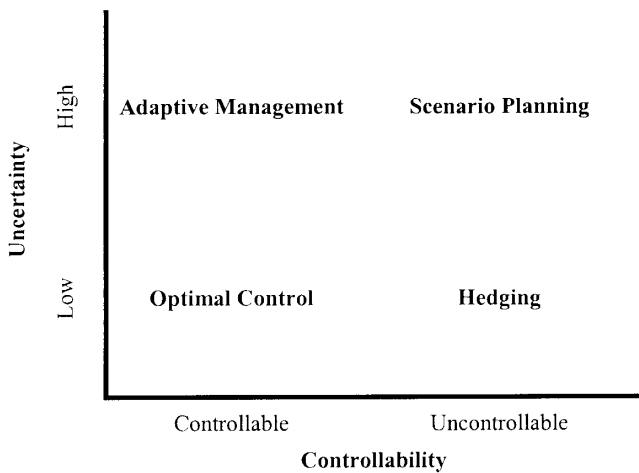


Figure 5—Planning and management approaches used under different future environments of control and certainty.<sup>28</sup>

potential to result in tremendous social and human cost. One recognized approach to avoiding activity traps is logic modeling.<sup>3</sup>

The map of antecedent conditions developed in this study can help guide future health and safety interventions. Even though the consensus map is two-dimensional and limited in capturing dynamic aspects of a situation, it provides a framework to construct evolving relationships. This is especially useful in selecting specific interventions relative to exceedingly complex antecedent conditions, such as those factors contributing to the high incidence of mining accidents in Zambia. In conditions that have highly uncertain futures with uncontrollable key variables, a method called “scenario planning” simplifies the continuum of possible new states to a manageable number of plausible ones for analysis and planning (Figure 5). Scenario planning explores joint impacts of many variables and uncertainties to identify patterns and stimulate decision makers to consider a wider range of possible outcomes. This differs from other planning methods that more objectively look at the impact from a change in one uncertainty, as in contingency planning, or a change in a single variable, as in sensitivity analysis.<sup>27</sup> Logic models can provide the framework for developing plausible scenarios. Scenario planning can be used to allow well-defined actors (e.g., Fogarty programs) with clear goals and objectives (e.g., improve worker health and safety) to develop robust strategies and interventions for an uncertain future. Scenario planning also helps groups of disconnected people or organizations (e.g., mining companies, government agencies) with divergent goals to create a shared understanding of the uncertainties that can facilitate mutually acceptable strategies and policies. We anticipate working with our Zambian partners to incorporate scenario planning into this analysis.

## Limitations

Despite the strengths of the ATM approach, it is not without limitations. While a complete discussion is published elsewhere,<sup>19</sup> a concise overview of the potential limitations of the process used in this analysis is warranted. One of the first limitations identified was that the interviews were completed by Zambian in-country partners who possessed content knowledge not universally understood by the American researchers. As a consequence, the person creating the summary map was at the disadvantage of not understanding cultural nuances inherent in the interview maps. The authors attempted to compensate for these limitations in two ways. First, a draft of the summary map was distributed to the Zambian partners and their input was solicited. Flaws in technical or cultural content should have been detected and remedied at that point. Second, assistance in understanding the cultural and technical content was provided by an American mining expert familiar with the Zambian context. His suggestions were subsequently incorporated into the map.

A second limitation pertains to the range of expert opinions incorporated into the summary map. When identifying content experts as interview subjects, it is essential to achieve representation from all stakeholders, including those who are affected by the problem.<sup>28</sup> Relative to this study, the miners themselves were underrepresented in the interview process. The potential consequence of not including more miners in the interview process is that the summary map may be missing some important antecedent conditions that have yet to be identified.

## CONCLUSION

Despite the investment of substantial resources by international humanitarian and aid organizations, there have been few tangible improvements in mitigating the horrific safety record associated with indigenous mining activities in many mineral-rich developing countries. One major reason these interventions fail to achieve their objectives is that they do not address the specific underlying causes of why accidents and worker injuries occur. To rectify this situation, analytic tools such as logic modeling are being proposed for use by decision makers in order to identify the antecedent conditions responsible for mine accidents and to help design and formulate interventions to remedy these conditions. In addition to decision making, logic-modeling techniques also possess real value in assisting researchers to understand why specific strategies aren't working and to perform cost-benefit analyses of potential interventions, and providing the means for conducting additional analysis. As a consequence, organizations are able to improve their ability to reallocate and budget resources in response to dynamic condi-

tions, increase resource efficiency, and improve the effectiveness of their intervention programs.

In the present study, it was determined that policy interventions had the greatest potential for substantive improvement in reducing the high incidence of mine accidents and worker injuries in Zambia. The ATM approach demonstrated that interventions oriented towards educating government officials and executives of Zambian mining companies about the economic and social benefits of health and safety programs were paramount and severely needed. In addition, interventions directed towards improving the organizational structure and function of regulatory government agencies were also identified as an area of immediate need. The nature of these interventions will necessitate the collaboration of numerous organizations both in and outside the country.

While specifically oriented towards the conditions found in Zambia, the proposed method and analysis used in this study are applicable to other mineral-rich countries within the region. It is hoped that the use of logic models as a viable decision-making tool will assist other international organizations and in-country professionals in their efforts to improve the quality of life for miners and mining communities in the developing world.

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