# Economic Consequences of Mining Injuries

**By:**

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## ABSTRACT

Direct costs such as medical, legal, administrative, and worker's compensation costs, property damage, lost earnings, and lost benefits are typically used to compute the economic impacts of occupational injuries. However, there are also a number of less obvious, indirect costs that substantially contribute to the overall loss costs. In fact, for every $1 of direct costs an estimated $3 to $5 of indirect costs are also incurred.

This paper presents a systems approach that incorporates engineering, economics, psychology, and sociology in order to evaluate the total value of investments in safety. By studying the interrelated system comprised of the injured worker, their family and coworkers, as well as the organizational structure that was the setting for the incident, a methodology can be developed that will more accurately capture the true costs of mine injuries.


## INTRODUCTION

From 1980-1995, mining had the highest fatal occupational injury rate recorded in the National Traumatic Occupational Fatalities Surveillance System (NTOF), with a rate of 30.3 fatalities per 100,000 workers. This is 50% higher than the next highest industry division—agriculture, forestry, and fishing—with a rate of 20.1 per 100,000 workers, and double the fatality rate for the third highest industry, construction, with a rate of 15.3 per 100,000 workers (NIOSH, 2000).

The purpose of the National Institute for Occupational Safety and Health (NIOSH) is to deliver on the promise of occupational safety and health for all workers through research and prevention. The NIOSH Spokane Research Laboratory (SRL) is specifically tasked with performing research related to mine safety and health. This paper outlines a systems approach research methodology related to an on-going NIOSH project that seeks to identify the costs and associated consequences of workplace injury and fatality in the workplace and to identify the complex dynamics involved in workplace accidents. This information will be useful in designing safer work practices, developing focused training in the consequences of risky behavior, and providing estimates of the economic incentives of safer workplaces.

## SYSTEMS THEORY IN SAFETY RESEARCH

*Systems* and *systems thinking* are terms used frequently by many disciplines. While common sense dictates that the entire sequence of events leading up to an occupational injury must be examined when trying to determine the causes and ultimate effects of a particular injury, formal scientific systems approaches are a relatively new means of examining the problem.

### <u>General Systems Theory</u>

The root meaning of the word *system* is derived from the Greek word *syshistanai*, which literally means "to place together." A *system* can be thought of as "an integrated whole whose essential properties arise from the relationships between its parts," and *systems thinking*, "the understanding of a phenomenon within the context of a larger whole" (Capra, 1996). Understanding things systematically means putting them into context to establish the nature of their relationships.

One of the first people credited with the establishment of systems thinking as a major scientific movement was von Bertalanffy (Capra, 1996). According to von Bertalanffy (1968), systems theory is a general science of "wholeness" with an emphasis on mathematics to define principles that apply to systems in general.

The work done by von Bertalanffy distinguishes between *closed systems* (systems which are considered to be isolated from their environment) and *open systems*. Typical closed system approaches are physical chemistry and thermodynamics, whereas systems comprised of living organisms are considered open. Such open systems maintain a continuous inflow and outflow, building up and breaking down of components, such that they are never in a state of chemical or thermodynamic equilibrium (von Bertalanffy, 1968). But, although a living system is never in a state of equilibrium, it is constantly seeking a state of stability. A system's stability is continually tested by fluctuations which can cause a deviation that can be either corrected or magnified by positive or negative feedback. *Homeostasis* is the systems terminology used to describe the state of dynamic balance characterized by multiple, interdependent fluctuations (Capra, 1982).

Another term used to describe the interconnected aspect of systems theory is *rheomode* (*rheo* from Greek meaning "to flow") (Bohm, 1980). Bohm was a quantum physicist who believed the tendency to describe the universe as discrete fragments provided an inadequate world view. He used the rheomode as a way to describe the universe in essence, as everything in an unbroken and undivided whole movement. To attempt to describe the universe in individual fragments will miss the essence of the connected nature of the universe. "Rather, it implies that any describable event, object, entity, etc., is an abstraction from an unknown and undefinable totality of flowing movement" (Bohm, 1980, p. 49). Bohm used the image of a flowing stream, an ever-changing pattern of waves and ripples which have no independent existence apart from the stream. Applying this principle to human health, Bohm stresses that the fragmented nature of current culture with its emphasis on autonomy, has adverse effects. The paradox of human nature is that society has a sense that wholeness or integrity is necessary to make life worth living, yet most social structures emphasize a fragmented existence. The word health in English is based on the Anglo-Saxon hale meaning whole—to be healthy is to be whole (Bohm, 1980). The totality of existence is an unbroken wholeness, an undivided flowing movement without borders.

In systems theory, the interactions and relationships among parts of a system are as important as their individual characteristics in understanding the dynamics of the system. This is particularly important when studying human behavior within a system. A key characteristic of the organization of living organisms is the tendency to form multileveled structures of systems within systems, referred to as *hierarchies*. Hierarchies, in this sense, are different from the term as it is typically thought of in organizations where there may be a clear-cut order of “above and below” or of “management and subordinates.” Rather, in naturally ordered systems, there are networks within other networks. Understanding these complex connections, relationships, and context are fundamental to understanding the system.

## Systems Engineering

Systems engineering is an interdisciplinary approach which helps enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem which may include:

- Operations
- Performance
- Testing
- Manufacturing
- Costs and scheduling
- Training and support, and
- Disposal

Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Both the business and technical needs are considered all with a goal of providing a quality product that meets the customer needs (INCOSE, 1999).

## Bowen Systems Theory

When applied to the workplace, Bowen’s theory provides a framework for describing a safer, more meaningful work environment in terms of an individual worker. For example, if a worker feels pressure to conform to the demands of a group or a boss, the worker may compromise his or her own safety to avoid appearing weak or unproductive. This may happen even when there is no expectation to perform a work function in an unsafe manner and such a perception is held by the worker only.

The cornerstone of Bowen’s family systems theory is the concept of *differentiation of self* (Goldenberg and Goldenberg, 2000). Bowen developed a theoretical scale for evaluating a person’s level of self differentiation using values from 0 to 100. Complete undifferentiation exists in a person who has achieved no emotional separation from the system (i.e. the family or work organization the person is in). These individuals may be referred to as "no self" and are generally incapable of being an individual in a group. This level of functioning would be assigned a scale value of zero (Kerr and Bowen, 1988). On the other end of the spectrum, someone who has achieved complete differentiation has fully resolved the inappropriate (too close or too distant) emotional attachment to his or her system (i.e. family and/or work relationships) and would be arbitrarily assigned a self-differentiation scale value of 100. The scale is not intended to be diagnostic or to assign exact levels to individuals; rather it can be useful in determining general patterns of behavior and to define an individual's ability to adapt to stressful situations. The higher the level of differentiation, the more stress required to trigger an unhealthy symptom (Kerr and Bowen, 1988). In addition, the higher the level of differentiation, the more likely a person is to cooperate, to look out for one another's welfare, and to stay in adequate contact during stressful as well as calm periods. The theory indicates that a worker with higher self-differentiation is more likely to respond in a thoughtful manner to an unsafe situation and more likely to handle the stress of an injury, fatality, or other stressful experience in the workplace in a healthy, constructive manner.

## SRL's SAFETY SYSTEM MODEL

The safety system model developed for the on-going SRL project includes four main components:

1. Economics
2. Social consequences
3. Engineering, and
4. Human factors.

These components provide a model based on viewing the safety of a work organization as an overall system. Using principles from systems theory and systems engineering, this allows evaluation of an injury or fatality from multiple perspectives: (1) economics considers direct, indirect, productivity, and intangible costs; (2) social consequences examines psychosocial effects, stress, anxiety, depression, and group conflict; (3) engineering considers the design and types of equipment, the work environment, and how they interact; and, (4) human factors include work design, organizational culture, worker ability, and training. Using this four-part systems model allows researchers to focus on key areas and interrelationships of the overall safety system of a work setting. Two factors of this research model, economics and social consequences, are presented below.

### Economics

Costs to the employer**:** The cost to individuals and industry from occupational injury and fatality is enormous. According to the National Occupational Research Agenda, "the costs of work-related illness and disability (both in human and economic terms) justify devoting substantial resources to the control of workplace hazards; yet surprisingly little attention had been paid to describing and measuring these costs" (NIOSH, 2002). In addition to standard losses such as lost wages and health care costs, there are numerous direct and indirect costs associated with workplace injuries that are often not taken into account when assessing the monetary impact of a workplace injury or fatality. Leigh et al., (1997) described direct costs as including actual dollars spent on medical expenses, health care, property damage, police and fire services, and legal and administrative expenses for insurance and workers' compensation. While direct costs can be substantial, they only represent about 34% of the total costs with indirect costs contributing to 66% of the total (Leigh, et al., 1996). Indirect costs to employers include costs associated with additional hiring and re-training, time delays due to the disruption of work processes, and the effects of workplace injury, exposure, or fatality on the productivity of coworkers who see themselves at heightened risk. However, costs to the employer are only part of the total.

<u>Costs to the injured worker and their family:</u> A workplace injury has direct medical, employment and earnings consequences for a worker, and these consequences are the focus of a growing literature (Leigh, et al., 1997; Miller, 1997; Miller and Galbraith, 1995; and Viscusi, 1996). Indirect costs to workers and their families may include reduced income, depletion of savings, and loss of assets (which could include automobiles or even homes). Oftentimes, indirect costs to a worker and their family will also occur in the form of lost fringe benefits and lost home production when other members of the household are required to quit or cut back on their own work hours to care for the injured family member. Additional potential costs to workers and their families include professional counseling, caregiver services in the home, home modifications and equipment related to disability, and deferral or loss of education opportunities for family members.

<u>Costs to the community:</u> The changed economic circumstances of the family and possible increased care required for the injured worker may also affect the economic and social outcomes and behaviors for other family members including children. Costs may also be absorbed by the community with the increased use of social services. While fatalities are the most dramatic and tragic, nonfatal injuries may still have devastating impacts on families, often with fewer organized sources of support. Extending the literature on earnings losses for workers with injuries to losses in family income and social consequences is an area of increasing interest to occupational economics researchers.

<u>Estimates of actual costs of occupational injuries in the industry:</u> Occupational injuries, fatalities, and illnesses can be very costly. The International Labor Organization estimates these costs to the global economy at $1.25 trillion per year based on the calculation that accidents and work-related illnesses cost some 4 percent of the global gross domestic product. Other sources report that the average cost of a fatality is $2.57M to $5M (Miller and Galbraith, 1995;

Viscusi, 1996), and for each $1 of direct costs, there are associated indirect costs of $3-5 (Liberty Mutual, 2003). A study of costs of injuries at sand and gravel mines estimated the average cost of nonfatal injuries to be $46,400 per incident (Camm, 2000: December 1990 dollars; Camm et al., 2000). However, the actual costs may be substantially higher than what has been presented in the literature to date, and costs per incident are expected to increase in the future. For example, in March 2003 a jury awarded $163.8M to the widow and children of a contractor fatally injured at a mine (MSHA, 2003). The Liberty Mutual Research Institute for Safety (2003) also reported that the direct costs of the three leading causes of work-related injuries (for all industries) grew at rates substantially greater than inflation (12% to 17% higher) and 2.5% overall.

## **Social Consequences**

"The American Institute of Stress…estimates that stress and the ills it can cause—absenteeism, burnout, mental health problems—costs American business more than $300 billion a year" (Daniels, 2002).

Symptoms of stress can be physical, mental, and/or behavioral. Mental and behavioral effects include depression, anger, and anxiety (Freudenberger, 1998). Forty percent of workers reported their job is "very or extremely stressful" in a survey by Northwestern National Life (NIOSH, 1999). This report went on to report that health care expenditures are nearly 50% greater for workers who report high levels of stress. Clearly, a comprehensive investigation of the costs of injury requires including occupational health psychology (Sauter, et al., 1999), along with the disciplines of engineering and economics. Integrating the social consequences of workplace injuries with economic impacts in a systems engineering framework provides a rich and comprehensive analysis of the effects of workplace injuries.

There are also substantial non-economic consequences of workplace injuries and illnesses on quality of life. Physical and psychological functioning in everyday activities may be affected, self-esteem and self-confidence may be reduced, and an individual's role in the family and community may change. Even less research has been focused on these non-monetary costs. Studies of unemployed workers and their families and of people with chronic illnesses and disabling injuries show that income and employment losses, illness, and physical impairment can have profound human consequences on both workers and their families. Better measures of both economic impacts (direct and indirect) and non-economic impacts will help improve targeting of resources for research, prevention, and compensation (NIOSH, 2002).

## SUMMARY

Clearly, a comprehensive investigation of the costs of injury require including the traditional disciplines of engineering and economics, but valuable information can also be gathered by including occupational health psychology and sociology in the analysis of overall costs. By studying the interrelated system comprised of the injured worker, coworkers, family and community, as well as the organizational structure that was the setting for the incident, a systems methodology can be developed that will more accurately capture the true costs of safety.

Results of this project will add to the body of knowledge on how much occupational injuries truly cost, thereby lending measurable economic credence to the value of accident prevention. This type of information is valuable for safety professionals who must justify safety procedures as a bottom line value to the mining company and have no methodology to follow in order to correctly capture the true costs of safety. A combination of traditional research that studies the causes of mine injuries and worker behaviors, coupled with systematic economic analyses of occupational injuries will provide a framework for prioritization of prevention resources and efforts. The findings will also be useful in documenting the social consequences of frequently occurring injuries to the workers who may not have considered the impact of occupational injures beyond their own individual concerns to include their co-workers and families. Finally, the results will add to the body of knowledge concerning methodologies to gather quantitative and qualitative data to measure economic and social consequences of occupational injuries, and will provide a new level of understanding of occupational injuries and fatalities that cannot be determined using engineering, economic, managerial, sociological, psychological, or other disciplines alone.

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