2nd Solicitation for Single Investigator Research Grants

(AFC215)

ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

Final Technical Report

1.0 Cover Page

Project Title: Characterization and Effectiveness of Safety and Health Management Systems in the U.S. Mining Industry

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2.0 Executive Summary

This project began as U.S. companies were adopting safety and health management systems (SHMSs), such as the National Mining Association's CORESafety initiative. The stated goals of the project were: 1. Establish the first characterization of the independent variables affecting SHMS development, implementation and performance; 2. Track trailing and leading metrics associated with both SHMSs and regulatory compliance at selected sites over three years; 3. Provide analysis of the relationships among the individual elements and the entire SHMS system with the system's effectiveness at each site.

The project was scheduled to begin on August 1, 2015, but was effectively delayed one year. First, approval from the University of Utah's Internal Review Board, which is required for research involving eight or more human subjects, was delayed; second, one of the project's principal investigators, Tom Hethmon, resigned from the University. The Alpha Foundation granted a one-year project extension, and work began in February 2016.

Phase 1 of the project was an assessment of safety and health management practices and of SHMS implementation in 15 selected U.S. mines. Phase 2 included ongoing observation of parameters identified in Phase 1 and continued tracking SHMS and regulatory compliance at the participating mines. Phase 3 was a detailed closing assessment to define the performance of the SHMS at each participating site.

Unfortunately, as the project was beginning, the global commodities markets experienced a substantial downturn, and several companies decided not to participate. It was thus necessary to find other participants. This problem continued through the duration of the study, as companies changed ownership or declared bankruptcy and mines changed managers. Scheduling mine visits was a continuing challenge.

By January 2020, the project team had made 22 visits to a group of 14 mines. Three mines were visited three times, two mines twice, and nine mines once. The team administered more than 4,000 surveys, generating almost 230,000 data points for analysis. The team also analyzed the SHMS in each of the 22 visits, rating each site's effectiveness in four of the components of an SHMS.

The study reached the following conclusions:

1. The implementation of safety and health managements systems varies widely in U.S. mines. Even in companies that are CORESafety certified, the implementation of the systems varies widely from one mine to another, and from one year to the next.

2. A safety and health management system can contribute significantly to standards and performance at any mine, but such a system alone does not guarantee a safe and healthy workplace.

3. Longitudinal effects at a given mine are very difficult to identify and quantify, because a single, uncontrollable variable, such as a new mine manager, can markedly change the workplace climate and culture in a short time.

4. The most important components of any safety and health management system are leadership and workplace culture.

The large database produced in the study will be further analyzed by members of the project team, who will also continue annual visits to the at least some of the mines.

3.0 Problem Statement and Objectives

3.1 Problem Statement

This research project was conducted in response to the second solicitation from the Alpha Foundation. It addresses the “Safety and Health Management and Training” focus area and the “Safety and Health Management” topical area.

When the proposal was prepared, U.S. mining companies were voluntarily adopting safety and health management systems (SHMSs) to supplement regulatory compliance requirements. These risk-centered systems showed promise for improving safety and health performance in U.S. mines. Unpublished data from the National Mining Association (NMA) suggested that between 2011 and 2014 only 25% of U.S. mining fatalities occurred in companies that used an SHMS. However, the claims of benefits for such systems were at the time primarily anecdotal and qualitative. A study was therefore proposed to improve the understanding of how SHMSs function, and to identify the most effective variables for their development and implementation, and to assess the relative impact of MSHA regulations versus SHMSs on mine safety outcomes.

3.2 Objectives

The objectives of this study, as stated in the project proposal, were:

1. Conduct an assessment of safety and health management philosophies, and of SHMS approaches, implementation, and performance metrics at a minimum of 15 U.S. mines.
2. Conduct annual assessments of the parameters identified in the Objective 1 by visiting each mine site, surveying employees, and interviewing management, and then analyze how these parameters are related to regulatory compliance and incidence rates.
3. After the third round of mine-site visits, complete a closing assessment of safety management, company culture, and workplace climate at each site, and examine the relationships of these variables to regulatory compliance and incidence rates.

4.0 Research Approach

The research for this project was approached in four areas, as described below:

4.1 Literature Review

Literature specifically relating to the use of pressure balancing for control of spontaneous combustion in coal mines was collected. References were organized into two categories: safety and health management and statistics and survey design.

4.2 Preliminary Analysis

Jake C. Seiter, the first graduate student supported by the project, completed a study entitled “Safety and Health Management Systems: A Comparison of Structural Elements.” Seiter started with the Dalrymple Scheme (Redinger and Levine 1990), which is shown in Appendix A. The Dalrymple Scheme is widely recognized as a universal occupational safety and health management system (OHSMS) model. It

includes 27 structural elements, each assigned to one of five categories: OHS inputs, OHS process (formulation), OHS process (implementation/ operations), OHS feedback, and open system elements. Based on an analysis of the National Mining Association's safety management system, CORESafety (CORESafety 2017), Seiter added seven additional SHMS structural elements. The result, shown in Appendix B, is a "benchmark" description of the ideal SHMS. This analysis was the basis of the surveys administered later in the study, and of the discussions with mine management personnel regarding the SHMS at each mine site.

Seiter compared his benchmark system to eight, globally-recognized SHMSs by government or non-profit agencies, as listed in Table 4.2.1. The comparison analyzed each SHMS for the presence of the desired components listed in Seiter's modified Dalrymple Scheme. Figure 4.2.1, on the next page, summarizes the analysis of the SHMSs from non-profit organizations.

Table 4.2.1 Non-profit Safety Health Management Systems Analyzed

Organization	**Standard**
National Mining Association	CORESafety
International Organization for Standardization	ISO 45001 (draft)
International Labour Organization	(ILO-OSH) 2001
Occupational Safety and Health Administration	VPP
Occupational Health and Safety Management System	OSHAS 18001
American National Standards Institute	ANSI Z-10
Canadian Standards Association	CSA Z1000
British Standards	BS 8800-2004

Seiter also compared the benchmark system with the systems used by 10 companies in the mining industry: Xstrata, Dyno Nobel, Freeport McMoRan, Barrick, Newmont, Hecla, Potash Corp., Rio Tinto, Anglo American, and Duke Energy.[1] Figure 4.2.2, on page 6, summarizes the analysis of SHMSs from companies in the mining industry.

[1] The information listed for these companies was obtained from publically-available sources. No confidential information is disclosed here.

OHSMS Elements (Modified Dalrymple Scheme)	CORESafety	ISO/DIS 45001	ILO-OSH-2001	OSHA VPP	OHSAS 18001	ANSI Z10	CSA Z1000	BS 8800 - 2004
Legend: X = Present \ = Partially Presnt O = Not Present								
Plan, Do, Check, Act Ideal	X	X	X	X	X	X	X	X
INITIATION (OHS Inputs)								
Scope, Purpose, Application (Additional)	X	X	X	X	X	X	X	X
Initial Review (Additional)	X	X	X	X	X	X	\	X
Management Commitment and Resources	X	X	\	X	\	X	X	X
Regulatory Compliance and OHSMS Conformance	X	X	\	\	X	\	X	X
Accountability, Responsibility, and Authority	X	X	X	X	X	X	X	X
Employee Participation	X	X	X	X	X	X	X	X
FORMULATION (OHS Process)								
Occupational Health and Safety Policy	X	X	X	X	X	X	X	X
Goals and Objectives	X	\	X	X	X	X	X	X
Performance Measures	X	X	X	X	X	X	X	X
System Planning and Development/Implementation	X	X	X	X	X	X	X	X
Baseline Evaluation and Hazard/Risk Assessment	X	X	X	X	X	X	X	X
OHSMS Manual and Procedures	X	\	\	X	\	\	\	X
IMPLEMENTATION/OPERATIONS (OHS Process)								
Training System	X	\	X	X	X	X	X	X
Technical Expertise and Personnel Qualifications	X	X	O	X	\	X	\	X
Hazard Control System	X	X	X	X	X	X	X	X
Process Design/Management of Change	X	X	X	X	\	X	X	\
Emergency Response	X	X	X	X	X	X	X	X
Hazardous Agent Management	X	\	\	\	\	\	X	X
Preventive and Corrective Actions	X	X	X	X	X	X	X	X
Procurement and Contractor Selection	X	X	X	X	\	X	X	X
EVALUATION (OHS Feedback)								
Communication System	X	X	X	X	X	X	X	X
Document and Record Management System	X	X	X	X	X	X	X	X
Evaluation System	X	X	X	X	X	X	X	X
Audit and Self-Inspection	X	X	X	X	X	X	X	X
Incident Investigation and Root Cause Analysis	X	\	X	X	X	X	X	X
Medical Program and Surveillance	X	\	\	X	\	\	\	X
IMPROVEMENT/INTEGRATION (Open System Elements)								
Continual Improvement	X	X	X	X	X	X	X	X
Integration	X	\	\	X	\	\	\	X
Management Review	X	X	X	X	X	X	X	X
Supplementary Information (Additional)	X	X	O	X	O	X	X	X
Success Factors (Additional)	X	X	O	O	O	X	O	X
Culture Enhancement (Additional)	X	O	O	O	O	O	O	X
Reinforcement and Recognition (Additional)	X	O	O	O	O	O	O	O
Behavior Optimization (Additional)	X	O	O	O	O	O	O	O

Figure 4.2.1 Analysis of SHMSs from Government and Non-profit Organizations

OHSMS Elements (Modified Dalrymple Scheme)	Xstrata	Dyno Nobel	Freeport McMoran	Barrick	Newmont	Hecla CORESafety	Potash Corp	Rio Tinto	Anglo	Duke Energy
Legend: X = Present \ = Partially Presnt O = Not Present										
Plan, Do, Check, Act Ideal	\	X	X	X	X	X	X	X	X	X
INITIATION (OHS Inputs)										
Scope, Purpose, Application (Additional)	X	X	X	X	X	\	X	X	X	X
Initial Review (Additional)	\	\	\	\	\	\	\	X	X	\
Management Commitment and Resources	X	X	X	X	X	X	X	X	X	X
Regulatory Compliance and OHSMS Conformance	X	X	X	X	X	X	X	X	X	X
Accountability, Responsibility, and Authority	X	X	X	X	X	X	X	X	X	X
Employee Participation	\	X	X	X	X	X	X	\	X	\
FORMULATION (OHS Process)										
Occupational Health and Safety Policy	\	X	X	X	X	X	X	X	X	X
Goals and Objectives	\	X	X	X	X	\	X	X	X	X
Performance Measures	\	\	\	X	\	X	X	X	X	X
System Planning and Development/Implementation	X	X	X	X	X	X	X	X	X	X
Baseline Evaluation and Hazard/Risk Assessment	X	X	X	X	X	X	X	X	X	X
OHSMS Manual and Procedures	\	\	X	X	X	X	\	X	X	X
IMPLEMENTATION/OPERATIONS (OHS Process)										
Training System	\	X	X	X	X	X	X	X	X	\
Technical Expertise and Personnel Qualifications	X	X	X	X	X	X	\	X	X	\
Hazard Control System	X	X	X	X	X	X	X	X	X	X
Process Design/Management of Change	X	X	\	X	X	X	X	X	X	\
Emergency Response	X	X	X	X	X	X	X	X	X	X
Hazardous Agent Management	X	X	X	\	\	X	\	X	\	\
Preventive and Corrective Actions	X	X	X	X	X	X	X	X	X	X
Procurement and Contractor Selection	X	X	X	X	X	X	X	X	X	X
EVALUATION (OHS Feedback)										
Communication System	X	X	X	X	X	X	X	X	X	X
Document and Record Management System	X	X	X	X	X	X	X	X	X	\
Evaluation System	X	X	X	X	X	X	X	X	X	X
Audit and Self-Inspection	\	X	X	X	X	X	X	X	X	X
Incident Investigation and Root Cause Analysis	X	X	X	X	X	X	X	X	X	X
Medical Program and Surveillance	X	\	X	X	\	X	X	X	O	O
IMPROVEMENT/INTEGRATION (Open System Elements)										
Continual Improvement	X	X	X	X	X	X	X	X	X	X
Integration	X	\	\	X	X	\	X	X	X	X
Management Review	X	X	X	X	X	X	X	X	X	X
Supplementary Information (Additional)	O	O	O	O	O	\	X	\	X	O
Success Factors (Additional)	\	X	X	O	X	X	X	\	X	O
Culture Enhancement (Additional)	\	\	\	X	\	X	O	O	O	O
Reinforcement and Recognition (Additional)	\	\	X	\	\	X	X	O	O	O
Behavior Optimization (Additional)	X	O	O	\	X	X	X	O	O	O

Figure 4.2.2 Analysis of SHMSs from Companies in the Mining Industry

Seiter's analysis revealed many interesting points, three of which are key to this study, and are corroborated by the study's findings.

1. CORESafety is the *only* SHMS that includes all the elements of Seiter's benchmark scheme.
2. The greatest deficiencies, shown by the letter 'O" in both of the preceding figures, occur in the Improvement/Integration area. All deficiencies are in areas related to human behavior and human interaction.
3. With the exception of CORESafety, the SHMSs from non-profit organizations show a greater deficiency in the Improvement/Integration area than do the SHMSs from companies in the mining industry.

4.3 Design and Testing of Analysis Instruments

4.3.1 Employee Surveys

4.3.1.1 Survey Design

The survey used in this study was designed by members of the Alpha project research team to assess the perceptions of the mine site employees in terms of mine safety, including the various components of the site's SHMS and how that system functions in the workplace.

The survey questions were designed to assess employee perceptions of four particular measurable variables, called the Assessment Variables: MSHA Compliance, Risk Management, Leadership, and Culture. Participants responded to statements in the survey using a variation of the well-known Rensis Likert scale (Likert et al. 1934). In this case, the scale has a five possible responses: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree. These verbal responses are translated respectively as 5, 4, 3, 2, and 1, allowing quantification for statistical analyses.

The survey asked respondents to classify themselves in two areas. The first was employment category: frontline supervisor, middle manager, senior manager, member of support/technical services, hourly employee, or contractor. The second was level of experience: 0–1 year, 2–5 years, 5–10 years, or 10+ years.

After the surveys were administered at the first few mine sites, the initial survey was altered by the research team to improve the coverage the questions provided for the four assessment variables, and to make some of the questions clearer and easier to understand. There were thus two versions of the survey used in this study. Both were designed to assess perceptions of the four assessment variables, so with some manipulation of the data, the results of both could be used and compared in the study. Appendix C shows both versions of the survey. It also shows which questions in each were designed to measure perceptions of the assessment variables, and a sample survey form.

4.3.1.2 Survey Power and Reliability

Sample size is a critical variable when it comes to the reliability of any survey. The necessary sample size determined for this survey was 82 respondents per mine site. This was determined by using the generally accepted technique to have a sample size of N greater than or equal to [50+8*m], where 50 is the lowest acceptable sample size and m equals the number of variables in the study (Green 1991). Four separate independent variables were evaluated by this survey, so the required sample size was at least 82 respondents per site.

Statistical power is usually referred to the probability that the hypothesis in a given study is true, or the probability in rejecting the null hypothesis (null hypothesis being that there is no correlation between two variables (Everitt 1998). As the statistical power increases and approaches 1.0, one is less likely to see results that disagree with the main hypothesis—the chance of a false negative is decreased.

The statistical power of a given survey can be determined using G*POWER 3.1 (UCLA IDRE 2017). The statistical power was calculated for some of the first surveys given, using the number of survey respondents, and employing the *Post Hoc* setting was used in the test parameters. This allowed determination of the actual power of the study, based on the number of surveys used. The statistical power of the surveys analyzed was in every case greater than 0.950.

Cronbach's alpha coefficient is determined to assess the reliability of a measuring instrument, in this case a written survey (Ellis 2010). The range of the alpha coefficient is from 0 to 1, where 0.6 is usually accepted as sufficiently reliable, with higher values pointing to higher reliability. The Cronbach's alpha coefficient for this study was greater than 0.940 for both versions of the survey, indicating that the reliability of these surveys as measuring tools quite high.

Bartlett's test of sphericity determines whether a group of samples has equal variances. In effect, it analyzes the homogeneity of variances (Snedecor and Cochran 1983). Several statistical tests make assumptions that the variances are equal across a group of samples, making Bartlett's test unique and necessary. When this test has an outcome of significance, it indicates that the variables can be correlated. This is important to prove a correlation of items so they can be grouped into one factor. Bartlett's test gave satisfactory results for both versions of the survey.

The Keiser-Meyer-Olkin measure of sampling adequacy is a measure of how well-suited a sample set is for factor analysis. "The test measures the sampling adequacy for each variable in the model and for the complete model" (Statistics Solutions 2016). As do the other tests, this test gives a result between 0 and 1, and any value greater than 0.6 indicates the test is appropriate for factor analysis. The KMO measures

calculated using SPSS were greater than 0.930 for all the versions of the survey, indicating that that factor analysis is in fact acceptable for this data set.

Based on these analyses, the survey as designed was deemed an effective analysis tool.

4.3.2 SHMS Assessment Matrix

4.3.2.1 Matrix Design

In addition to the survey discussed above, assessment of safety and health management practices at each mine site included, an interviews and informal discussions with the mine's management. Using the benchmark SHMS developed by Seiter, as described above, the project team developed the SHME Assessment Matrix, shown in Table 4.3.1.

Table 4.3.1 SHMS Assessment Matrix

Company Name **Mine Name**			
SHMS Assessment Matrix			
#	**Category**	**Visit #1**	
		Date	
		Rating	**Comments**
1	Risk Management and Fatality Prevention		
2	Behavior Based Safety		
3	Training and Competence		
4	Emergency Management		
5	Work Procedures and Permits		
6	Occupational Health		
7	Incident Reporting and Paperwork		
8	Documentation and Information Management		
9	Management Systems Coordinator		
10	Change Management		
11	Contractor Management		
12	Responsibility and Accountability		
13	Leadership Competency Model		
14	Leadership and Professional Development		
15	Collaboration and Communication		
16	Culture Enhancement		
17	Incident and Near Miss Reporting and Sharing		
18	Reinforcement and Recognition		
19	Assurance		
20	SHMS Function Overall		

Appendix D gives the definitions of the 19 categories in the SHMS Assessment Matrix, and lists some sample questions that can be asked in discussions with mine management to determine the extent to which the mine has implemented practices associated with that category.

The team also developed guidelines for assigning a numerical rating in each category, as shown in Table 4.3.2.

Table 4.3.2 SHMS Assessment Matrix Ratings Criteria

SHMS Assessment Rating System	
Rating	**Description**
1	Doesn't have it
2	Has informal version and uses it.
3	Has it but doesn't use it, or follows MSHA minimum requirements.
4	Has it and uses it.
5	Has it and uses it effectively.

4.3.2.2 Assessment Methods

The meetings with mine management had two goals. The first goal was to determine the extent to which the management had implemented the mechanics of safety and health management—for example, risk analysis, change management, and incident reporting. The second goal was to gain an intuitive feeling for the approach of to safety and health management by the entire management team and by key individuals. within that team.

4.4. Mine Visits

Members of the project team visited 14 mines during the duration of the project. The intent was to visit each mine once each year for three years. However, 11 of the mines changed owners, ceased operations, or simply decided not to continue participation in the project, so only three mines were visited three times, and two were visited twice. Table 4.4.1 summarizes the mine visits; the 14 mines are listed in order, based on the date of the first visit to each.

Table 4.4.1 Summary of Mine Visits

Mine	Visits		Product	Method	Comments
1	1	Jun 2016	Coal	Surface	Changed owners after Visit 2
	2	Oct 2017			
2	1	Jun 2016	M/NM	Surface	Visits 2 and 3 repeatedly postponed
	2	Sep 2018			
3	1	Jun 2016	Coal	Surface	Closed after Visit 1
4	1	Jun 2016	Coal	Surface	
	2	Apr 2018			
	3	Jul 2019			
5	1	Jul 2016	Coal	UG	Scheduling difficult
6	1	Jul 2016	Coal	Surface	Closed after Visit 1
7	1	Sep 2016	Coal	Surface	Closed after Visit 2 was scheduled
8	1	Nov 2016	Coal	UG	Scheduling difficult—budget cuts
9	1	Aug 2017	M/NM	UG	
	2	Jan 2019			
	3	Jan 2020			
10	1	Oct 2017	M/NM	Surface	
	2	Oct 2018			
	3	Aug 2019			
11	1	Jan 2018	Coal	Surface	Scheduling difficult—budget cuts
12	1	Jul 2018	M/NM	UG	Scheduling difficult
13	1	Aug 2018	M/NM	Surface	Management changed
14	1	Aug 2019	Coal	Surface	Last minute for substitute for Mine 7

4.4.1 Administration of Employee Surveys

In each visit, the survey was administered to as many of the mine employees as possible, including hourly, technical and management, and office personnel. In administering the survey to hourly personnel, it was important that employees not be influenced by the presence of supervisors or managers, who in some cases might desire to influence the outcome of the survey at a given site. Usually the project team members were introduced by a member of mine management, who assured the employees that the study was independent, and that management would use employee responses only for information purposes. All supervisory personnel then left the room. Survey participants were guaranteed confidentiality and anonymity, to help ensure honest and accurate responses.

After each group of employees finished the survey, project personnel would elicit comments from those employees about the management of safety at the site, and about the culture and climate of the workplace.

Table 4.4.4.1 summarizes data regarding the surveys given in the 22 mine visits.

Table 4.4.4.1 Summary of Data Regarding Mine Surveys

			Experience, yrs					Role						
Mine	Visit	# Survey Responses	0-1	2-5	6-10	>10	Not Indicated	Contractor	Frontline Supv	Hourly Emp	Support/ Tech Serv	Middle Mgr	Senior Mgr	Not Indicated
1	1	164	11	53	27	63	11	0	12	142	1	7	3	0
	2	204	15	58	45	79	10	0	4	183	4	3	3	10
2	1	427	54	133	100	125	15	172	25	146	43	28	3	10
	2	749	242	146	133	211	17	7	27	601	36	15	3	60
3	1													
4	1	105	2	30	26	47	0	2	6	94	1	1	1	0
	2	145	7	31	28	63	16	0	7	112	5	3	4	14
	3	168	2	20	38	88	20	1	10	125	10	2	2	18
5	1	212	10	167	23	8	4	0	21	185	2	4	0	0
6	1	127	11	40	37	31	8	1	7	91	11	8	2	7
7	1	200	28	61	42	59	10	11	5	156	7	4	7	10
8	1	200	29	63	56	46	6	31	7	148	0	7	1	6
9	1	234	45	82	38	44	25	4	20	158	20	8	4	20
	2	79	29	17	9	20	4	2	1	59	14	0	0	3
	3	115	14	34	34	28	5	0	5	85	15	5	0	5
10	1	113	15	24	20	47	7	3	8	79	6	6	2	9
	2	79	25	14	11	19	10	4	5	46	14	0	2	8
	3	115	18	28	19	40	10	7	11	76	6	4	1	10
11	1	196	41	41	33	76	5	0	29	123	17	11	6	10
12	1	47	7	18	7	10	5	0	2	30	5	2	1	7
13	1	342	93	36	58	151	4	3	26	218	49	11	7	28
14	1													

Notes: Data for Mine 3 were not analyzed because the mine closed shortly after the first visit.
Data for Mine14 have not been analyzed because Mine 14 was substituted at the last minute for Mine 7, where a second visit had been scheduled. (Mine 7 was shut down on the day of the scheduled visit.)

In administering surveys, the project team learned several important lessons regarding survey design and administration. These lessons are described in detail in the paper by Richins et al. (2020). Its conclusions are summarized here.

4.4.1.1 Survey Statements

1. When survey responses are based on a five-point Likert scale (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, or Strongly Agree) the responses are later assigned numerical values, to facilitate statistical analysis. It is thus important to be sure that a given response has the same meaning for every question. For example, a response of “Strongly Agree” to the statement, “Teamwork is valued for getting things done at this mine,” is *positive*, but a similar response to, “Drugs and alcohol are a problem at this mine,” is *negative*. The second statement should be re-phrased as “Drugs and alcohol are not a problem at this mine.

2. Statements should be clear and as specific as possible. For example, the words “supervisor” and “manager” may each have more than one meaning, and in many cases, employees have more than one supervisor, so “shift supervisor” or “direct supervisor” should be used, instead of just “supervisor.”

4.4.1.2 Preparation

Participation in a site-wide survey requires a significant commitment from the mine and its employees. Careful preparation is important, to show that the researchers respect the cooperation they are receiving.

Researchers should confer with the cognizant mine employees—usually members of the safety department—to understand clearly when and where surveys will be given, so that as many employees as possible can give their opinions. For example:

1. Make sure to understand the shift schedule and the rotation.
2. Determine where employees will be when they take the surveys. Will they have chairs and tables, or be standing in a shop or in a stope underground? (Clip boards may be required, and 10 to 12 should always be available.)
3. Is the relationship between management and hourly employees cordial? If not, will this affect the way hourly employees respond to the survey, and to the researchers?

4.4.1.3. Survey Administration

The researchers’ demeanor and presentation will have a significant influence on the successful administration of the survey, especially when surveying hourly employees, who may be skeptical of “college people.”

The research team will usually comprise two or three people. One

person (the survey director) should introduce the researchers and explain the project. This person should be capable of engaging the respondents' attention, putting them at ease, and maintaining a friendly and relaxed atmosphere while the survey is taken.

One or two other researchers should assist with distributing the survey forms and providing pens and clip boards to those who need them. These researchers can also help in creating and maintain a friendly and relaxed atmosphere, but should not distract attention from the survey director.

When surveying hourly employees, it is particularly important to offer continuing assurance that the results of the survey will not reveal the responses of any individual. Supervisors and managers should leave the room, so that hourly employees are not intimidated by their presence.

Often the best insights into the culture and climate of a workplace are gained in conversation with employees. This is especially true when researchers can engage in conversation with hourly employees. In doing this, the skills of the survey director are critical. The director must able to gain the confidence of the survey group and engage them in conversation. The director should watch for workers who are having side conversations among themselves, and encourage them to speak openly.

As the surveys are completed, researchers should collect and organize them, keeping track of which group to which they belong: office employees, maintenance crew B, operations crew A, etc.

4.4.2 Completion of SHMS Assessment Matrix

During each mine visit there were numerous opportunities to converse with safety personnel at the site. Surveys were administered to as many hourly shifts as possible, and there was usually time between the shift changes for such conversations. Those conversations provided an ideal opportunity to discuss safety management at the site. Safety personnel were almost always open and honest in describing their approaches to safety management.

The project team also made an effort to meet with the mine manager at each site visited. This often required making an appointment prior to the visit, and was sometimes not possible. Unlike the safety personnel, mine managers were usually more guarded in these discussions.

Project team members had ample opportunity to discuss their observations and conversations with one another during each visit. The Assessment Matrix for a given visit was often completed during the return travel from the visit, or during a meeting thereafter. Team members discussed their observations and consulted their notes, and then came to a consensus of the rating to be assigned to each element in the Matrix, for the mine and the visit in question.

A completed SHMS Assessment Matrix for one mine is included in Appendix E.

4.4.3 Data Processing and Reporting

The completed surveys were scanned as Adobe Acrobat (.pdf) documents. The availability of a sheet-feed scanner in the office of the Mining Engineering Department was invaluable in this process. To facilitate the digitization of the data, it was important to ensure that all the survey forms were oriented correctly—top to bottom and back to front.

The scanned surveys were digitized using the Remark Office OMR software from Gravic, Inc. This software digitized each page of the Acrobat file, using a template designed to reflect the layout of the survey form. The digitized files required manual checking, for correction of contradictory or unclear responses, but such corrections usually included less than 10% of the data. The scanning and correction of the surveys from a single mine site could usually be completed in six to eight hours.

The digitized Remark files were exported to Microsoft Excel, unpivoted,[2] and saved a master data file for analysis. These files were large—eight columns by 4,000 to 11,000 rows, depending on the number of survey respondents.

The unpivoted master data file for each visit was used to prepare an Excel Workbook for each visit. The Workbook included the master data file, instructions on using Excel to prepare charts and graphs from the master data file, and a list of the survey questions.

A summary report was prepared for each visit Each report contained the following information:

1. An explanation of the survey and the Likert scale.
2. The average responses to all the statements in the survey
3. The survey statements (usually four or five) that received the *highest* average response.
4. The survey statements (usually four or five) that received the *lowest* average response.
5. Examples of graphs that were prepared from the Excel Workbook

The Excel Workbook and the summary report were sent to the mine manager and safety manager at each site, as well as to other personnel who requested copies. A sample summary report is included as Appendix F.

[2] For a discussion of unpivoting, see Excel University. 2020. Unpivot Excel Data https://www.excel-university.com/unpivot-excel-data/

4.4.4 Summary of Data

Table 4.4.4.1 shows the average perception values of the four Assessment Variables (Culture, Leadership, MSHA Compliance, and Risk Management) for each mine visit, as indicated by the survey results.

Table 4.4.4.1 Average Perceptions of Survey Assessment Variables

		Average Perception of Assessment Variable				
Mine	Visit	Culture	Leadership	Risk Management	MSHA Compliance	Average, All Four Variables
1	1	3.66	3.40	3.25	3.72	3.53
	2	3.49	3.27	3.54	3.45	3.37
2	1	3.51	3.66	3.12	3.57	3.54
	2	3.62	3.49	3.59	3.56	3.54
3	1	(See note 1 below)				
4	1	4.19	3.98	3.64	4.10	4.04
	2	3.42	2.88	3.51	3.28	3.12
	3	3.42	2.88	3.51	3.28	3.12
5	1	3.62	3.37	3.79	3.60	3.51
6	1	3.66	3.58	3.71	3.59	3.61
7	1	3.73	4.00	4.15	3.64	3.88
8	1	3.47	3.77	3.92	3.45	3.65
9	1	3.67	3.63	3.77	3.65	3.65
	2	3.57	3.54	3.56	3.53	3.54
	3	3.71	3.64	3.81	3.71	3.68
10	1	3.51	3.27	3.56	3.46	3.45
	2	3.82	3.87	3.84	3.91	3.86
	3	3.85	3.89	3.74	3.88	3.86
11	1	2.52	2.48	2.61	2.52	2.50
12	1	4.04	4.18	4.22	4.33	4.18
13	1	3.83	3.73	3.84	3.78	3.77
14	1	(See note 2 below)				

Notes: 1. Mine 3 was closed shortly after the first visit, so the data were not analyzed

2. Visit 2 to Mine 7 was cancelled because that mine closed on the day of the scheduled visit. The company instead scheduled a visit to Mine 14. Since no followup was possible, the survey data were not analyzed.

The values in Table 4.4.4.1 range from 1 to 5, with a rating of 1 indicating a fully negative response to a survey statement regarding a given variable, and a rating of 5 indicating a fully positive response.

Table 4.4.4.2, on the next page, shows the SHMS Assessment Matrix ratings for each of the mine visits.

Table 4.4.4.2 SHMS Assessment Matrix for Each Mine Visit

Mine	1		2		3	4			5	6	7	8	9			10			11	12	13	14
Visit	1	2	1	2	1	1	2	3	1	1	1	1	1	2	3	1	2	3	1	1	1	1
Risk Management and Fatality Prevention	4	4	See note below.	4	2	2	3	3	2	2	4	4	4	4	4	4	4	4	4	1	5	4
Behavior Based System	5	5		5	2	2	3	3	2	2	4	4	4	2	2		4	4	3	1	4	4
Responsibility, Accountability, and Competence	4	4		4	5	5	5	5	4	4	4	4	4	3	3	5	5	5	3	4	4	4
Emergency Management	4	4		4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	3	5	5
Work Procedures	4	4		4	2	2	2	2	2	2	4	4	4	4	4	5	5	5	4	3	4	4
Incident and Reporting and Permits	3	3		3	3	3	3	3	4	3	4	4	5	5	5	5	5	5	4	3	4	4
Occupational Health	3	3		3	4	4	4	4	4	4	4	4	3	3	3		4	4	4	3	4	4
Training	3	3		3	3	4	4	4	3	3	5	5	4	4	4	4	4	4	5	1	4	5
Documentation and Information Management	1	2		2	2	2	3	3	4	4	5	5	4	3	3	4	5	5	5	1	5	5
Change Management	2	1		1	2	2	2	2	3	3	4	4	2	3	3		4	4	3	1	4	3
Construction and Contractor Management	3	2		2					3	3	4	4	5	3	3	5	4	4	4	1		4
Engineering	2	2		2	5	5	5	5	5	5	4	4	4	3	3	4	4	4	4	2	4	4
Purchasing	2	2		2	2	2	2		2	2	4	4	2	2			4	4	4	1	4	4
Resources and Planning	2	2		2	5	5	3	2	5	3	1	1	4	2	2	4	4	4	2	2	5	2
Leadership and Professional Development	2	2		2	5	5	5	2	5	4	1	1	2	2	2	4	4	4	2	2	4	2
Collaboration and Communication	2	2		2	5	5	5	2	5	4	1	1	4	2		4	4	4	3	4	4	1
Reinforcement and Recognition	4	3		3	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	3	4	4
Culture Enhancement	2	2		2	5	5	5	5	5	5	2	2	4	2	3	4	4	4	4	2	4	4
Assurance									4	4	4	4	1	1	1	3	3	3	4		4	4
Overall (Average)	2.9	2.8		2.8	3.5	3.6	3.6	3.3	3.7	3.4	3.6	3.6	3.6	2.9	3.1	4.2	4.2	4.2	3.7	2.1	4.2	3.7

Note: Mine 2 used its own personnel to administer the first survey, so project personnel were unable to complete the SHMS Assessment Matrix.

4.4.5 Data Analysis

The study generated a large data set, and there are many relationships that can be analyzed from that data. To date, two M.S. theses have been based on the data set, and a Ph.D. dissertation is in progress.

4.4.5.1 Initial Analysis

The thesis by Hodgson (2018) used data from the first visits to Mines 1, 3, 5, 6, 7, and 8 to examine five hypotheses:

1. There is a negative correlation between employee perceptions of a mine's SHMS and the MSHA injury and citation rates for that mine.
2. There is a negative correlation between employee perceptions of a mine's MSHA compliance and MSHA the MSHA injury and citation rates.
3. There is a negative correlation between employee perceptions of a mine's risk management and the MSHA injury and citation rates.
4. There is a negative correlation between leadership and the MSHA injury and citation rates.
5. There is a negative correlation between employee perceptions of a mine's culture and the MSHA injury and citation rates.

The first hypothesis was analyzed based on the average of the responses of the employees surveyed at a given mine, characterizing their perceptions of the four Assessment Variables. In the analyses of the four remaining hypotheses, employee responses for each Assessment Variable were averaged.

Each survey's responses were sorted into the four variable groups and the respective ratings were averaged, yielding an overall score per variable per survey. The average variable scores were the correlated with the 2016 MSHA data: operator injuries, contractor injuries, and citation rates per site, by calculating the Spearman's Rho correlation for each relationship. The results are shown in Table 4.4.5.1. All are significant at the 0.01 level (2-tailed).

Table 4.4.5.1 Single-Factor Spearman's Rho Correlations

Variable	Employee Injuries	Contractor Injuries	MSHA Citations	Average, Each Variable
Leadership	**-0.313**	-0.236	-0.207	**-0.252**
Risk Management	-0.198	-0.054	**-0.287**	-0.180
Culture	**-0.277**	-0.084	**-0.331**	-0.231
MSHA Compliance	-0.039	-0.016	0.019	-0.012
Average, All Variables	-0.207	-0.098	-0.202	-0.169

The *negative* correlations indicate that, as employee perception of each Assessment Variable increases, injury and citation rates decrease.

There are five generally recognized levels of correlation between two variables (*Statistics Solutions* 2016):

1.00 > 0.75 – high correlation,

0.75 ≥ 0.50 – moderate correlation,

0.50 ≥ 0.25 – low correlation, and

0.25 – 0.00 – no correlation.

Figure 4.4.5.1 shows the correlation values graphically. The dashed line at –0.25 indicates the level of no correlation.

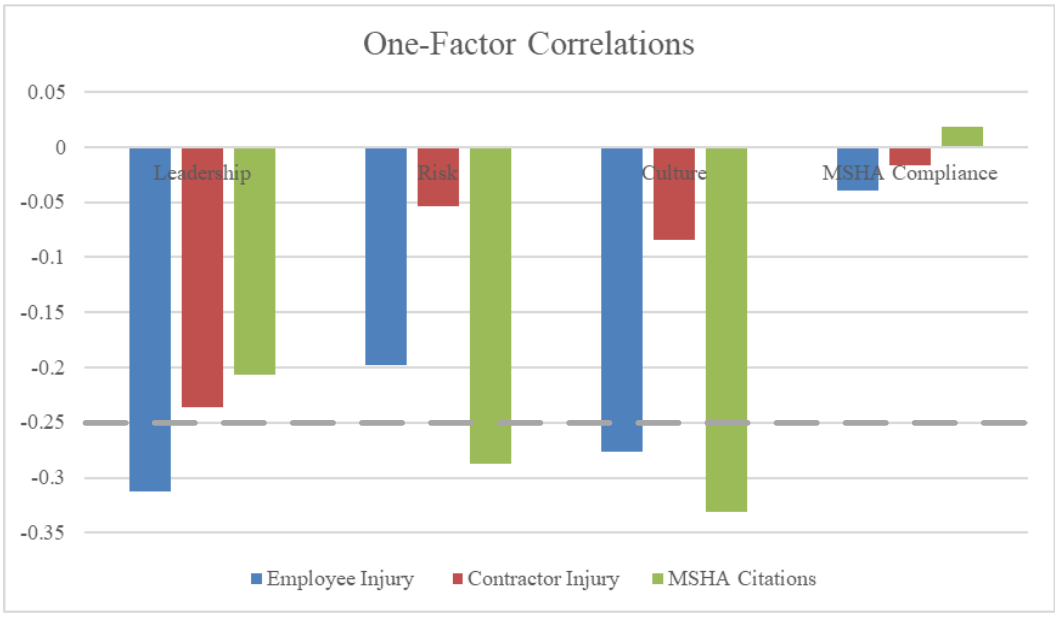

Figure 4.4.5.1 One-factor Correlations of Assessment Variables with MSHA Data

The analysis showed that there is a low correlation between employee perception of a mine's SHMS (as characterized by perceptions of the four Assessment Variables) and its MSHA injury and citation rates, supporting Hypothesis 1. None of the correlations are strong or moderate; the four highest correlations (shown in bold type) are close to 0.3, indicating low correlation. This is not surprising, due to the lack of variability in the 21 dependent variables, comprising employee injuries, contractor injuries, and MSHA citations for seven mines.

Almost all of the calculated correlation values in Figure 4.4.5.1 are negative, supporting Hypotheses 2–5, and indicating that as employee perception of each Assessment Variable increases, injury and citation rates decrease. Although these correlations are not strong, they do indicate show that there is a relation between each of the four assessment variables and a decrease in injury and citation rates. The only positive correlation in Figure 4.4.5.1 is between employee perception of MSHA compliance and MSHA citations for the site. This is curious, but because the value is very low, it is not considered significant.

It is worthwhile to note that, of the average correlation values for each of the four Assessment Variables with the safety statistics, as shown in Table 4.4.5.1, only the Leadership variable shows even a *low* correlation. This is in accordance with the researchers' perception over many visits that Leadership is one of the most important components of safety and health management.

The preceding discussion describes a *one-factor* analysis, which examines the correlation of a single variables from two categories. A *two-factor* correlation can sometimes often offer additional insight.

A two-factor correlation is a measure of how well a linear function of two variables correlates with a single, given variable. Here the correlation of MSHA injury and citation rates with the products of the average employee approval of various pairs the assessment variables was examined, again by calculating the Spearman's Rho correlation for each relationship, at a 2-tailed significance level of 0.01. The results are shown in Table 4.4.5.2, which gives the correlation of each safety statistic with the two Assessment Variables in the first column.

Table 4.4.5.1 Two-Factor Spearman's Rho Correlations

Variables	Employee Injuries	Contractor Injuries	MSHA Citations	Average, Each Variable
Leadership*Culture	**-0.322**	-0.180	**-0.288**	**-0.263**
Leadership*Risk Management	**-0.281**	-0.159	**-0.270**	-0.237
Leadership*MSHA	-0.181	-0.130	-0.090	-0.134
Culture*Risk Management	**-0.248**	-0.069	**-0.327**	-0.215
Culture*MSHA	-0.158	-0.046	-0.147	-0.117
MSHA*Risk Management	-0.130	-0.040	-0.136	-0.102

This analysis yielded results similar to those in the one-factor analysis. It indicates that employee perceptions of Leadership and Culture have the highest correlation with the safety statistics, again comporting with the observations of the research team. However, that correlation is still low. Figure 4.4.5.2 again allows visualization of these data.

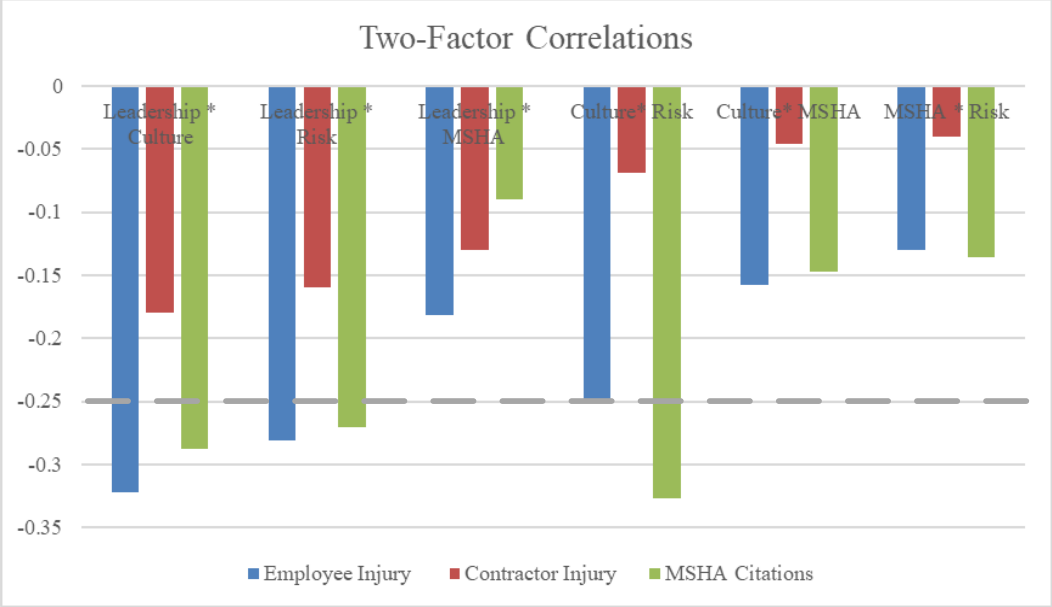

Figure 4.4.5.2 Two-factor Correlations of Assessment Variables with MSHA Data

4.4.5.2 Two-visit, Longitudinal Analysis

The thesis by Richins (2019) used data from five mines, Mines 1, 2, 4, 9, and 10. Each of these mines had been visited twice. Richins examined a single hypothesis:

1. There is a longitudinal correlation between employee perception of a mine's SHMS, as reflected in the four Assessment Variables, and MSHA injury and citation rates.

The data analysis from the Hodgson thesis has been presented in detail for two reasons: First, to show the statistical methods and rigor that were applied, and second, because it showed some correlation between the assessment variables and MSHA metrics.

In Richins' analysis, the changes in Likert scores from the first survey to the second survey were compared with the change in the monthly frequencies of reported injuries and MSHA citations. This was done by determining the number of months, *n*, between the two surveys at each mine, then tabulating the monthly MSHA injury and citation data beginning at a point *n* months before the first visit. The monthly frequencies were then calculated for *n* months before the first visit, for the *n* months between the first and second visits, and for months between the second visit and the time at which the analysis was made, in June of 2019.

The data analysis from the Richins thesis will not be presented in detail, again for two reasons: First it is voluminous, comprising analysis of more than 126,000 individual data, resulting in 12 tables and 45 graphs; second, because almost no correlation among the two groups of variable was observed.

The hypothesis would have been confirmed if the analyses had shown a correlation between changes in perception of one or more of the Assessment Variables and changes in the MSHA injury or citation rates. Correlations between the two groups of variables were examined for five sites, resulting in 40 correlation analyses. Although parallel movement was seen in some instances, a statistically significant correlation was observed in only one case, and that correlation was weak.

Richins offers a cogent analysis of why so little correlation was observed:

1. Testing for longitudinal correlations implicitly assumed changes in SHMS implementation would be the primary variable with time. This was not true. Other factors— ownership changes, management changes, and ongoing industry-wide changes, especially in the coal industry, were more significant in influencing the study's variables.
2. Evaluation of SHMS effectiveness by comparing reportable accidents and MSHA violations and citations is constrained by the nature of the MSHA data. These criteria are subject to variation depending on local conditions, and to changes in MSHA procedures and personnel, and it is difficult to control for these variations. A much better analysis could be made by having researchers visit a given mine two or three times each year, and combining the observations made during those visits with survey results and MSHA data to make an assessment of the effectiveness of the safety and health management at that mine.

Richins further describes conditions the conditions and changes at each of the five mines that seem likely to have affected the outcome of the analysis. The following material is quoted from her thesis.

- **Mine 1** has a strong labor union, and the union-management relationship is very antagonistic. Mine 1 also has a few employees who seemed to be particularly

antagonistic towards mine management. Mine 1 had a new mine manager and new safety coordinator at the time of the first visit.

The safety coordinator reported that, on days when an MSHA inspection is not scheduled, union employees are likely to call MSHA's toll-free number to report an "unsafe condition," so that an MSHA inspector will come to the site. Mine 1 thus has four or five MSHA inspections weekly; this doubtless contributes to its high rate of MSHA violations.

Before the second visit by the project team, a new safety coordinator was appointed, and Mine 1 adopted a "simplified version" of the CORESafety program. Accident and violation rates had decreased at the time of the second visit, and continued to do so up to the present time.

- **Mine 2** is the largest of the five mines discussed in this study. The surveys at Mine 2 included employees in the mine and the mill. Hourly employees at Mine 2 have been unionized for many years, and union-management relations are sometimes antagonistic. Mine 2 is owned by a large, multi-national corporation, and because of its size, the facility receives frequent inspections from MSHA. In addition, employees at the site—both hourly and salaried—expressed frustration at the fact that many important decisions were made at regional or corporate headquarters.

  Mine 2 participates in the official, corporate safety health management system, and in several other programs that the corporation has instituted to improve employee health and safety. Employees expressed consternation that there were so many policies and procedures that it could "take a day to get all the permits needed to change a tire." Mine 2 also has frequent changes in its organizational structure, and in senior management personnel. The entire operation includes the mine, mill, and metallurgical processing plants, and the corporation appoints a new general manager every two to four years.

  The hourly workers seemed to feel little or no loyalty to the company, or indeed to one another. It appears that this is, at least in part, because the workforce is large, and is drawn from a wide geographic area that includes cities, suburbs, and rural communities, and because management personnel and policies change frequently.

  The survey results showed little change in employee perceptions from the first to the second visit. In the same interval, accident frequency increased slightly and violation frequency increased markedly. In contrast, from the second visit to the present time, frequency of violations decreased, while that of accidents increased.

  During the second visit, the research team learned that the number of employees dealing solely with worker safety at the site had been reduced to just one. There had previously been a safety department of six to 10 individuals. The manager of the mine and mill explained that the HR Department, which is located in another country, had decided that individual workers should be responsible for their own safety, since it's obviously in their interest to be safe. The research team spoke with the only "safety guy," who reported that he spends almost all of his time doing paper work.

- **Mine 4** is in a rural area, and most of the workers live in the small communities close to the mine. The employees associate with one another in their communities, schools, and churches.

  The first visit to Mine 4 showed a strong leadership, in which the mine manager had a personal relationship with virtually every employee. There was also a strong

communal culture, in which employees openly expressed their concern and affection for their co-workers. All this was reflected in the survey results, and in the low rate of accidents. The workforce is racially diverse, but this did not appear to cause any problems with safety management and workplace culture.

In the second visit, discussions with mine employees found that the mine manager, who had taken on additional corporate duties, was less involved with the employees on a day-to-day basis. The survey results for the Assessment Variables were lower in the second visit. Although the changes were not statistically significant, these were the largest year-on-year changes observed in any of the mine visits. Also notable was the increase in the monthly accident frequency following the second visit. This change indicates that changes in leadership may be a significant leading indicator for safety performance.

Mine 4 also had very few MSHA violations, but, this could be at least partly due to the much lower number of inspections—sometimes only one per year—made by MSHA at this mine.

- **Mine 9** is in a remote location, and draws its workforce from a wide area. Many workers commute large distances (as much as 3,000 miles) for their two-week rotations. The surveys at Mine 9 included employees in the mine and in the mill.

  Accident and violation frequencies decreased markedly between the first and second visits to Mine 9, and again from the second visit to the present time. The company that owns Mine 9 had adopted CORESafety shortly before the research team made its first visit to the site. However, these improvements should not be attributed to the implementation of CORESafety, because in the second visit, none of the hourly employees had heard of CORESafety, and the safety coordinator said they “hadn’t really got into it yet.” Employee perceptions, as reflected in the survey results, showed essentially no change from the first to the second visit.

- **Mine 10** is similar is some ways to Mine 4. It is in a rural area, where most of the workers have close associations outside work. However, the workforce is not racially diverse. The surveys at Mine 10 included employees in the mine and in the mill.

  There is a strong communal culture at Mine 10. The safety coordinator is very proud of his profession, and of the fact that he is carrying on a family tradition begun by his grandfather, who was a manager of safety for one of the large, national railroads.

  The frequency of accidents and of violations increased between the first and second visits, but the survey results do not indicate any change in employee perceptions over that interval. The safety coordinator had a heart attack during that time, and also experienced a serious family tragedy. These events may have affected his performance at work.

4.4.5.3 Mine Visits, Third Round

At the conclusion of the analysis of the five mines that were visited twice, project personnel intended to complete a third visit to each of the mines that were visited in that study. The third visit to Mine 4 was made in August 2019, the third visit to Mine 10 was completed in October 2019, and the third visit to Mine 9 was completed in January 2020. (All of these visits were completed with funding from the University of Utah, or with personal funds. ***Project closeout funds will not be used to offset these expenses.***)

The ownership of Mine 1 was changed as the result of a bankruptcy, and the new owners did not want to schedule another visit for at least a year. The mine manager at

Mine 2 stated a willingness for a third visit early in 2020, but a change in corporate management early in the delayed scheduling, and now the mine is operating on under special procedures as a result of the Covid 19 pandemic.

The data from the third visits to Mines 4, 9, and 10 are being processed, and study personnel are maintaining contact with Mines 1 and 2. The author of the two-year longitudinal study, Amy Richins, received a Ph.D. Fellowship grant from the Society for Mining, Metallurgy, and Exploration (SME), and thus has funding to pursue a Ph.D. in continuation of this study.

5.0 Summary of Accomplishments

5.1 Tasks Accomplished

1. The study assembled and reviewed 114 pertinent references, 80 related to safety, health, and safety and health management; 34 related to statistical analysis and survey design. Those references are listed in section 9.0 of this report.
2. The study analyzed the conceptual design of safety and health management systems (SHMSs), and developed a list of the benchmark elements in such a system.
3. The study then analyzed the elements 28 SHMSs, eight from government or other non-profit organizations and 10 from companies in the mining industry. This analysis revealed three important things:
    a. CORESafety is the *only* SHMS that includes all the elements of the benchmark scheme.
    b. The greatest deficiencies occured in the Improvement/Integration area. All deficiencies are in areas related to human behavior and human interaction.
    c. With the exception of CORESafety, the SHMSs from non-profit organizations show a greater deficiency in the Improvement/Integration area than do the SHMSs from companies in the mining industry.
4. The study designed a survey to assess employee perception of four variables—Culture, Leadership, Risk Management, and MSHA Compliance—related to safety and health management systems in U.S. mines. The adequacy of the survey was verified using standard statistical methods.
5. The study devised a systematic method, the SHMS Assessment Matrix, for assessing the implementation and effectiveness of the safety and health management system at a given site.
6. The study made 22 visits to 14 mines, administered the perception survey at each mine, and completed the SHMS Assessment Matrix for each mine.
7. The study scanned, digitized, and analyzed the data from 20 of the 22 mine visits.
8. The study developed a standard method for processing survey data.
9. The study completed a preliminary analysis of the data from the first seven mine visits, and found weak correlations between some of the assessment variables and injuries and MSHA citations.

10. The study completed a longitudinal study of the five mines that were visited twice. This study found only one instance of correlation between the assessment variables and reported incidents and MSHA citations, and that correlation had a low statistical significance.
11. Study personnel completed and successfully defended two M.S. theses and one M.E. technical report. Personnel also published two papers, made two invited presentations, and seven conference presentations.
12. On the basis of her work in the study, one of the study personnel, Amy J. Richins, received an SME Ph.D. Fellowship, in the amount of $60,000 per year for up to four years. This fellowship will allow Ms. Richins to continue her analysis of the data gathered and observations made during the study, and to conduct additional visits to some of the mine sites that participated in the study.

5.2 Accomplishment of Objectives

The project proposal lists many objectives and sub-objectives, all of which have been condensed into five objectives for assessment.

Objective 1 Conduct a cross-sectional assessment of safety and health management philosophies, strategies, prerequisites, priorities and SHMS approaches, structures, resources and performance metrics at a minimum of 15 U.S. mines.

The study completed assessments of health and safety management at 14 sites. This was done in spite of significant changes in the mining industry during the study period, which changes made it difficult to schedule and complete those assessments.

Objective 2 Perform longitudinal surveillance of parameters identified in objective one, and track SHMS and regulatory compliance performance metrics for two years to allow for an adequate intervention effect.

Five of the 14 mines visited were visited twice, over a period of two years. Analysis of the data from these visits found no longitudinal correlations that were statistically significant.

Objective 3 Find the most effective variables for the development and implementation of risk management-centered SHMSs in U.S. mining.

The large body of data gathered in the study did not demonstrate that the effectiveness of the assessment variables (Culture, Leadership, Risk Management, and MSHA Compliance) on the effectiveness of SHMSs, as characterized by MSHA data. However, based on observations and conversations during the mine visits the personnel who conducted the study agreed that effective leadership and effective development and maintenance of a good workplace culture were the most important components of safety management.

Objective 4 Determine the relative effectiveness of MSHA regulatory compliance in relation to the impact of SHMSs in lowering mining operational risk and associated safety and health morbidity and mortality.

The first seven mine visits found only slightly significant correlation between employee perceptions of MSHA compliance with employee and contractor injuries, and MSHA citations. Longitudinal analysis of data from mines were visited twice showed only one,

very weak correlation in the 40 correlations that were calculated.

Objective 5 Complete a detailed closing assessment repeating phase one to clearly define the organizational, regulatory, and safety performance impacts of the SHMS.

This report constitutes the closing assessment.

6.0 Papers and Presentations

To date, the following papers have been written and presentations have been made on topics describing the outcomes of this project:

Hodgson, A.D. 2018. *Intervention Effectiveness of Safety Health Management Systems: Initial Assessment*. M.S. Thesis. Salt Lake City: The University of Utah.

Hodgson, A.D., Nelson, M.G., Richins, A.J., and Rogers, W.P. 2018. Preliminary Analysis of SHMS Intervention Effectiveness with MSHA Data, SME Annual Meeting, February 24–29, Minneapolis, Minnesota.

Hodgson, A.D., Nelson, M.G., Richins, A.J., and W.P. Rogers. 2018. On-site Assessment of Safety and Health Management Effectiveness, SME Annual Meeting, February 24–29, Minneapolis, Minnesota.

Richins, A.J. 2019. *Intervention Effectiveness of Safety Health Management Systems: Secondary Assessment*. M.S. Thesis. Salt Lake City: The University of Utah.[3]

Richins, A.J., and Nelson, M.G. 2019. Leadership and Culture—Two Key Elements in Safety and Health Management. Invited presentation to Newmont and Goldcorp Technical Meeting, March 20, Greenwood Village, Colorado.

Richins, A.J., Nelson, M.G., Hodgson, A.J., and Rogers, W.P. 2018. On-site Assessment of Safety and Health Management System Effectiveness. Seventh National Occupational Injury Research Symposium (NOIRS**),** Morgantown, West Virginia, October 16–18. (Invited presentation; abstracts refereed.)

Richins, A.J., Wallin, and Nelson, M.G. 2020. Intervention Effectiveness in Safety Management—Quantifying Qualitative Data. SME Annual Meeting. February 22–27, Phoenix, Arizona.

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[3] The Richins thesis has not yet been released by the Graduate School. A draft copy is sent with this report as a separate document.

[4] A copy of this preprint is sent with this report as a separate document.

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The abstracts for the theses and the technical report are presented in Appendix C.

7.0 Conclusions and Impact Assessment

7.1 Conclusions

1. Preparation and administration of employee surveys at mine sites requires careful technical and logistical preparation.
2. Understanding the safety and health management practices and system at each site requires empathetic observation and conversation with as many site employees as possible.
3. Conditions at mine sites change often and change unexpectedly. This makes it difficult to conduct longitudinal studies at those sites. Meaningful longitudinal effects the implementation of an SHMS will probably not be measurable over a period of two or three years, because changes at the sites will likely overwhelm the effects of implementing the SHMS.
4. A well-designed safety and health management system can contribute to employee health and safety, but such a system alone is not sufficient to guarantee improvement in safety and health outcomes. At some sites visited by the project, the mechanical, procedural components of CORESafety were being followed to the letter, but hourly employees told project personnel that "…the only thing that matters underground is *tons*."
5. The most important components of safety and health management are exercise of effective leadership and development and maintenance of a positive workplace culture.

7.2 Impact Assessment

1. This study advanced the knowledge of the effective design and administration of large-scale, longitudinal surveys in the U.S. mining industry. It also identified some of the systemic difficulties in conducting such studies in the U.S. mining industry.
2. This study identified the key elements of a benchmark safety and health management system. It also showed that CORESafety is the *only* SHMS that includes all of those 20 elements, and that the deficiencies of the 18 other SHMSs analyzed were in the Improvement/ Integration area—all in areas related to human behavior and human interaction.
3. This study showed that, in many cases, data from MSHA, such as incidence and citation rates, may not be suitable as dependent variables, because those data are often sparse, and subject to change based on administrative policies and individual site-specific practices and conditions.

4. The study found that, while a well-designed and effectively implemented SHMS can contribute greatly to the safety and health of mine employees, such a system may not guarantee good health and safety practices. If leadership is lacking, and the workplace culture does not communicate the importance of health and safety to all the employees, injuries will continue to occur.
5. The study observed that, in every case, mine leadership and mine culture were the most important factors in establishing and maintaining a safe and healthy workplace.

As noted above, one of the graduate students who participated in the project has successfully received funding—a 4-year fellowship—to allow continuation of this research, leading to a Ph.D.

8.0 Recommendations for Future Work

The following tasks are recommended for future work:

1. Continue annual assessment visits to the three mines that were visited three times during this study.
2. Improve the SHMS Assessment Matrix for use in assessing leadership and culture in workplaces.
3. Examine leadership development systems and courses, to determine those that are most likely to be successful in the mining industry.
4. Develop a collection case histories and specific examples of successful leadership and culture development and enhancement at mine sites.
5. Develop training methods and materials for improving leadership and culture development practices in the mining industry.

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References are listed in two groups, those pertaining to safety and health management, and those pertaining to statistical analysis and survey design.

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10.0 Appendices

10.1 Appendix A: Dalrymple Scheme for SHMS Systems

OHSMS Elements (Dalrymple Scheme)
INITIATION (OHS Inputs)
Management Commitment and Resources
Regulatory Compliance and OHSMS Conformance
Accountability, Responsibility, and Authority
Employee Participation
FORMULATION (OHS Process)
Occupational Health and Safety Policy
Goals and Objectives
Performance Measures
System Planning and Development/Implementation
Baseline Evaluation and Hazard/Risk Assessment
OHSMS Manual and Procedures
IMPLEMENTATION/OPERATIONS (OHS Process)
Training System
Technical Expertise and Personnel Qualifications
Hazard Control System
Process Design/Management Of Change
Emergency Response
Hazardous Agent Management
Preventive and Corrective Actions
Procurement and Contractor Selection
EVALUATION (OHS Feedback)
Communication System
Document and Record Management System
Evaluation System
Audit and Self-Inspection
Incident Investigation and Root Cause Analysis
Medical Program and Surveillance
IMPROVEMENT/INTEGRATION (Open System Elements)
Continual Improvement
Integration
Management Review

Source: Data from Dalrymple et al. 1998.

10.2 Appendix B: Dalrymple Scheme as Modified by Seiter (2017)

OHSMS elements (Modified Dalrymple Scheme)
Plan, Do, Check, Act Ideal
INITIATION (OHS Inputs)
Scope, Purpose, Application (Additional)
Initial Review (Additional)
Management Commitment and Resources
Regulatory Compliance and OHSMS Conformance
Accountability, Responsibility, and Authority
Employee Participation
FORMULATION (OHS Process)
Occupational health and safety policy
Goals and Objectives
Performance Measures
System Planning and Development/Implementation
Baseline Evaluation and Hazard/Risk Assessment
OHSMS Manual and Procedures
IMPLEMENTATION/OPERATIONS (OHS Process)
Training System
Technical Expertise and Personnel Qualifications
Hazard Control System
Process Design/Management of Change
Emergency Response
Hazardous Agent Management
Preventive and Corrective Actions
Procurement and Contractor Selection
EVALUATION (OHS Feedback)
Communication System
Document and Record Management System
Evaluation System
Audit and Self-Inspection
Incident Investigation and Root Cause Analysis
Medical Program and Surveillance
IMPROVEMENT/INTEGRATION (Open System Elements)
Continual improvement
Integration
Management Review
Supplementary information (Additional)
Success Factors (Additional)
Culture Enhancement (Additional)
Reinforcement and Recognition (Additional)
Behavior Optimization (Additional)

10.3 Appendix C: Mine Surveys

10.3.1 Mine Survey Questions, Survey 1

Question	Variable
All employees at this mine/facility understand their specific safety responsibilities	Culture
Discipline is administered fairly and equitably at this mine	Culture
Drugs and alcohol are a safety problem at this mine	Culture
I am confident about what to do in an emergency	Culture
I am uncomfortable when there has not been an incident in a long time	Culture
I believe all incidents are preventable	Culture
I feel responsible for my safety and the safety of my co-workers	Culture
I work just as safely when the supervisor/manager is not around	Culture
Management/leadership does not knowingly compromise safety for productivity	Culture
Minor incidents cause so much hassle they are often ignored	Culture
Task training here is effective	Culture
Teamwork is valued to get things done at this mine	Culture
The culture of this mine/facility makes it easy to learn from the mistakes of others	Culture
This mine/facility has clear procedures for those who violate safety rules and procedures	Culture
A high priority is placed on safety training and learning	Leadership
Changes to my workplace and work procedures are communicated to me	Leadership
Contractors are consulted about safety issues whenever necessary	Leadership
Employees are held accountable for following safety rules and procedures	Leadership
Employees at this mine/facility are encouraged to stop co-workers from behaving unsafely	Leadership
Employees often receive positive recognition from managers for exhibiting safe behaviors	Leadership
I have a fair opportunity to influence the decisions made by my superiors	Leadership
I receive appropriate feedback about my work performance	Leadership
I regularly see management people in the mine	Leadership
I trust my coworkers	Leadership
I trust my supervisor(s)	Leadership
I trust senior management	Leadership
Injured workers get the blame after an incident	Leadership
Management is aware of the day-to-day conditions in my workplace	Leadership
Safety is constantly reinforced as a value in this mine/facility	Leadership
Safety professionals have an accurate perception of safety at this mine/facility	Leadership
Supervisors and managers are responsible for safety outcomes in this mine	Leadership
Almost all incidents, including injuries, property damage, and near misses, are reported	MSHA Compliance
Personnel frequently disregard rules or procedures that are established for this mine/facility	MSHA Compliance
The right equipment is available to get the job done safely	MSHA Compliance
The rules and procedures do not always describe the safest way of working	MSHA Compliance
I sometimes feel under pressure from my coworkers to take chances	Risk Management
I would feel safe having my adult children work here	Risk Management
In my workplace managers work quickly to address safety problems	Risk Management
In my workplace the chances of being involved in an incident are quite high	Risk Management
Management clearly considers the safety of employees to be of great importance	Risk Management
Managers and workers are trained to recognize the visible and unseen hazards of their work	Risk Management
This mine/facility will stop work because of safety concerns, even if it means losing money	Risk Management

10.3.3 Mine Survey Version 3, Sample Survey Form

Page 1

University of Utah Alpha Project 2016

I am a (mark all that apply):

- o Frontline Supervisor
- o Middle Manager
- o Senior Manager
- o Member of Support/Technical Services
- o Hourly Employee
- o Contractor

I have:

- o 0 – 1 Years of work experience at this mine
- o 2 – 5 Years of work experience at this mine
- o 6 – 10 Years of work experience at this mine
- o 10+ Years of work experience at this mine

Years with this company _____

	Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
All injuries are reported in this mine.	o	o	o	o	o
At this mine, lessons learned from past incidents prevent future incidents.	o	o	o	o	o
Workers always stop to assess the risk(s) of the task they are about to do.	o	o	o	o	o
This mine's safety training is effective.	o	o	o	o	o
Complying with MSHA regulations is important to keep this mine safe.	o	o	o	o	o
Workers receive recognition when they do an outstanding job.	o	o	o	o	o
Workers can shut work down if it's unsafe or if other problems arise.	o	o	o	o	o
All workers and managers are aware of the worst risks at this mine.	o	o	o	o	o
Unsafe acts are not tolerated by other workers at this mine.	o	o	o	o	o
I trust my supervisor.	o	o	o	o	o
I trust senior management in my organization.	o	o	o	o	o
Workers always follow "safe work" procedures at this mine.	o	o	o	o	o
It is possible for this mine to operate without injuries.	o	o	o	o	o
Hazards are identified and corrected in an appropriate amount of time.	o	o	o	o	o
My work area is safe.	o	o	o	o	o
I work just as safely when the supervisor/manager is not around.	o	o	o	o	o
Everyone in this mine is held accountable for their responsibilities.	o	o	o	o	o
My supervisor and I communicate well.	o	o	o	o	o
Workers are responsible for their own safety at this mine.	o	o	o	o	o
Supervisors and managers are responsible for safety outcomes in this mine.	o	o	o	o	o
The equipment used by workers in this mine is properly maintained.	o	o	o	o	o
Workers are not pressured to cut safety corners for production at this mine.	o	o	o	o	o
Unsafe acts are allowed by supervisors at this mine.	o	o	o	o	o
Supervisors in this mine are committed to providing a safe workplace.	o	o	o	o	o
Workers understand what their supervisor expects of them in this mine.	o	o	o	o	o
Workers at this mine are encouraged to find better ways to do things.	o	o	o	o	o
Discipline is administered fairly and equitably at this mine.	o	o	o	o	o
This mine is managed through a clear and consistent set of values.	o	o	o	o	o
Teamwork is valued for getting things done at this mine.	o	o	o	o	o

Continued on other side →

10.3.3 Mine Survey Version 3, Sample Survey Form

Page 2

University of Utah Alpha Project 2016

	Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
Supervisors at this mine follow the rules when under pressure.	o	o	o	o	o
Workers regularly think about what might go wrong at this mine.	o	o	o	o	o
Workers are allowed to make decisions regarding routine tasks.	o	o	o	o	o
This mine is managed through a clear and consistent set of values.	o	o	o	o	o
Management treats workers at this mine with dignity and respect.	o	o	o	o	o
Supervisors do a good job of "catching" workers doing things right.	o	o	o	o	o
Supervisors are reliable and dependable at this mine.	o	o	o	o	o
Workers at this mine sometimes take unnecessary risks to get jobs done.	o	o	o	o	o
Workers report all near-miss incidents that are experienced at this mine.	o	o	o	o	o
Workers receive regular feedback and coaching from supervisors.	o	o	o	o	o
I make decisions about how to complete my tasks.	o	o	o	o	o
The feedback and coaching received from supervisors is effective.	o	o	o	o	o
Concerns and suggestions are communicated to management when appropriate.	o	o	o	o	o
My supervisor treats me with respect.	o	o	o	o	o
Drugs and alcohol are a safety problem at this mine.	o	o	o	o	o
I make decisions about when to complete my tasks.	o	o	o	o	o
Supervisors ensure workers participate in required training.	o	o	o	o	o
The tools needed to do jobs correctly are available at this mine.	o	o	o	o	o
Supervisors here have the knowledge to help workers complete their tasks.	o	o	o	o	o
Supervisors are willing to help out, even with small tasks.	o	o	o	o	o
Workers effectively communicate with each other at this mine.	o	o	o	o	o
Supervisors keep workers informed of activities and changes at this mine.	o	o	o	o	o
Supervisors understand the requirements of routine tasks at this mine.	o	o	o	o	o
Safety equipment needed to do jobs correctly is available at this mine.	o	o	o	o	o
Supervisors at this mine are effective leaders.	o	o	o	o	o
My decisions have an effect on my workplace.	o	o	o	o	o
I am confident about what to do in an emergency.	o	o	o	o	o
At this mine a high priority is placed on safety training and learning.	o	o	o	o	o

Comments:

_____

_____

_____

_____

_____

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_____

_____

_____

Thanks for your help!

For admin use only

0	o	o	o	o
1	o	o	o	o
2	o	o	o	o
3	o	o	o	o
4	o	o	o	o
5	o	o	o	o
6	o	o	o	o
7	o	o	o	o
8	o	o	o	o
9	o	o	o	o

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions

1	SHMS Assessment Category	Risk Management and Fatality Prevention
	Definition	The ultimate function of risk management is to prevent fatalities.
	Sample Assessment Questions	Do you have a procedure for assessing the risk in a new task, with a new piece of equipment, or new project?
		Is there a risk management committee or team?
		Who is on that committee?
2	SHMS Assessment Category	Behavior Based Safety
	Definition	Behavior-based safety is the "application of science ofbehavior change to real world problems". or "A process that creates a safety partnership between management and employees that continually focuses people's attentions and actions on theirs, and others, daily safety behavior."
	Sample Assessment Questions	What are the components of a BBS? 1. Informing and Educating the work force. 2. Ensuring active employee involvement. 3. Cooperation amongst teams/Teamwork (Observation, feedback, communication, and safe space to talk freely about their concerns)
		How do you know if your BBS program is working? Do you check it? Do you have a formal observation and feedback system? Who is that system between employees & management or just between employees?
3	SHMS Assessment Category	Training and Competence
	Definition	Assessing training needs based on level. Knowledge and skills required for each task. Ensuring workers know how to do their jobs. Ensuring workers know the hazards and risks of their assigned tasks. Verifying worker competency through demonstrations.
	Sample Assessment Questions	How do you know if your training is effective? Do you have task training? Equipment training? Standard procedure training? MSHA training? Any additional trainings? Leadership trainings? Stress Management? Life Skills?
		Who all is involved in your trainings? Do you contract it out? Do you create your own? Where do the trainings come from? Individual sites or corporate? Site specific?
		Do you verify that those trained are competent by demonstrating the acquired knowledge and skills? How do you verify? How do you keep your records of trainings?

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions (cont.)

4	SHMS Assessment Category	Emergency Management
	Definition	Emergency management is the creation of plans through which corporations reduce vulnerability to hazards and cope with disasters.
	Sample Assessment Questions	Do you have emergency response drills? How often?
		How do you organize your emergency response plan? (binders, folders, etc.) Who and where are the copies and why?
		Do you have an emergency response team? Who is on it and why?
5	SHMS Assessment Category	Work Procedures and Permits
	Definition	Integrating safety and health into operations and maintenance by organizing and conducting work in a predictable manner. Specifying ways to carry out an activity or process. Using more controlled procedures for those activities or processes that are high risk or require a permit.
	Sample Assessment Questions	Do you have safe work procedures and permits to work? What are they and what do they consist of? Who creates the safe work procedures? Do you involve the employees in this process?
		Do you use these procedures for training? (on the job training)
		How do you check that the safe work procedures are being used? Who does the checking?
6	SHMS Assessment Category	Occupational Health
	Definition	Treating health on par with safety by anticipating, recognizing, evaluating, and controlling occupational health hazards leading to illness. Applying appropriate new technologies, with an emphasis on exposure assessment and medical surveillance.
	Sample Assessment Questions	Do you conduct periodic exposure assessment when employees face potential overexposure to hazards (noise, dust, welding fumes, radiation, chemicals)? Or when deemed appropriate by a professional industrial hygienist?
		Do you do any medical monitoring of potential exposures?

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions (cont.)

7	SHMS Assessment Category	Incident and Reporting and Permits
	Definition	Understanding and reporting of recordable/reportable incidents. Investigating all incidents, including relevant near misses, to establish root cause, as appropriate. Capturing lessons learned/root cause data for management review and communication to employees
	Sample Assessment Questions	What types of reporting do you have? For reportable? Non-reportable? Near miss events? Property Damage?
		Are all of your employees aware of what a reportable incident is? What is the process of reporting an incident? Do you train them on this?
		Root cause analysis? How do you know if incidents are being reported? Is your root cause analysis procedure integrated with the structure of your SHMS? How?
8	SHMS Assessment Category	Documentation and Information Managememt
	Definition	Collecting appropriate safety and health data for leading and lagging performance metrics. Establishing and maintaining appropriate safety and health management records. Records should include Safety and Health Policy, Objectives, Responsibilities, Audit Investigations, and Management Reviews.
	Sample Assessment Questions	What do you do for your documentation and information management? What do keep track of? How do you identify those documents that require retention and maintenance?
		Do you think that your SHMS requires too much paperwork? Do you feel that the documentation is deflecting resources from proactive safety and health management activities?
		Do you have a documentation retention process that balances the need to retain with the need to perform and improve?
9	SHMS Assessment Category	Management Systems Coordinator
	Definition	Person responsible for development and management of the safety and health management system.
	Sample Assessment Questions	Do you have someone in this role? What are their responsibilites?
		How is this employee received by the overall workforce?
		What kind of record keeping if any is this person responsible for?

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions (cont.)

10	SHMS Assessment Category	Change Management
	Definition	Identifying changes in the organization and operation that may introduce new risk or increase risk by proactively looking for and controlling change at every level of the organization, across functional areas, including emergency mangement.
	Sample Assessment Questions	Do you have a change management process? What areas of the organization does it apply to? Does is apply to every level of the organization?
		Do your personnel have a clear understanding of what "change" requires inclusion in the management process? What changes does your process include? Planned or unplanned? Temporary? Incremental or permanent?
		How do you manage changes that result in unacceptable risk? Through what controls?
11	SHMS Assessment Category	Contractor Management
	Definition	Ensuring all company-sponsored project proposals include safety and health management criteria or requirements. Pre-screening contractors for acceptable safety and health management experience, qualification and procedures. Ensuring all contractors and third parties are aware of your organization's safety and health management requirements and expectations
	Sample Assessment Questions	Do you have a contractor selection process? What does it include? How do you ensure adequate safety and health competencies and experience?
		What trainings do your contractors go through?
		Are company employees authorized to question the safety practices and behaviors of any contractor or other third party working on site?
12	SHMS Assessment Category	Responsibility and Accountability
	Definition	Setting appropriate safety and health goals. Assuring employees understand their safety and health management roles and responsibilities. Providing sufficient resources. Employing appropriate tools to measure and review for continuous improvement. Applying positive and negative consequences relative to performance against responsibilities.
	Sample Assessment Questions	Do you have an accountability system? Who does it include? Does it dentify the work to be conducted?
		Does your accountability system establish goals?
		How often are your goals renewed?

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions (cont.)

13	SHMS Assessment Category	Leadership Competency Model
	Definition	A generic set of traits, qualities, and principles that the company has established as a standard for leadership practice.
	Sample Assessment Questions	At what organizational levels is the model applied?
		When do employees learn of the model's existence?
14	SHMS Assessment Category	Leadership Development
	Definition	Identifying and developing employees in leadership positions or with leadership potential who can: Influence safety and health performance improvement, Positively and knowingly affect safety culture. To effectively influence safety and health performance improvement, leaders should: Hold themselves and their subordinates accountable, Be action-oriented, be collaborative, be an effective communicator, have integrity, provide effective performance feedback, be systems-focused, and have a personal vision and passion for safety excellence.
	Sample Assessment Questions	Do your leaders understand their strengths and weaknesses?
		How do you determine who is a safety and health leader?
		How do you identify a leader? What should a leader have? Or be? Is it anyone who can control their own behavior and influence others?
15	SHMS Assessment Category	Collaboration and Communication
	Definition	Communication of critical safety & health information
	Sample Assessment Questions	Do you have a process to address safety and health concerns?
		Is this process integrated with reporting procedures discussed in the SHMS incident reporting ?
		Do you have a process for confidential reporting?
16	SHMS Assessment Category	Culture Enhancement
	Definition	Identifying desired safety culture characteristics. Assessing strengths and weaknesses. Developing and implementing a culture improvement plan. Culture change takes planning, broad involvement, and patience. It does no occur quickly.
	Sample Assessment Questions	How do you as a company measure culture? Employee perception survey? Employee interviews?
		How do you ensure confidential and optimal data analysis?
		How do you identify strengths and weaknesses?

10.4 Appendix D: SHMS Assessment Matrix Definitions and Questions (cont.)

17	SHMS Assessment Category	Near-miss Reporting and Sharing
	Definition	An anonymous procedure that allows workers to report near-misses, and a company procedure that encourages and facilitates discussion of these incidents among all employees.
	Sample Assessment Questions	How are near misses addressed?
		Are near miss reports integrated into the company's risk ID matrix and its enterprise risk management plan?
		How do you know that near misses are being reported?
18	SHMS Assessment Category	Reinforcement and Recognition
	Definition	Using formal and informal positive feedback and rewards. Recognizing and reinforcing behaviors and actions that contribute to good health and safety performance.
	Sample Assessment Questions	Do you have any formal procedures for reinforment and recognition for safety and health performance? Positive? Negative?
		Do you give any rewards? Or have any symbolic recognition? Public recognition?
		Do you have any monetary rewards? (Safety Bonuses) Who receives those? Why? When?
19	SHMS Assessment Category	Assurance
	Definition	Implementing a process to assure internal and external stakeholders of the adeguate structure, fitness, and effectiveness of the safety and health management system. Ensuring management is using assurance information to determine how to improve the safety and health mangaement system. Providing for corrective action and continual improvement based on senior management direction.
	Sample Assessment Questions	Do you have an assurance system? For SHMS?
		How do you address non-conformance? Paperwork, documentation, etc.?
		How do you ensure that senior management participates in the performance assurance process? As well as the lowest tier of employees (hourly).

10.5 Appendix E: SHMS Assessment Matrix Rating—Completed Example

Company A Mine 1							
SHMS Rating Matrix							
#	Category	Visit #1		Visit #2		Visit #3	
		Date	Aug-18	Date	Feb-19	Date	Jan-20
		Rating	Comments	Rating	Comments	Rating	Comments
1	Risk Management and Fatality Prevention	4	5x5 risk matrix, take 5	4		4	Still discussing risk matrix with employees; requiesting clarification from corporate
2	Behavior Based Safety	4	interactions, supervisor observes employee	2	Had less this time than the 1st time, a lot of feedback from different groups not knowing who their safety representative was	2	No change; safety coordinators mainly do paperwork and training; few workplace observations
3	Training and Competence	4	site specific videos, work site inspections	3	feedback from hourly about rushing through training and lack of specific trainings. This category has also gone down since the last visit	3	No change
4	Emergency Management	5	emts, paramedics, mine rescue, remote location	5	Remote location forces them to be very good at this	5	No change
5	Work Procedures and Permits	4		4		4	
6	Occupational Health	5	lead levels, fit testing, pulmonary, hearing, etc	5		5	
7	Incident Reporting and Permits	3	MSHA compliant	3	MSHA compliant	3	New incentive pay correlates with decrease in reportable incidents
8	Documentation and Information Mgmt.	4	Intellex	4		4	
9	Management Systems Coordinator	4	Safety Mgr, had other repsonsibilities but is driving the system, paper copies of trainings	3	New Safety Mgr and some changes on safety team. It seemed they weren't sure exactly what their roles and responsibilities	3	Safety group seems to be concerned with compliance and following procedures, not necessarily engaging the workforce
10	Change Management		no observation		no observation		no observation
11	Contractor Mgmt	5	contractors have to follow company standards at a minimum	3	Contractor death - insufficient training?	3	No change
12	Responsibility and Accountability	4	positive and negative, silver coins awarded, favortism	3		3	
13	Competency Model	2		2			
14	Leadership and Professional Development	4	nuts and bolts leadership training, bring a speaker in every year	2	No one mentioned any kind of leadership or professional development. When asked about CORESafety, they didn't know what it was.	2	
15	Collaboration and Communication	2	departments in different locations, communication is difficult	2		2	
16	Culture Enhancement	4	tons first then safety, but trying to change that	2			
17	Near Miss Reporting and Sharing	4	trying to get more near misses	3	MSHA compliant	3	
18	Reinforcement and Recognition	4		2		3	
19	Assurance	1		1		1	
20	SHMS Function Overall	3.7		2.9	MSHA compliant	3.1	

10.6 Appendix F: Sample Mine Visit Report

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mineeng@mines.utah.edu

Safety and General Managements,

The following is a summary of the data collected from the surveys on our second visit to the mine.

In our visit, we asked employees to respond to 56 statements in a survey. The statements are listed for your reference on the last page of this report. The data set includes approximately 30,000 data points. For each statement, participants selected a response from the scale below.

Strongly Agree
= 5 Agree = 4
Unsure = 3
Disagree = 2
Strongly Disagree = 1

In general, a response of “Strongly Agree” or “Agree” is favorable, indicating good practice of safety management and behavior. However, some of the statements (shown in **bold type** on the attached list) are phrased so that a “Strongly Agree” or “Agree” response indicates an area that might require attention. The responses to these questions were “inverted” so that a low number indicates an area that may require
attention. This way, when the data are shown in a graph, it is easy to see areas of interest, both positive and negative.

Figure 1, on the next page, shows the responses to all 56 statements, averaged over the entire survey population. The average response was 3.8, and the standard deviation among all the responses was 0.9. The responses to all statements were within one standard deviation of the average. The statements that showed the highest response scores:

1. I work just as safely when the supervisor/manager is not around: **4.3**
2. Complying with MSHA regulations is important to keep this mine safe: **4.2**
3. Employees can shut work down if it’s unsafe or if other problems arise: **4.2**
4. Employees are responsible for their own safety at this mine: **4.2**
5. My work area is safe: **4.2**

These responses are consistent with the quality of leadership and workplace culture that we observed during the site visit.

The statements that showed the lowest scores were:

1. Supervisors do a good job of “catching” employees doing the right thing: **3.3**
2. Discipline is administered fairly and equitably at this mine: **3.1**
3. Employees at this mine never take unnecessary risks: **3.1**
4. Employees report all near-miss incidents that are experienced at this mine: **2.8**

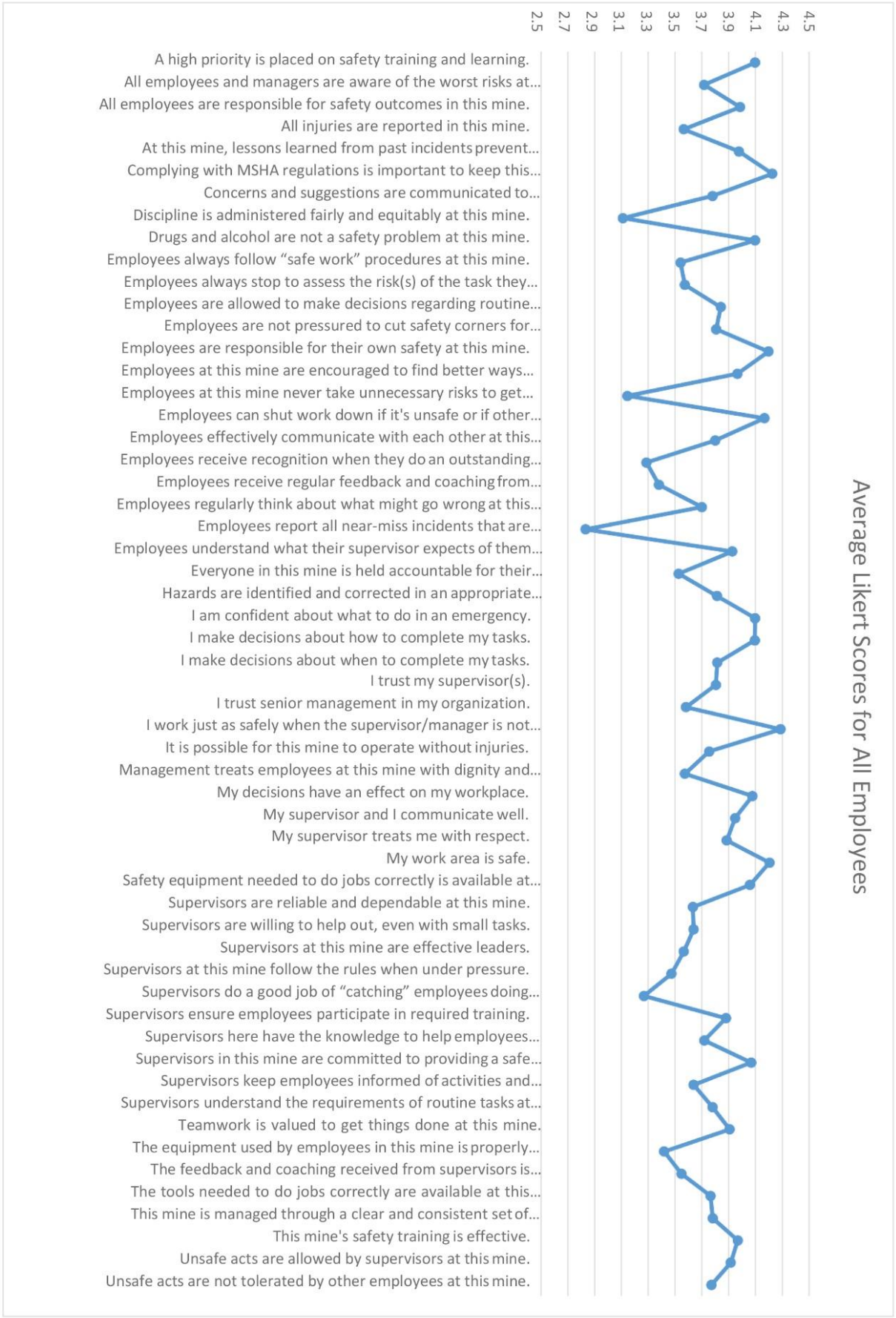

Figure 1. Average Likert Scores for all employees at this mine, 2018

With all the data analysis tools available and the large amount of data from the survey, it is possible to look at the results in many different ways. For example, we can look at the survey responses according to a certain category of question. In this study we divided the survey questions into four categories of safety management variables that are known to effect safety performance: Leadership, Culture, Risk Management, and MSHA Compliance. Figure 2 shows only the rankings for survey questions pertaining to Culture, sorted by employee role. Similarly, Figure 3 shows rankings for questions related to Risk Management, sorted by employee experience.

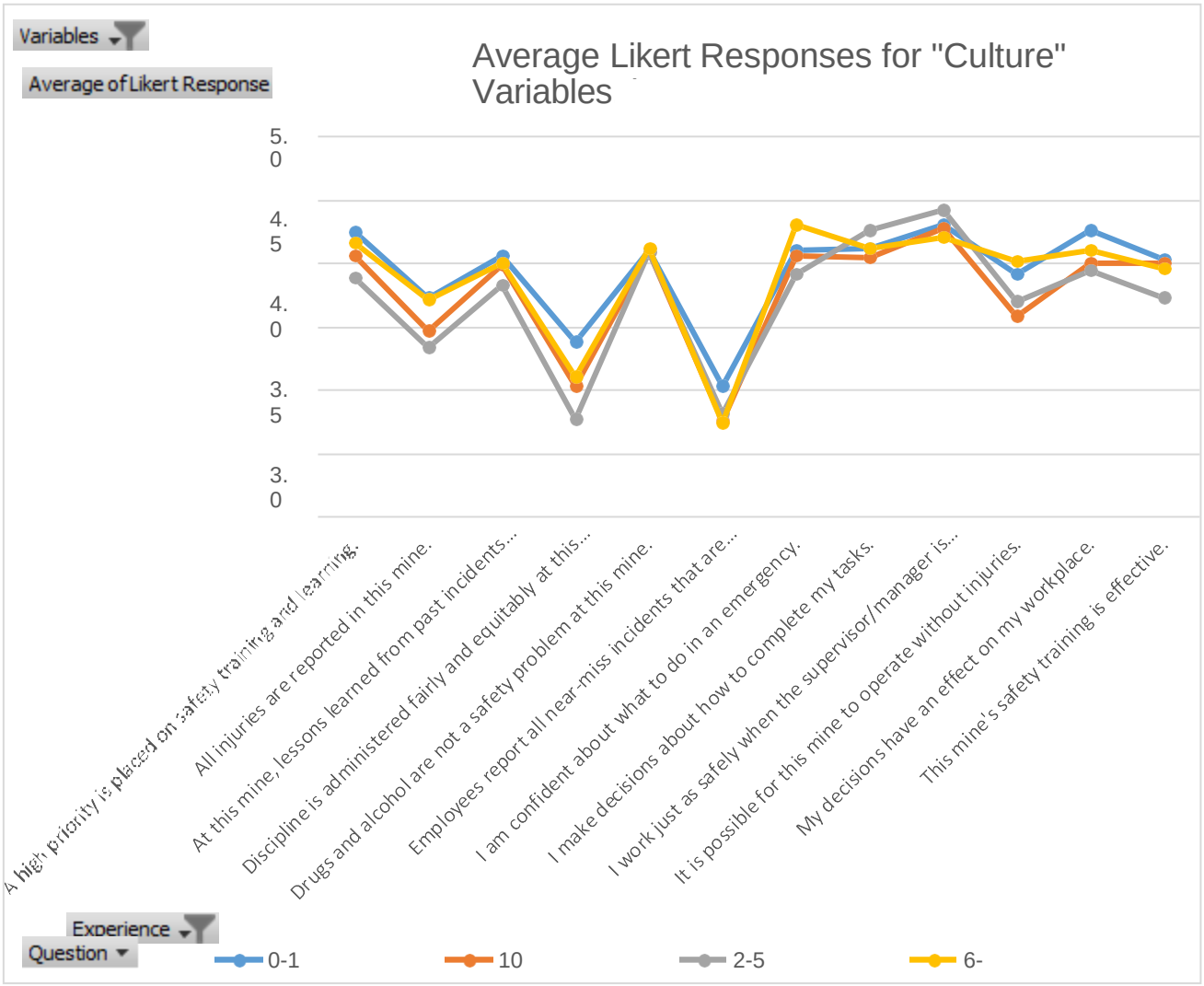

Figure 2. Culture-specific question results sorted by employment role

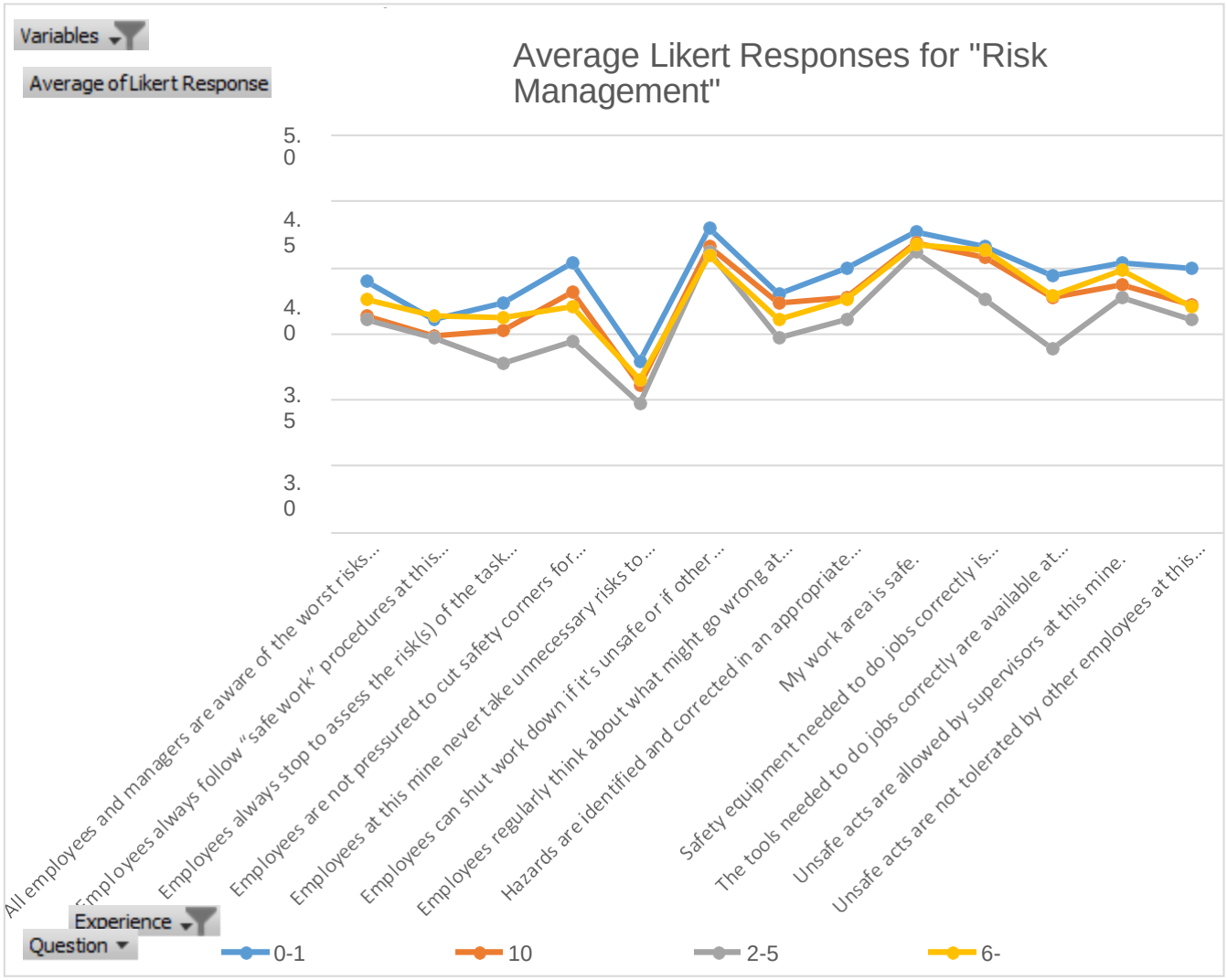

Figure 3. Risk Management-specific survey question results sorted by employee experience in years

We are also e-mailing an interactive EXCEL workbook that includes all of the data collected and instructions on how to display the results as you would like to see them. Please let us know if you have any questions or concerns.

Thank you again for your participation in this study; it is greatly

appreciated. We look forward to seeing you again soon!

Your research team,

Amy Richins

Dr. Mike Nelson

Questions included in the employee survey and the variable characterized by each:

	Question	Variable
1	All injuries are reported in this mine.	Culture
2	At this mine, lessons learned from past incidents prevent future incidents.	Culture
3	Employees always stop to assess the risk(s) of the task they are about to do.	Risk Management
4	This mine's safety training is effective.	Culture
5	Complying with MSHA regulations is important to keep this mine safe.	MSHA Compliance
6	Employees receive recognition when they do an outstanding job.	Leadership
7	Employees can shut work down if it's unsafe or if other problems arise.	Risk Management
8	All employees and managers are aware of the worst risks at this mine.	Risk Management
9	Unsafe acts are not tolerated by other employees at this mine.	Risk Management
10	I trust my supervisor(s)	Leadership
11	I trust senior management in my organization.	Leadership
12	Employees always follow “safe work” procedures at this mine.	Risk Management
13	It is possible for this mine to operate without injuries.	Culture
14	Hazards are identified and corrected in an appropriate amount of time.	Risk Management
15	My work area is safe.	Risk Management
16	I work just as safely when the supervisor/manager is not around	Culture
17	Everyone in this mine is held accountable for their responsibilities.	Leadership
18	My supervisor and I communicate well.	Leadership
19	Employees are responsible for their own safety at this mine.	Leadership
20	All employees are responsible for safety outcomes in this mine	Leadership
21	The equipment used by employees in this mine is properly maintained.	MSHA Compliance
22	Employees are not pressured to cut safety corners for production at this mine.	Risk Management
23	Unsafe acts are allowed by supervisors at this mine.	Risk Management
24	Supervisors in this mine are committed to providing a safe workplace.	Leadership
25	Employees understand what their supervisor expects of them in this mine.	Leadership
26	Employees at this mine are encouraged to find better ways to do things.	Leadership
27	Discipline is administered fairly and equitably at this mine	Culture
28	This mine is managed through a clear and consistent set of values.	Leadership
29	Teamwork is valued to get things done at this mine	Leadership
30	Supervisors at this mine follow the rules when under pressure.	Leadership
31	Employees regularly think about what might go wrong at this mine.	Risk Management
32	Employees are allowed to make decisions regarding routine tasks.	Leadership
33	Management treats employees at this mine with dignity and respect.	Leadership
34	Supervisors do a good job of “catching” employees doing things right.	Leadership
35	Supervisors are reliable and dependable at this mine.	Leadership
36	Employees at this mine sometimes take unnecessary risks to get jobs done.	Risk Management
37	Employees report all near-miss incidents that are experienced at this mine.	Culture
38	Employees receive regular feedback and coaching from supervisors.	Leadership
39	I make decisions about how to complete my tasks.	Culture
40	The feedback and coaching received from supervisors is effective.	Leadership

41	Concerns and suggestions are communicated to management when appropriate.	Leadership
42	My supervisor treats me with respect.	Leadership
43	Drugs and alcohol are a safety problem at this mine	Culture
44	I make decisions about when to complete my task	Leadership
45	Supervisors ensure employees participate in required training.	MSHA Compliance
46	The tools needed to do jobs correctly are available at this mine.	Risk Management
47	Supervisors here have the knowledge to help employees complete their tasks.	Leadership
48	Supervisors are willing to help out, even with small tasks.	Leadership
49	Employees effectively communicate with each other at this mine.	Leadership
50	Supervisors keep employees informed of activities and changes at this mine.	Leadership
51	Supervisors understand the requirements of routine tasks at this mine.	Leadership
52	Safety equipment needed to do jobs correctly is available at this mine.	Risk Management
53	Supervisors at this mine are effective leaders.	Leadership
54	My decisions have an effect on my workplace.	Culture
55	I am confident about what to do in an emergency	Culture
56	A high priority is placed on safety training and learning	Culture

10.8 Abstracts

10.8.1 Jake C. Seiter Technical Report Abstract

Worker safety is a persistent issue in the mining industry and the number, and rates of miners who suffer occupational illness and injury continue to decline; however, notwithstanding these improvements, miner safety can and should continue to be improved. In numerous industries worldwide safety and health management systems (SHMS) have been implemented and presumed to improve efficiency, productivity and business performance.

A review of the limited literature on SHMS used in industry provided a justification for a review of the structure of different primary SHMSs and the determination of a modern benchmark for future SHMS structural research. As a basis for the review, an initial benchmark list of SHMS structure elements was determined to exist in the Dalrymple Scheme presented by Redinger and Levine in the late 1990s. The Dalrymple Scheme is considered to be a universal occupational safety and health management system (OHSMS) model, composed of 27 structural elements, assigned respectively to one of five categories: OHS inputs, OHS process (formulation), OHS process (implementation/ operations), OHS feedback, and open system elements. For the establishment of a modern benchmark, a list of additional SHMS structural elements was defined through analysis of the National Mining Association (NMA) management system, CORESafety. The analysis highlighted the need for seven additional SHMS structural elements to be integrated with the Dalrymple Scheme for a more contemporary benchmark.

The objective for the report is to demonstrate the application of the CORESafety structural elements for the use as a modern benchmark for SHMS structure research. The proposed benchmark was compared to seven globally-recognized SHMSs, and 10 mining industry-specific SHMSs. Additionally, the identification and characterization of the three most important SHMS structural elements was determined. As a basis of knowledge, a review of management systems is presented and further analysis of the 10 mining company’s safety performance was conducted.

10.8.2 Ashley D. Hodgson Thesis Abstract

In recent years, many mining companies have adopted formal systems for the management of health and safety. An example is the CORESafety system from the National Mining Association (NMA 2017). This study conducted research to analyze the intervention effectiveness of safety health and management systems (SHMSs) in the United States mining industry.

Intervention effectiveness of management systems is determined by first, reviewing and characterizing the SHMS as described by mine management, and second, by visiting the mine site, interviewing personnel from all occupational areas, and distributing a written survey to all possible company employees. After these two steps, the data are analyzed statistically and subjectively to determine the system's effectiveness.

This thesis presents the process of using quantitative and qualitative data to assess the impacts of SHMSs (safety and health management systems) on the United States mining industry, with a specific focus on demonstrating compliance with MSHA regulations. The author intends to find, by assessing and analyzing these aspects, that they will be related.

The research objectives are as follows:

1. Visit seven mine sites in the United States and administer a standard SHMS survey to mine employees to collect qualitative data in the form of responses to the survey.
2. Collect quantitative MSHA data for each mine site from the MSHA online database, including operator and contractor injury rates and citation rates.
3. Enter the survey response data and MSHA data into an Access database for simple retrieval.
4. Perform statistical analysis of the data set, using factor analysis, Cronbach's alpha test, Bartlett's test of sphericity, and the Kaiser Meyer Olkin test on the data set.
5. Construct frequency plots from survey data.
6. Find correlations and statistical significance between MSHA injury and citation rates and employee views of their company's SHMS.

10.8.3 Amy J. Richins Thesis Abstract

In recent years, many mining companies have adopted formal systems for the management of health and safety. An example is the CORESafety system from the National Mining Association (NMA 2017). This study conducted research to analyze the intervention effectiveness of safety and health and management systems (SHMS) in the United States mining industry.

Intervention effectiveness of management systems is determined by first reviewing and characterizing the SHMS as described by mine management, and second, by visiting the mine site, interviewing personnel from all occupational areas, and distributing a written survey to all possible company employees. After these two steps, the data are analyzed statistically and subjectively to determine the system's effectiveness.

This thesis presents the process of using quantitative and qualitative data to assess the impacts of SHMS (safety and health management systems) on the United States mining industry, with a specific focus on demonstrating compliance with MSHA regulations. The author intends to find, by assessing and analyzing these aspects, correlations and statistical significance between MSHA injury and citation rates and employee perceptions of their company's SHMS. The research objectives are as follows:

1. Visit five mine sites twice in the United States and administer a standard SHMS survey to mine employees to collect qualitative data in the form of responses to the survey.
2. Collect quantitative MSHA data for each mine site from the MSHA online database, including operator and contractor injury rates and citation rates.
3. Enter the survey response data and MSHA data into an EXCEL database for simple retrieval.
4. Perform statistical analysis of the data set.
5. Find correlations and statistical significance between MSHA injury and citation rates and employee views of their company's SHMS.

11.0 Disclosure

The Alpha Foundation sponsored this study for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.