Analysis of Recommendations from Mining Incident Investigative Reports: A 50-Year Review

Emily Tetzlaff [1], **Tammy Eger** [1,2,*], **Ann Pegoraro** [1,2], **Sandra Dorman** [1,2] and **Victor Pakalnis** [3]

[1] Centre for Research in Occupational Safety and Health, Laurentian University, 935 Ramsey Lake Road, Sudbury, ON P3E 2C6, Canada; etetzlaff@laurentian.ca (E.T.); apegoraro@laurentian.ca (A.P.); sdorman@laurentian.ca (S.D.)

[2] School of Human Kinetics, Laurentian University, 935 Ramsey Lake Road, Sudbury, ON P3E 2C6, Canada

[3] Radiation Safety Institute of Canada, 100 Sheppard Ave. East, Suite 760, North York, ON M2N 6N5, Canada; vpakalnis@radiationsafety.ca

[*] Correspondence: teger@laurentian.ca; Tel.: +1-705-675-1151 (ext. 1005)

check for updates

Abstract: A systematic analysis was conducted using ten occupational health and safety commissioned reports from Canada, New Zealand, United States, United Kingdom, and Australia spanning from 1967 to 2015. The objective was to identify commonalities and differences in the key recommendations across the identified reports. The text-mining software Leximancer was utilized to analyze the content of the recommendations through the semantic extraction of dominant themes, and the relational extraction and mapping of thematic relationships against each other. The identified themes were then analyzed within the concept map to fully understand the relationships. Based on the concept map, the thematic analysis provided a longitudinal perspective of the recommendations, identifying six key themes and 49 sets of overlapping recommendations. Key themes included: health and safety hazards (n = 10), legislation, regulations and organizational structure (n = 13), emergency management and mine rescue (n = 9), training, education and competence (n = 10), technology (n = 4), and research (n = 3). The results of this analysis illustrate that the same hazards continue to be identified across reports and recommendations, regardless of time or country of origin. This indicates that the communication of recommendations and/or the strategies developed in response to the recommendations need to be further addressed.

Keywords: health; safety; mining; accident; investigation; recommendations; leximancer

1. Introduction

"In 1992, a violent explosion . . . occurred in the depths of the Westray coal mine, instantly killing the 26 miners working there at the time" [1]. "In 2006, an explosion occurred at the Sago mine . . . fifty-two hours later, the bodies of 12 miners had been recovered from the mine" [2]. In 2010, on Easter Monday, "a powerful explosion tore through the Upper Big Branch mine . . . twenty-nine miners died" [3]. In 2010, the Pike River coal mine exploded, "twenty-nine men underground died immediately, or shortly afterwards, from the blast or from the toxic atmospheres" [4]. Following each of these tragedies, inquiries were established, new rules and regulations were formulated, and recommendations to eliminate organizational hazards were designed in order to prevent an accident reoccurrence [5]. However, the previously stated examples illustrate four cases where the accident causation chain ended with similar fatal methane explosions. Although the incidence of occupational injuries and diseases associated with the mining industry have declined markedly following developments in science and technology [6], there is still a need to review and evaluate

recommendations stemming from previous occupational health and safety (OHS) commissioned reports, in order to understand occupational accidents for miners.

Reoccurring accidents are not unique to the mining industry. Aviation, aerospace, transportation, oil, healthcare, and construction, among others, all have a history of accidents that have commonalities between them [7–9]. Lessons from these accidents for risk prevention and reduction of consequences are drawn from the analyses of several types of single events and series of events [10]. Although the contexts of various work environments can be different, there is an opportunity to learn from occupational accident investigations and recommended practices from other countries, industries, or variations within the same sector (i.e., metalliferous and coal mining) [11–13].

In the mining industry, various methods of disaster analysis have used official accident reports [11, 14–16]. Accident reports rely on a large body of data from a variety of sources to reach their conclusions, and therefore provide a great resource for conducting a large-scale longitudinal review of the industry to identify lessons for risk prevention [10,17]. However, it is recognized that not all accident inquiries are free of influences that come from, for example, the government, appointed investigators, the terms of reference, the legislation governing safety and the investigation process itself, time and resource constraints, and media coverage [16]. Another consideration when conducting historical analysis of such reports is the influence of how investigations are shaped by the current technical knowledge, dominant discourses, and community structures during the time period. Preoccupations with certain influences can detract attention from other underlying failures. Therefore, it must be recognized that the findings, and subsequent recommendations, identified in an investigation report are relative to how the investigation was conducted.

A key part of an accident investigation, and the subsequent accident report, is the proposal of remedial actions, usually referred to as recommendations. The recommendations are established to prevent a reoccurrence of that particular accident [5,18]. In many cases, accident investigation recommendations focus on new rules and regulations that influence the health and safety legislation of the country, state, or province in which they were published. The formulation of recommendations is therefore a reactive process, aimed to provide proactive solutions for the future [19]. In many accident inquiries, the commissioners acknowledge the presence of previously identified themes from inquiries into previous tragedies. However, if the recommendations fall into a common set of themes that reappear, an argument can be made that the recommendations are not being adequately implemented or shared broadly across the mining industry sector.

Similar to how accident investigations are influenced by the accident model, recommendations are also influenced by various factors (e.g., political and economic considerations, limitation of the number of recommendations to be published, and expediency) [20]. The recommendations may therefore be affected by factors other than the outcome of the accident analysis. Another key issue with the formulation of recommendations and subsequent implementation is described as "problem framing" because there are multiple levels of specificity in describing what, how, or why [20]. The recommendation process is further complicated by how the recommendations are communicated and how they are interpreted by industry stakeholders.

Quinlan posed the following questions: "Why do mine disasters continue to occur in wealthy countries when major mine hazards have been known for over 200 years and subject to regulation for well over a century? What lessons can be drawn from these disasters and are mine operators, regulators and others drawing the correct conclusions from such events?" [16]. These questions warrant the consideration of the recommendations that have accompanied previous accident inquires, and what insight they may offer to the cyclical nature of the repetition of similar accidents. In 2015, the Ontario Ministry of Labour released the Mining Health, Safety and Prevention Review, a comprehensive review of underground mining. Of the sixteen published recommendations, recommendation 5.4 focused on reviewing past public enquiries into mining health and safety and from coroners' inquests into mining fatalities [21]. To date, and to the knowledge of the authors, a comprehensive review of accident

investigation reports in the mining industry that aims to determine if repetition of recommendations occurs does not exist. Therefore, the purpose of this research was to:

(I)   Identify whether any recommendations were repeated in a sample of English language mining inquiries over the past 50 years; and

(II)   Determine whether there were similarities in recommendations between coal and metalliferous mining accident reports.

These research findings are imperative for identifying whether the current methods used in the mining industry for accident investigation and recommendation implementation are effective.

2. Materials and Methods

The research approach follows the protocol outlined by Indulska and Recker [22] and Cretchley, Rooney, and Gallois [23] in their analysis of conceptual drift in journal publication history.

2.1. Report Dataset

The OHS reports were selected through a review of the literature and in consultation with industry professionals known for their expertise in mining, safety, and accident investigation. The inclusion criteria were reports from: English-speaking countries, coal mining and metalliferous mining, and reports on single accidents, disasters, and broader industry reviews. In addition, the report had to be deemed to have had a significant impact on OHS in the mining industry (i.e., established to investigate new and emerging issues; provided advice on an area where government lacks expertise; accessed external knowledge; identified key issues on policy problems; provided recommendations for the future) [24]. The final list contained ten reports focusing on OHS from five countries: Canada (n = 5), United States (n = 2), Australia (n = 1), New Zealand (n = 1), and the United Kingdom (n = 1) (Table 1).

Table 1. Occupational health and safety commission descriptions.

Commission	Date of Incident	Date Inquired	Date Published	Country	Industry	Pages
Report of the Tribunal Appointed to Inquire into the Disaster at Aberfan [25]	21 October 1966	19 July 1966	19 July 1967	United Kingdom	Coal Mining	151
Report of the Royal Commission on the Health and Safety of Workers in Mines [26]	N/A	10 September 1974	30 June 1976	Canada	Metalliferous Mining	380
Towards Safe Production [27]	N/A	July 1980	April 1981	Canada	Metalliferous Mining	422
Improving Ground Stability and Mine Rescue [28]	N/A	24 October 1984	February 1986	Canada	Metalliferous Mining	107
Report on an Accident at Moura No. 2 Underground Mine [29]	7 August 1994	18 October 1994	6 April 1995	Australia	Coal Mining	102
The Westray Story: A Predictable Path to Disaster—Report of the Westray Mine Public Inquiry [1]	9 May 1992	15 May 1992	November 1997	Canada	Coal Mining	831
Report on the Sago Mine Disaster [2]	2 January 2006	9 January 2006	19 July 2006	United States	Coal Mining	124

Table 1. *Cont.*

Commission	Date of Incident	Date Inquired	Date Published	Country	Industry	Pages
Upper Big Branch: A Failure of Basic Coal Mine Safety Practices [3]	5 April 2010	13 April 2010	May 2011	United States	Coal Mining	126
Royal Commission on the Pike River Coal Mine Tragedy [4]	November 19 2010	December 14 2010	October 2012	New Zealand	Coal Mining	448
Mining Health, Safety and Prevention Review [21]	N/A	December 2013	March 2015	Canada	Metalliferous Mining	108

2.2. Analysis of Recommendations

The recommendations were analyzed via an inductive thematic analysis, an approach that allowed for categories to emerge from the data rather than categories being determined a-priori. The researchers utilized the qualitative software Leximancer to analyze the recommendations. Leximancer conducts conceptual (i.e., thematic) and relational (i.e., semantic) analysis on written words as well as visual text [30]. For analysis, all standard operational settings in Leximancer were set to default with the exception of removing the identification of name-like words, turning off auto-paragraphing, and merging word variants [31]. Word-like concepts with similar semantic meaning were merged (e.g., workers and miners), and concepts of low semantic meaning were removed (e.g., mine). To explain further, in an exploratory analysis of the recommendations (where no changes are made to the standard operational settings) the dominant theme that would emerge is "mine." As the recommendations are all from the mining industry, identifying "mine" as a theme adds no additional support for addressing the research objective, and further, its presence may suppress a relevant theme from emerging.

The analysis was undertaken in two stages. First, Leximancer was used to jointly analyze the content of the recommendations within the 50-year data set through semantic extraction of dominant themes, followed by relational extraction. The relational extraction then provided a concept map that was used to identify and explore core themes within the recommendations through color coding and theme centrality indicated on the concept map [32].

2.3. Interpretation of Results

Once Leximancer has completed its analysis, the researchers then interpret the visual concept map to accurately capture the nature of the content. This combination of computer and human coding has been used in various studies analyzing larger data sets (e.g., [33]). Within the visual map, words (concepts) are clustered into higher-level "themes" that are depicted as colored circles based on frequency of use in relation to each other. The themes are also heat-mapped to indicate importance, where the most dominant theme appears in red, the next in orange, and so on to colder colors such as purples and blues. The location of the themes and concepts on the map also indicates relational relevance, with overlapping themes indicating the strongest relationship, and themes on opposite ends of the map demonstrating a lesser relationship. Additionally, the size of the circles indicates prominence within the dataset being analyzed. The grey network of lines between concepts indicates the most likely connection between concepts. Lastly, the additional tags added to a map indicate the source document and therefore indicate the dominant themes from a specific report. When analyzing the map, additional features are available to interact with the visual map, such as the spanning tree function which appears as green lines from a theme to the related concepts. In addition to what is shown on the visual map, the underlying text references are then used to understand the context behind each word and to identify overlap or repeating recommendations [34]. Furthermore, the recommendations were manually reviewed by the researchers to ensure all occurrences of repetition were captured, which further supported the interpretation of the context of the overall recommendation discussion.

3. Results

3.1. Description of OHS Commission Reports

The 10 reports span from 1967 to 2015 and represent a combination of coal mining (n = 6) and hard rock mining (n = 4). The average number of days from the date of an incident to the date of the commission being inquired were 46.2 days (min: 5 days; max: 73 days), and the average duration from inquiry to publication was 552 days (min: 170 days; max: 1996 days). The reports on average were 280 pages in length, with the shortest report at 151 pages and the longest report at 831 pages. Overall, the sample included 2799 pages of data. On average, each report published 53.2 recommendations (min: 16 recommendations; max: 116 recommendations).

3.2. Thematic Analysis

Based on the concept map (Figure 1), 55 "word-like" concepts and six key recommendation themes emerged. These themes were: Legislation, Regulations and Organizational Structure, Health and Safety Hazards, Emergency Management and Mine Rescue, Training, Education and Competence, Technology, and Research. Table 2 provides reference to the number of recommendations grouped within each theme, and the following subsections provide specific examples of recommendations repeating within the categories.

Table 2. Number of recommendations coded per theme by report year.

| Theme	Report Year										Total
	1967	1976	1981	1986	1995	1997	2006	2011	2012	2015	
Legislation, Regulations and Organizational Structure	16	30	50	16	2	23	6	13	11	4	**171**
Health and Safety Hazards	0	72	11	4	6	31	16	6	0	4	**150**
Training, Education & Competence	2	5	14	25	7	9	7	9	2	3	**83**
Emergency Management and Mine Rescue	0	0	2	5	8	5	37	11	3	3	**74**
Technology	1	2	0	5	0	2	7	11	0	0	**28**
Research	0	7	5	6	2	3	1	0	0	2	**26**
	19	116	82	61	25	73	74	50	16	16	532
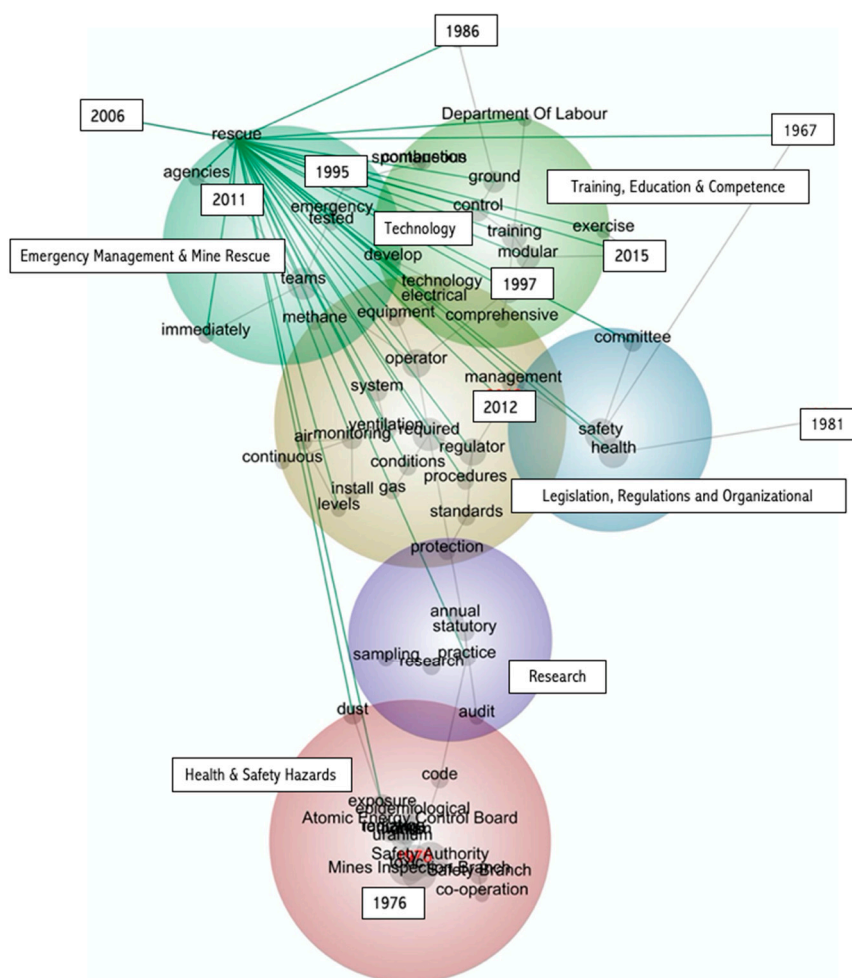
Figure 1. Concept map generated by Leximancer, resulting in six major themes: Legislation, Regulations and Organizational Structure (yellow and blue), Health and Safety Hazards (red), Emergency Management and Mine Rescue (green), Training, Education and Competence (light green), Technology (green/yellow overlap), and Research (purple).

3.3. Historical Analysis of Concept Map

In order to grasp a historical perspective, the locations of the year markers present on the concept map were reviewed (Figure 1) along with the values indicated in Table 2. The 1976 report appears to have focused on recommendations (related to OHS hazards) that were different from the other reports. This is recognized by its distinct location at the bottom of the concept map (Figure 1), and supported by the number of recommendations identified relating to OHS hazards (n = 72); significantly higher than found in other reports (min = 0; max = 31). It is also noted that the 1976-year marker is located within the most dominant theme, indicating that the majority of the recommendations within this report focused on addressing health and safety hazards. In contrast, the yellow concept cluster, which focused on legislation and governance, was very centrally located (Figure 1). The central location of this theme indicates that many of the reports had recommendations related to legislation, regulations, and organizational structure. Again, this is supported by Table 2, which indicates that all reports analyzed had recommendations related to this theme (n = 171). Both the 2006 Sago and 2011 Upper Big Branch reports were located in close proximity to each other and swayed peripherally with the discussion around emergency management and mine rescue. The Sago report had the highest number of recommendations specific to mine rescue and emergency management (n = 37), and the Upper Big Branch report had the second highest frequency (n = 11). The 1995 Moura report was also placed

near the discussion of emergency management and mine rescue, as it had the third highest number of emergency management recommendations (n = 8) (Table 2).

The 1986 report is directly linked to the terms "ground" and "control" and in proximity to the discussion of training (n = 25) (Table 2). The 1997 Westray report is also placed near the concept cluster focused on training (n = 9) (Table 2). The 1967 and 1981 reports are both linked to the cluster focused on OHS and committees, which is overlaid with the cluster focused on legislation and governance. Table 2 indicates that the majority of recommendations within these two reports related to regulatory frameworks (n = 16, n = 50). Lastly, the 2015 report is placed near training (n = 3), and close to the concept of "exercise" relating to fitness standards; however, the recommendations within the 2015 report were fairly evenly distributed between the various categories.

This analysis provided the necessary preparation for identifying the overlap between themes discussed in the recommendations and specific examples of direct replication, along with identifying concepts that only occurred in distinct reports.

3.4. Categorization of Recommendations

3.4.1. Legislation, Regulations, and Organizational Structure

A total of 171 recommendations were identified as being related to regulations and regulatory bodies. Of the 171 recommendations, there were 13 sets of recommendations that demonstrated repetition related to the revision of legislation. Recommendations related to legislative changes were from all five countries, both types of mining, and were present across the full 50-year time period. For example, recommendations related to incentive plans were identified in two reports, published 16 years apart, from the same country. However, they were from different provincial jurisdictions, and one report was from hard rock mining and one from coal mining:

> *"That the government make known its intention to legislate an end to direct individual (or small crew) production incentive plans in Ontario mines if these plans are not voluntarily discontinued."* (1981 [25])

> *"Incentive bonuses based solely on productivity have no place in a hazardous working environment such as an underground coal mine. Such schemes should be replaced, where practical, by safety..."* (1997 [1]).

3.4.2. Health and Safety Hazards

A total of 150 recommendations were identified as being related to health and safety hazards. Of the 150 recommendations, there were 10 sets of recommendations that overlapped in two or more documents. Recommendations related to fall protection were identified in two reports from the same country and same type of mining. The recommendations were published five years apart and provide an example of an initial recommendation to install equipment wherever was deemed practical, followed by the subsequent recommendation referring to making fall-on equipment installation mandatory.

> *"That wherever practical, fall-on protection be installed on all man-operated underground equipment."* (1981 [25])

> *"That Fall-On Protection shall be mandatory on all vehicles operating in areas requiring this type of protection."* (1986 [31])

Both the 1981 report and the 1986 report also demonstrated repetition related to inspections:

> *"That these inspections be carried out under an auxiliary source of high intensity lighting."* (1981 [25])

> *"That auxiliary high-intensity lighting be available in all active work areas to assist in ground-control-related activities such as inspection and scaling."* (1986 [31])

3.4.3. Training, Education, and Competence

A total of 83 recommendations were identified as being related to training, skills, and qualifications. Of the 83 recommendations, 10 sets of recommendations were found to overlap in two or more documents. The following examples illustrate the repetition of recommendations related to emergency training:

"That the necessary additional training in non-fire emergencies be developed by a tripartite committee consisting of representatives of mine management, unions, and government." (1986 [31])

"Training for SCSR donning and escape must be wholly separate from all other types of training miners currently receive. This training must be repeated every 90 days." (2006 [2])

"SCSR training should be conducted quarterly, instead of annually." (2011 [3])

"SCSR and escape training must be done in actual conditions underground and, to the extent possible, reflect real-life emergency situations. Miners must don the SCSR training model and walk at least a portion of the escape-way." (2006 [2])

"SCSR training should be realistic and conducted in actual mining situations, such as riding in a man-trip and working on a longwall. It should incorporate a variety of actual in-mine scenarios for which the SCSR must be donned and activated. The training should emphasize the importance of activating the SCSR at the very first warning of an emergency." (2011 [3])

This example demonstrates repetition in recommendations of the broader concept of emergency training but also demonstrates repetitions in specific aspects of that training (e.g., frequency of training, and training in actual mining situations). These recommendations came from two different countries, and there is a distinction between the type of emergency training. In the hard rock mining environment, the recommendation relates to non-fire emergencies, and in the coal mining environment it relates to self-contained self-rescue (SCSR) training. Within the coal mining reports that were published five years apart, there is distinct repetition in the recommendations relating to the frequency of the training and the training occurring in actual mining situations.

3.4.4. Emergency Management and Mine Rescue

A total of 74 recommendations were identified as being related to emergency management and mine rescue. Of the 74 recommendations, there were nine sets of recommendations that overlapped in two or more documents. These examples suggest that regardless of time or geography, recommendations for emergency underground facilities continue to appear in the commissioned reports. Another strong example of repetition is evident in the recommendations for emergency response plans and procedures through five similar recommendations from four countries:

"It is recommended that mines be required to put in place Mine Safety Management Plans to cater for key risk areas." (1995 [32])

"Every mine operator, indeed, every industrial plant or facility, should have a well-defined and comprehensive emergency procedures manual . . . " (1997 [1])

"Mine operators' emergency response plans (ERPs) must be treated more than just more paperwork. ERPs should be developed collaboratively with miners, their families, local responders, and mine rescue team members, and revised based on mine-specific drills and table-top exercises." (2011 [3])

"Emergency management in underground coal mines needs urgent attention: Operators of underground coal mines should be required by legislation to have a current and comprehensive emergency management plan that is audited and tested regularly; The emergency management plan

should be developed in consultation with the workers and the Mines Rescue Service; The emergency management plan should specify the facilities available within the mine, such as emergency equipment, refuges and changeover stations, and emergency exits . . . " (2012 [4])

"The Ministry of Labour to require mining companies to conduct risk assessments to establish Emergency Response Plans for exploration sites, new mines, surface mines and mining plants." (2015 [21])

These four examples suggest that over this 20-year period recommendations that related to emergency response plans and procedures in mining were consistently part of commission findings.

3.4.5. Research

A total of 26 recommendations were identified as being related to research. Of the 26 recommendations, three sets of recommendations overlapped in two or more documents. Although the earlier recommendation relates to radio devices and the latter refers to wireless communication, the following example provides an indication that despite technological advances, research into mine communications systems reappeared as a recommendation:

"That research to perfect the development of an effective radio communication device for use underground be continued and accelerated, with active government support." (1986 [31])

"MSHA and NIOSH must be mandated to fund and direct continued studies and research to develop a new generation of wireless communications technology." (2006 [2])

These recommendation examples came from two different countries, different mine environments (hard rock and coal mining), and were published 20 years apart.

3.4.6. Technology

A total of 28 recommendations were identified as being related to technology. Of the 28 recommendations, four sets of recommendations overlapped in two or more documents. The recommendations related to technological changes demonstrated that regardless of the different technologies available at the time, the industries response to technological advances still requires attention:

"That task groups set up by the Occupational Health and Safety Authority to advise on codes of practice and statutory regulations relating to technological change in mining include representatives of labour." (1981 [33])

"The mine's joint occupational health and safety committee should periodically review training standards, policies, and programs to make sure that they adequately reflect changing technology and mining conditions and practice within the mine." (1986 [1])

These examples came from the same country, however, they represent different types of mining and were published 21 years apart.

4. Discussion

The findings of this study provided an opportunity to retrospectively analyze mining report recommendations from the past 50 years. The aim of this study was to identify if there were any recommendations that were consistently reappearing in English language mining inquiries over the past 50 years, and to determine if there were any similarities between coal mining and metalliferous mining accident report recommendations. The results of this study have captured the numerous repeating recommendations and have provided evidence of similar recommendations between coal mining and metalliferous mining. This study further provides evidence for how centralized the overall focus has been, as all recommendations fell into six key themes as captured by the visual concept map (Figure 1).

4.1. Legislation, Regulations, and Organizational Structure

As depicted in the concept map (Figure 1), recommendations focusing on legislative changes and regulations were present in all commissions analyzed in the study. This is consistent with what is expected in the literature, as legislative changes offer a direct means to improve safety related outcomes: "OHS legislation is essential as a first step for the implementation of improved measures for safety and health as well as the prevention of accidents and diseases in the world of work" [34]. Although legislative changes and regulations are fundamental for improving OHS outcomes, the presence of rules or guidelines does not ensure they will be followed [35]. Therefore, it is not whether an organization has a reporting system, it is whether, as a matter of practice, errors and near misses are reported [5]. The recommendations within this theme reiterated the importance of communicating who is being held accountable for the change being proposed. Recommendations which specifically state an organization do not leave room for questioning whom the authoring body is placing accountability on. The Scottish Inquiries into Fatal Accidents and Sudden Deaths Bill [36] is addressing this same concern by outlining that when a recommendation is made, the relevant person/organization whom the recommendation addresses has eight weeks to respond explaining how they will implement, or why they will not be implementing, the recommendation. This bill addresses both accountability and feasibility and provides a greater ability to measure/monitor compliance and reduce future repetition.

4.2. Health and Safety Hazards

In the change management literature, it is evident that communication is a foundational aspect of change. Mento, Jones, and Dirndorfer [37] stated that the process in which change is introduced sets the tone for recipients with respect to acceptance or rejection. For example, what was uniquely noted in the analysis of health and safety hazards is that there were occasions where an initial recommendation "suggested" a change, and the following report published x-years later would restate the recommendation with stronger language, such as "regulate" or "mandate." For example, in 1981 it was recommended that "that wherever practical, fall-on protection be installed on all man-operated underground equipment" [25], and five years later in 1986 it was recommended that "Fall-On Protection shall be mandatory on all vehicles operating in areas requiring this type of protection" [31]. Other terms provide leeway for interpretation, such as "manway sizes, escape routes and refuge stations be sufficient to accommodate rescue operations" [31] or "every effort should be made to coordinate the emergency response of the federal, state and local agencies" [2]. Individual interpretations of "sufficient" and "every effort" may be drastically different. If a recommendation for change leaves room for interpretation errors, it may lead to organizational resistance to change.

4.3. Emergency Management and Mine Rescue

Numerous emergency management and mine rescue recommendations were identified in almost all reports studied. Given that the investigation process is a retrospective analysis that reviews the events leading up to an accident, these findings are not unexpected. However, what was unexpected was the frequency of repetition found within these emergency recommendations. This provides support for highlighting the lack of sharing across the industry and global landscape as a potential factor in repeating recommendations. For example, the Pike River [4] report mandated a "compar [ison] with any similar matters in other countries." Upper Big Branch [3] referenced that "lifelines were already general practice in a number of other countries," and Sago [2] said "MSHA did not require the use of tracking devices to locate trapped miners underground, even though such technology has been available for over 30 years and is used widely in other countries." The Mining Review [21] has again recommended the need to share information on emerging injury and illness trends and information on incidents causing injury across the industry (recommendation 6.1), and has also recommended looking to other industries (e.g., transportation, military, and healthcare) to see how mining compares (recommendation 1.3). If information was more readily shared between company to company, country to country, and industry to industry there would be a greater number of learning opportunities and

potentially a reduction in repetition. Flyvbjerg [38] views accident investigations as case studies and has shown that conclusions can go beyond the individual case. This perspective further illustrates that there is an opportunity for recommendations to have benefits beyond their own scope.

4.4. Training, Education, and Competence

The findings identified recommendations related to training, education, and competence in all of the reports analyzed. These recommendations repeatedly covered the who (i.e., engineers, supervisors), what (i.e., ground control, emergency), where (i.e., simulated environment), when (i.e., college, refresher courses), and how (i.e., joint training, modular) the industry learns. The forecasted changes with staffing in the Ontario Mining industry provide even greater emphasis on the importance of organizational learning. It is projected that by 2018, approximately 50% of Ontario miners will exit the industry [39], creating large hiring requirements and training needs [40]. Turnover of employees can be associated to lost lessons. For example, four serious accidents in the UK chemical industry were repeated 10 or more years later in the same company; however, not always the same unit. Kletz [41] attributed this "with the passage of time and changes in staff, the recommendations made after the original accidents were forgotten" (p. 4). Kletz [41] emphasized that "organizations have no memory; only people have memories and they move on." The individuals that experience an accident, or are even employed by an organization at the time of an accident, are more likely to remember it. Therefore, changes that come of the accident are more likely to be understood by those workers. However, when those workers leave, the memory of why the change occurred may dissipate with them. This can relate back to why recommendations may repeat, because similar accidents may reoccur, resulting in the same changes being suggested. Therefore, these findings drive the importance of considering how young workers are being trained as they enter industry.

4.5. Research and Technology

The recommendations within this theme continued to call for the development or adoption of new technologies or research studies. The adaptation over time of recommendations related to technological advances and research is supported by the literature on framing theory. It is known that concepts can transform over time as new information is provided [42]. However, as new issues are often variants of older issues that have been discussed in the past [43], the repetition in this theme may also provide evidence for a need to improve the industries' reaction to incorporating change. Change management is a multifaceted process incorporating analytical, educational/learning, political, and cultural processes [44–46], and as a result, resistance to change can be multidimensional. Studies in other industries have found similar findings of organizations being more likely to repeat changes they have previously experienced [47,48]. Therefore, if the recommendations are not approached with a clear change management protocol then they are prone to fail and reappear as a recommendation in a future report.

During the analysis, the following quote from the Sago report stood out, as it emphasizes the importance of this research:

> *"The UMWA made many of these same recommendations after the 23 September 2001 Jim Walter #5 disaster. Had they been implemented, the events at Sago, Alma, and Darby may have been avoided. MSHA has a responsibility to move forward with these recommendations immediately. The UMWA and the nation do not intend to see more miners die as a result of regulatory inaction at any level of the government."* [2]

The four mine disasters referenced in that statement alone took the lives of 31 miners. Based on the repeating recommendations highlighted in this study, the list of events that "may have been avoided" had recommendations been implemented and shared across industry could now include Upper Big Branch and Pike River, amongst many others. The mining industry, including the various associations, companies, regulators, and governments that influence it, have a collective responsibility to act on the recommendations and enforce compliance with legislation.

4.6. Limitations and Future Research

While the study encompasses 50 years, five countries, and 10 reports, it is not without limitations, and there are numerous avenues of future research that can stem from the findings presented. Firstly, although the sample itself was large in scope, including over 2000 pages of data, there could have been a more diverse number of reports included. The countries included in the study were all English-speaking countries that are considered to have good OHS standards and practices. Therefore, having incorporated additional countries that may not have as robust standards for safety may have provided a more diverse discussion. Secondly, it is also important to acknowledge that commissioned reports, or investigation reports, have the potential to be influenced by the authoring body. Therefore, this study was limited to the interpretation of what was published as recommendations. It is acknowledged that there may have been discussion throughout the investigation process that further outlined recommended actions that were not captured in this data, or that were not included because of prioritization.

The breadth of the recommendations published were highly variable, with reports ranging from 16 recommendations to 116 recommendations. Although this was not a limitation of the study as a comprehensive review was conducted utilizing Leximancer and the researchers read all cases of repetition to verify, it identifies a unique opportunity for the future. Future studies could more specifically look at the number of recommendations published and how many are fully implemented to see if there is an optimal number for the industry to help prioritize future change management. Further studies could be conducted to assess affective and behavioral reactions to organizational change within the mining industry following substantial reviews or commissions such as those included in this study. In various industries, researchers have investigated reactions to change and have successfully identified best practices. This could therefore be conducted for the mining industry, to assist in identifying protocols for future change management processes.

Lastly, future research could further address the recently published comprehensive Mining Review [21] of the health, safety, and prevention issues related to underground mining in Ontario. This study demonstrated a methodology for conducting a historical review which addressed an array of reports simultaneously. This methodology could be specifically applied to answer recommendation 5.2 from the Mining Review (2015), which requests a method to "aggregate analysis of all past inquests into mining fatalities...[and] to use the analysis to improve future inquests into fatalities in the mining sector."

5. Conclusions

In 2015, there were hundreds of traumatic fatalities in the global mining industry, including, but not limited to, the United States (n = 28), Canada (n = 5), the United Kingdom (n = 1), Australia (n = 12), and New Zealand (n = 5) [49–53]. Unfortunately, these statistics and the findings of this study demonstrate that "lessons learnt from past tragedies do not automatically translate into better health and safety practices for the future" [4]. Despite the numerous commissions and inquiries previously established and the resulting recommendations, similar accidents continue to occur around the world. Inquiries have the power to collect a wealth of information and provide opportunities to impact the industry in a substantial way. However, inquiries and reports are only effective if industries and governments learn from them and implement their learnings. These research findings demonstrated that the methods used in the mining industry for accident investigation and recommendation implementation are currently ineffective. To continue to see repetition amongst recommendations across decades warrants consideration for how these recommendations are formulated, implemented, and evaluated.

Author Contributions: Conceptualization: T.E., A.P., and E.T.; methodology: E.T., T.E. and A.P.; software: A.P., E.T.; resources: T.E., A.P. and V.P.; data curation: E.T. and V.P.; writing—original draft preparation: E.T.; writing—review and editing: E.T., A.P., T.E., S.D., V.P.; visualization: E.T., A.P.; supervision: T.E. and A.P.; with additional project support provided by S.D. and V.P. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Richard, K.P. *The Westray Story: A Predictable Path to Disaster: Report of the Westray Mine Public Inquiry*; Lieutenant Governor in Council: Plymouth, NS, Canada, 1997.
2. Roberts, C.E.; Kane, D.J. *The Sago Mine Disaster*; United Mine Workers of America: Sago, WV, USA, 2006.
3. McAteer, D.J.; Beall, K.; Beck, J.A., Jr.; McGinley, P.C.; Monforton, C.; Roberts, D.C.; Spence, B.; Weise, S. *Upper Big Branch: The April 5, 2010 Explosion: A Failure of Basic Coal Mine Safety Practices: Report to the Governor of West Virginia*; Diane Publishing: Charleston, SC, USA, 2011; p. 122.
4. Panckhurst, G.; Bell, S.; Henry, D. *The Royal Commission on the Pike River Coal Mine Tragedy*; Governor General of New Zealand: Wellington, New Zealand, 2012.
5. Hopkins, A. *Safety Culture, Mindfulness and Safe Behaviour: Converging Ideas?* National Research Centre for OHS Regulation: Canberra, Australia, 2002.
6. Hale, A.R.; Hovden, J. Management and Culture: The Third Age of Safety. In *Occupational Injury: Risk, Prevention and Intervention*; Taylor & Francis: London, UK, 1998.
7. Cox, S.J.; Flin, R. Safety culture: Philosopher's stone or man of straw? *J. Work Stress* **1998**, *12*, 189–201. [CrossRef]
8. Pidgeon, N.F. The limits to safety? Culture, politics, learning and man-made disasters. *J. Conting. Crisis Manag.* **1997**, *5*, 1–14. [CrossRef]
9. Zhang, H.; Wiegmann, D.A.; Von Thaden, T.L.; Sharma, G.; Mitchell, A.A. Safety culture: A concept in chaos? In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*; SAGE Publications: Los Angeles, CA, USA, 2002; pp. 1404–1408.
10. Dechy, N.; Dien, Y.; Funnemark, E.; Roed-Larsen, S.; Stoop, J.; Valvisto, T.; Arellano, A.L.V. Results and lessons learned from the ESReDA's accident investigation working group. *J. Saf. Sci.* **2012**, *50*, 1380–1391. [CrossRef]
11. Turner, B.A. *Man-Made Disasters*; Wykeham Publications: London, UK, 1978.
12. Vuorio, A.; Rantonen, J.; Johnson, C.; Ollila, T.; Salminen, S.; Braithwaite, G. What fatal occupational accident investigators can learn from fatal aircraft accident investigations. *J. Saf. Sci.* **2013**, *62*, 366–369. [CrossRef]
13. Lind, S.; Kivistö-Rahnasto, J. Utilization of external accident information in companies' safety promotion—Case: Finnish metal and transportation industry. *J. Saf. Sci.* **2008**, *46*, 802–814.
14. Braithwaite, J. *To Punish or Persuade: Enforcement of Coal Mine Safety*; State University of New York Press: Albany, NY, USA, 1985.
15. Hopkins, A. A culture of denial: Sociological similarities between the Moura and Gretley mine disasters. *J. Occup. Health Saf.* **2000**, *16*, 29–36.
16. Quinlan, M. *Ten Pathways to Death and Disaster: Learning from Fatal Incidents in Mines and Other High Hazard Workplaces*; The Federation Press: Sydney, Australia, 2014.
17. Strauch, B. Can we examine safety culture in accident investigations, or should we? *J. Saf. Sci.* **2015**, *77*, 102–111. [CrossRef]
18. Leveson, N. Evaluating accident models using recent aerospace accidents (Part I: Event-Based Models). In *Software Engineering Research Laboratory, Aeronautics and Astronautics Department*; Massachusetts Institute of Technology: Cambridge, MA, USA, 2001.
19. Stoop, J.; Dekker, S. Are safety investigations pro-active? *J. Saf. Sci.* **2012**, *50*, 1422–1430. [CrossRef]
20. Lundberg, J.; Rollenhagen, C.; Hollnagel, E. What-You-Look-For-Is-What-You-Find—The consequences of underlying accident models in eight accident investigation manuals. *J. Saf. Sci.* **2009**, *47*, 1297–1311. [CrossRef]
21. Government of Ontario. *Mining Health, Safety and Prevention Review*; Ministry of Labour: Toronto, ON, Canada, 2015.
22. Indulska, M.; Recker, C.J. Design science in IS Research: A Literature Analysis. In *Faculty of Science and Technology*; ANUE Press: Canberra, Australia, 2008.
23. Cretchley, J.; Rooney, D.; Gallois, C. Mapping a 40-year history with Leximancer: Themes and concepts in the journal of cross-cultural psychology. *J. Cross Cult. Psychol.* **2010**, *41*, 318–328. [CrossRef]

24. Prasser, S. Royal Commissions in Australia: When should governments appoint them? *Aust. J. Public Adm.* **2006**, *65*, 28–47. [CrossRef]

25. Davies, S.H.E. *Report of the Tribunal appointed to inquire into the Disaster at Aberfan on October 21st*, 1st ed.; Her Majesty's Stationary Office: London, UK, 1967.

26. Ham, J.M. *Royal Commission on the Health and Safety of Workers in Mines*; Ministry of the Attorney General: Toronto, ON, Canada, 1976.

27. Burkett, K.M.; Riggin, R.P.; Rothney, K.E. *Towards Safe Production: Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario*; Government of Canada: Toronto, ON, Canada, 1981.

28. Stevenson, T. *Improving Ground Stability and Mine Rescue: The Report of the Provincial Inquiry into Ground Control and Emergency Preparedness in Ontario Mines*; Ontario Government Bookstore: Toronto, ON, Canada, 1986.

29. Qeensland. Wardens Court; Windridge, F.W. *Report on an Accident at Moura No. 2 Underground Mine on Sunday, 7 August 1994*; Australian Government: Moura District, Australia, 1996.

30. Bals, A.S.; Campbell, C.L.; Pitt, L.F. Viewer Reactions to Online Political Spoof Videos and Advertisements. In *Online Consumer Behavior: Theory and Research in Social Media, Advertising, and E-Tail*; Close, A., Ed.; Routledge: New York, NY, USA, 2012; pp. 185–208.

31. Leximancer. *Leximancer Manual*; Leximancer Pty Ltd.: Brisbane, Australia, 2014.

32. Smith, A.E.; Humphreys, M.S. Evaluation of unsupervised semantic mapping of natural language with Leximancer concept mapping. *Behav. Res. Methods* **2006**, *38*, 262–279. [CrossRef] [PubMed]

33. Frederick, E.; Pegoraro, A.; Sanderson, J. Divided and united: Perceptions of athlete activism at the ESPYS Sport and Society. *Sport Soc.* **2019**, *22*, 17. [CrossRef]

34. Yin, R.K. *Case Study Research Design and Methods*, 4th ed.; Sage: Thousand Oaks, CA, USA, 2009.

35. International Labour Organization. Chernobyl 20 Years After: From Disaster, Breeding a New Safety Culture. Available online: www.ilo.org (accessed on 20 September 2016).

36. Justice Committee. *Stage 1 Report on the Inquiries into Fatal Accidents and Sudden Deaths*; Edinburgh: Scotland, UK, 2015.

37. Mento, A.; Jones, R.; Dirndorfer, W. A change management process: Grounded in both theory and practice. *J. Chang. Manag.* **2002**, *3*, 45–59. [CrossRef]

38. Flyvbjerg, B. Five misunderstandings about case-study research. *J. Qual. Inq.* **2006**, *12*, 219–245. [CrossRef]

39. Mining Industry Human Resources Council. *Canadian Mining Labour Outlook*; MiHR: Kanata, ON, CA, 2009; Available online: www.mihr.ca (accessed on 18 September 2016).

40. Mining Industry Human Resources Council. *Canadian Mining Labour Outlook*; MiHR: Kanata, ON, CA, 2013.

41. Kletz, T. *Lessons from Disaster: How Organisations Have no Memory and Accidents Recur*; Institution of Chemical Engineers: London, UK, 1993; ISBN 0 85295 307 5.

42. Widmer, G.; Kubat, M. Learning in the presence of concept drift and hidden contexts. *J. Mach. Learn.* **1996**, *23*, 69–101. [CrossRef]

43. Chong, D.; Druckman, J.N. Framing theory. *Annu. Rev. Political Sci.* **2007**, *10*, 103–126. [CrossRef]

44. Pettigrew, A.M. *The Awakening Giant*; Basil Blackwell: Oxford, UK, 1985.

45. Pettigrew, A.M.; Ferlie, E.; McKee, L. *Shaping Strategic Change*; Sage: London, UK, 1992.

46. Johnson, G. Managing strategic change: The role of symbolic action. *Br. J. Manag.* **1990**, *1*, 183–200. [CrossRef]

47. Kelly, P.; Amburgey, T. Organizational inertia and momentum: A dynamic model of strategic change. *Acad. Manag. J.* **1991**, *34*, 591–612.

48. Meyer, A.; Brooks, G.; Goes, J. Environmental jolts and industry revolutions: Organizational responses to discontinuous change. *Strateg. Manag. J.* **1990**, *11*, 93–110.

49. Mine Safety and Health Administration. Mineral Resources. Available online: www.msha.gov (accessed on 20 September 2016).

50. Workplace Safety North. Mining Industry. Available online: www.workplacesafetynorth.ca (accessed on 22 September 2016).

51. Safe Work Australia. Mining. Available online: www.safeworkaustralia.gov.au (accessed on 22 September 2016).

52. WorkSafe New Zealand. Mining, Quarrying and Tunneling Operations. Available online: www.worksafe.govt.nz (accessed on 21 September 2016).

53. Government of the United Kingdom. Health and Safety Commission and Executive. Available online: http://www.hse.gov.uk/ (accessed on 21 September 2016).