Master Thesis

Occupational safety in Indian coal mines

Analyzing the impacts of interventions on occupational safety in Indian coal mines

IMPACT OF INTERVENTIONS ON OCOUPATIONAL SAFETY IN THE INDIAN COAL MINES

AUTHOR – ANUSHRI PRASHANT JAHAGIRDAR

MSc. Management of Technology

Student number – 5024307

To be defended on – 20 October 2021

SUPERVISORs

1st supervisor- Dr. Jan Anne Annema

2nd supervisor- Prof. Karolien van Nunen

Chair – Dr. Bert van Wee

TU Delft
Delft University of Technology

This page is intentionally left blank

SUMMARY

Improving coal mine safety has become one of the main objectives for policymakers and the Indian government in the past years. It is beneficial for the Indian government to ensure the proper functionality of the current safety interventions by assessing their impact on occupational safety. Comparing the number of fatal accidents in other major coal producing countries like Australia and USA (Figure 1), India still has a large number of fatal accidents. By the year 2017, where west Australia manages to reach 0 fatal accidents per year, USA had 8 fatal accidents per year, in the same year, India records 22 fatal accidents in the year 2017. Coal production in India is estimated to grow in the coming years. Having an extensive use of coal for commercial and domestic purposes, occupational safety gained importance in Indian coal mines. "Occupational safety" has gained immense attention from the early '90s when accident rates grew high in the coal industries nationwide. Even though occupational safety is used with occupational health, there is a thin line between the two concepts. "Occupational safety is primarily concerned with preventing injuries to employees as a result of occurrences related to the task they do in the workplace." This particular research is focused on the impacts of the intervention on "**occupational safety**" in the Indian coal mines. There was no evident scientific literature found on the impacts of interventions on occupational safety in the Indian coal mines. Therefore, this research aims to analyze the impacts of current Indian coal mining interventions on occupational safety. The central question of this research is: *"What impact do the safety interventions have on the occupational safety in the Indian coal mines?"*

Research methods: To approach the aim of the research, the proposed methodology comprises Literature review and ten semi-structured interviews. Literature review was aimed to gather information about the context of Indian coal mine safety. As limited resources are available on Indian coal mine safety, the approach was shifted to a general mining safety context for other major coal-producing countries like the USA, China and Australia. Per sub-question the methods will now be explained.

Method sub-question 01 *"what are the various safety interventions practiced by major coal producing countries? What are their impacts on occupational safety?***"** The research method used to answer the first sub-question is the literature review. The literature review is done with the help of scientific data bases like Scopus, Google scholar and web science & using keywords such as "Factors affecting occupational safety", "types of safety intervention", "Impacts of safety intervention in China", "factors affecting occupational safety in coal mines" "impacts of language and culture on occupational safety" etc.

Method sub-question 02 "*Which of the interventions practiced by major coal producing countries are practiced by India? What are the impacts of those interventions on occupational safety in Indian coal mines?***"** The second question is divided into two parts. The first part concerns with identifying which of the 14 globally practiced interventions are implemented by the Indian coal mines. To find this, data gathered from 10 semi-structured interviews is used. The

interviews were conducted with people working in the Indian coal mines with suitable experience. To find relevant audience for interviews, the preliminary research is used. The questions framed for the interviews are based on the theoretical model. The interviewees are selected based on their experience in management, technical/engineering and HR. Having people from diverse groups will increase the reliability of the findings. Digital platform was used to conduct interviews. The interviews are conducted with due consent from the interviewee and following the ethical guidelines. The audio recordings of the interviews are then processed into transcripts using "Otter.ai." The generated transcripts are then summarized into drafts and send to the respective interviewees to sign. With this process of verifying drafts, manipulation if the input is avoided. These approved drafts from the interviewees are then used for content analysis.

To answer the second part of the sub-question i.e. the impacts of the implemented interventions in the Indian coal mines, content analysis was used. By methodically finding specific properties of messages, content analysis is exposed to the methodology of making inferences. For content analysis, selective reduction is conducted to focus on the specific patters that answer the research sub-question.

Answering sub-question 03 "*What are the impact of unimplemented interventions, if implemented, on occupational safety in Indian coal mines?*" Using the theoretical model, interview questions are framed to find data regarding the impacts of the interventions that are not implemented in all the coal mines i.e. interventions with lower significance in India or the interventions that are not implemented at all. The interview responses (the approved drafts) were analyzed using content analysis to find the impact of unimplemented intervention on occupational safety in the Indian coal mines.

Results: Theoretical findings- The study has identified effective safety interventions practiced by major coal producing countries. In all there are fourteen safety interventions that contributes to the occupational safety positively.

Empirical findings- Referring to the table the results show that eight out of fourteen interventions are significantly practiced in the Indian coal mine. To find the impact of the eight interventions that are in practice, another content analysis is performed as per the code categories. Results for management interventions shows that:

Sr. No.	Intervention	Subject	No. of positive responses
1.	Management safety intervention	Maintenance of the equipment	7
		Management practices	5
		Safety audits and safety ratings	3
		Safety supervision	5
2.		Use Of IoT	0
		Emergency response system	5

	Technical safety intervention	Risk management system and warning control system	5
		Use of Virtual reality simulators	6
3.	Societal safety interventions	Safety awareness and knowledge	5
		Safety training and education	6
		Safety awards and promotions	6
4.	Behavior safety intervention	Sharing of safety concerns	0
		Safety behavior norms	2
		Behavior based safety programs	3

The table represents the interview responses. 1. Maintenances of the equipment and machineries have a positive impact on the occupational safety. The reason why it leaves a positive impact is the maintenance schedule. Every week, maintenance is scheduled to ensure proper functioning of the machineries and required equipment. However, it is also known that sometimes the maintenance schedule is only followed for the machineries that urgently needs repair or maintenance. This loop hole in the system at times lessen the positive impact on occupational safety. 2. The respondents believe that the management practices in the Indian coal mine has a positive impact on the occupational safety. An effective worker – supervisor (mine sardar) communication is established in the Indian coal mines. This is done regularly before mine workers are deployed on field 3. The supervisors keep in touch with the mine workers to supervise risky operations. From the research it is also confirmed that the mines, where safety supervision is not impactful, is due to lack of facilities for supervisor. There are no proper safety shelter for the mine supervisors which slightly impacts the occupational safety adversely.

The results of technical safety intervention shows that 1. The emergency response systems in the Indian coal mine is effective and impacts occupational safety positively. Even though the emergency response system is outdated and traditional, it shows positive impact due to it compatibility with the old coal mine infrastructure. It is also known that the emergency response time can be improved as compared to other countries. This can be achieved by installing emergency response system in regular distances. There are a few patches where there is no response system available. 2. Respondents say that the risk control and warning systems contributes to occupational safety positively in the Indian coal mines. There was a disagreement with the positive impact saying that there is a scope of technological advancement like use of artificial intelligence. Unfortunately, this is not achievable in recent times due to old mine infra-structure of the Indian coal mines. 3. Use of virtual reality simulators is very popular in Indian coal mines. The study shows that the use of virtual reality simulators has a huge positive impact on occupational safety. However, some of them believed that more VR simulators should be assembled as they are not sufficient.

The results of human safety interventions shows that 1.The safety awareness and knowledge leave a positive impacts on the occupational safety. Interviewee I also said that there is a scope of improvement with the awareness of safety regulations amongst the contract based workers. A more rigors measures needs to be taken for contract based workers. The safety awareness and knowledge can be enhanced by using multiple languages and interactive methods for safety

motivation like wages based on safety awareness and knowledge of the worker. 2. Safety trainings have positive impact on the occupational safety. In addition to this interviewees said that the safety assessments and mine inspections can be improved. This can be done by implementing surprise visits for mine safety inspections and audits.

It is noticeable that there are no behavior safety interventions that are significant in the Indian coal mines. This is explicitly observed from the analysis. All the behavior intervention that are implemented by the major coal producing countries, is not effectively implemented in India. According to the list of fourteen global interventions, there are seven safety intervention that are either not practiced in the Indian coal mine at all or have a very less significance. The result of content analysis shows that, when interviewees are asked about the impacts of the interventions that are not effectively in practice, what researcher finds is 1. The interviewees believed that safety audits and safety awards/promotion will impact occupational safety positively if they are implemented on a large scale. It is interesting to know that the safety awards and promotions also have negative impacts in some cases. For example, it is noticed on field that workers carry stress knowing that they might not get promoted and the stress impacts the occupational safety adversely. 2. Respondents believe that following safety behavior norms and implementing IoT technology in the Indian coal mines will impact occupational safety positively. It is also confirmed from the interview findings that implementing inter net of things is not possible anytime soon as the mine infrastructure is not compatible and needs a lot of advanced settings. 3. Sharing of safety concerns is another effective intervention that is not yet practiced in the Indian coal mines. Interviewee A, D and G strongly recommend the implementations of the intervention. Sharing of safety concerns helps to reduce risks and releases stress amongst workers impacting occupational safety positively.

Additional findings: Another interesting findings of the research explicitly concludes that 1. Not only safety education, but basic school education also impacts occupational safety. The respondents strongly believed that lack of education amongst mine workers impacts occupational safety adversely. Two of the respondents said that with their experience, basic education is not that necessary and does not create any major impact on the occupational safety as the training guides are in regional languages. 2. When the interviewees are asked the reason behind ineffectiveness of the interventions, the respondents raised a concern with the implementation of the interventions. The study also identified interesting ways of intervention implementation in Indian coal mines for more effective results such as video aids for training, methods to be implemented in multiple languages, more interactive way of implementation.

Conclusion & reflection: Occupational safety is related to injury causing situations. In past decade, occupational safety has gained a lot of attention and constant efforts are being made by the Indian government to improve occupational safety and reduce the risk of injuries in the coal mines. From the research conducted, the current interventions that are implemented in the Indian coal mines, impacts occupational safety positively. The interventions in practice can be further improved by providing proper mine infrastructure, adequate facilities for mine supervisors, availability of equipment and provision of basic school education. Similarly, the interventions that are not yet in practice can create a positive impact on the occupational safety if implemented in appropriate manner. It is important to focus on the current practices and enhance them by reducing the effect of moderating variables such as the basic education amongst the coal mine workers and method of implementation of the intervention. The main reason to

improve current safety interventions is that, the mine infrastructure of the Indian coal mines cannot be changed anytime soon due to lack of investments.

This paper has identified the interventions that are practiced in Indian coal mines and also analyzed their impacts on occupational safety. This study of Indian coal mine can be used to analyze the impacts of other possible factors such as culture, region, worker characteristics, technological progress and types of mine on occupational safety. A similar analysis framework can be implemented to analyze the impacts of interventions on occupational safety in other industries like construction.

The research contributes to safety of the workers. The study also provides insights for policymakers and the directorate general of mine safety to improve occupational safety, such as considering education, adequate facilities for mine supervisors and mine visits before framing policies to understand the real-life issues a worker deals with regards to occupational safety.

The study, on management level, recommends to ensure systematic training methods in different languages and simulators for training workers. To ensure the integrity of the research processes the study recommends research institutes to fundamental values to foster responsible research. This study identifies the impact of intervention on occupational safety with lack of basic school education and method of implementations as the significant moderating factors. It will be useful to research the impacts of other moderating factors like region, culture, worker characteristics, types of coal mines and technological advancement on occupational safety in the Indian coal mines.

This page is intentionally left blank

ACKNOWLEDGEMENT

This thesis signifies the end of Master of Science in Management of Technology at the Delft University of Technology.

I'd like to thank my graduation committee, without whom I doubt I'd have graduated. First and foremost, I'd like to thank my first supervisor, Dr. Jan Anne Annema, who believed in me from the start and guided me through my research. Second, Prof. Dr Bert Van Wee was a constant motivator and mentor to me. Finally, I'd like to thank Prof. Karoline Van Nunen for her insightful and timely feedback. Your suggestions, as well as your constant encouragement and motivation to put them into action, made my research more efficient.

Thank you to all the people I met in the past two years, which will be memorable. Last but not least, I want to thank my parents, especially my mom, for their constant love and encouragement—all my family and friends, who supported me in every decision I made. Finally, A big thank you to all the people who directly or indirectly inspired me to perform better each day and cheered me up in my downtime.

Yours sincerely,

Anushri Prashant Jahagirdar

CONTENTS

Summary…….. 04

Acknowledgement……10

Contents

List of figures……13

List of tables…….....14

List of abbreviations…….....15

1.	**INTRODUCTION**	
1.1	Research objective	17
1.2	Research question	18
1.3	Research relevance	19
1.4	Report structure	20
2.	**RESEARCH METHODS**	
2.1	Research methods sub-question 01	23
2.1.1	Intervention selection method	23
2.2	Research method sub question 02	24
2.2.1	Data collection methods	24
2.2.2	Interview structure	25
2.2.3	Data processing method	26
2.2.4	Data analysis method	26
2.3	Research method sub question 03	26
3.	**LITERATURE REVIEW**	

3.1	Safety interventions practiced by major coal producing countries	28
3.2	Types of safety interventions	28
3.2.1	Management safety interventions	29
3.2.2	Societal safety interventions	33
3.2.3	Technical safety interventions	37
3.2.4	Behavior safety interventions	41
3.3	The moderating effect	43
3.4	The conceptual model	43
4.	**RESEARCH FINDINGS**	**46**
4.1	Occupational safety in the Indian coal mines	46
4.2	Results from the preliminary research	46
4.3	Results from empirical findings	47
4.3.1	Impact of management safety interventions	47
4.3.2	Impact of technical safety interventions	49
4.3.3	Impact of societal safety interventions	52
4.3.4	Impact of behavior safety interventions	54
4.4	Impact of less important or unimplemented safety interventions	55
4.5	The additional findings	57
4.6	The empirical model	58
5.	**CONCLUSION**	**61**
5.1	Concluding points from theoretical findings	61
5.2	Concluding points from empirical findings	61

5.3	Key conclusions	62
6.	**DISCUSSION & RECOMMENDATIONS**	**64**
6.1	Scientific contribution and reflection	64
6.1.1	Scientific contribution	64
6.1.2	Personal reflection	64
6.1.3	Limitations and research challenges	64
6.2	Recommendations	65
6.3	Future scope	66
7.	**BIBLIOGRAPHY**	**69**
8.	**APPENDIX**	**76**
A	Interview questions	76
B	Draft layout	80

LIST OF FIGURES

1.	Figure 1 Number of fatal accidents	18
2.	Figure 2 Report structure	21
3.	Figure 3 Integrated safety interventions	29
4.	Figure 4 Safety management organization	29
5.	Figure 5 Worker management practices	30
6.	Figure 6 Information and interaction between worker and supervisor	32
7.	Figure 7 Death rate per M ton of coal	33

8.	Figure 7 Death rate per M ton of coal	34
9.	Figure 9 A safety motivation model	36
10.	Figure 10 Decrease in the injury rate	36
11.	Figure 11. Coal output v/s death rate	38
12.	Figure 12 Use of IoT in mining	40
13.	Figure 13 Focus on safety behavior program	42
14.	Figure 14 Conceptual model	44
15.	Figure 15 Frequency distribution of positive responses	46
16.	Figure 16 Overview of positive responses	51
17.	Figure 17 Overview of positive responses	53
18.	Figure 18 Overview of positive responses	55
19.	Figure 19 Empirical model	58

LIST OF TABLES

1.	Table 1 Inclusion and exclusion criteria	24
2.	Table 2 Interviewee's information	25
3.	Table 3 Overview of global safety interventions	46
4.	Table 4 Analysis of management interventions	47
5.	Table 5 Impact of management interventions	48
6.	Table 6 interviewee response overview	49
7.	Table 7 Impact of technology intervention overview	50
8.	Table 8 An overview of positive responses	52

9.	Table 9 Impact of societal safety interventions	52
10.	Table 10 Overview of positive responses	54
11.	Table 11 Impact of behavior safety intervention	54
12.	Table 12 Recommendations	65

LIST OF ABBRIVATIONS

1.	PTI – Press trust of India
2.	MT- Metric ton
3.	DGMS- Directorate General Of Mine Safety
4.	MoT- Management of Technology
5.	IMRaD- Introduction, Methods, Results and Discussion
6.	DGFASLI- Directorate General, Factory Advice Service and Labor Institutes
7.	IoT- Internet of Things
8.	AI – Artificial intelligence
9.	OSH- Occupational safety and health

This page is intentionally left blank

CHAPTER 01 INTRODUCTION

This report explains the impacts of implemented policies and measures to improve mine safety (an ex-post analysis) in Indian coal mines. India, "The coal nation", has a rich history of commercial coal mining, covering approximately 220 years. Coal mines are the source of 60% (approximately) of total energy consumed across the country for domestic and industrial purposes. Considering the news article issued by PTI in “The Hindu." "It is found that Indian mines have a considerably more accident and fatality rates than those in the USA and South Africa, respectively.” Union Coal and Parliamentary Affairs Minister Pralhad Joshi said in Lok Sabha, "Raw coal production in the country has increased from 567.77 MT in 2013-14 to 730.35 MT in 2018-19 (PTI, 2019).” Increasing coal production cannot be accomplished without increase in safety.

Coal mining is a dangerous profession and unfolds within an ambiguous environment (Verma & Chaudhari, 2017). Several factors add to an unreliable mining environment most critical **c**ontributing factors are pressure, heat and worker fatigue. It is, therefore, essential to build a safe working environment that will lessen the hazards and risks at workplace so that mining can continue with an assurance that the workers are working in a safe and hazard free environment. Does the mining laws, acts, safety methods, interventions and policies by the Indian government fulfil the intent of the implementation? This report leaves a reflection on the impacts of mining laws/policies/acts on worker safety.

It is important to realize the impacts of the implemented interventions. By conducting the impact analysis, it is clear to policymakers to consider potential changes in coming years to improve coal mine safety. A highly believed hypothesis is that open cast mines are safer than underground mines as chances of explosion are low due to accumulation of methane. This is one of the reason why most of the mines in India are now open cast. (Mandal & Sengupta, 2000| pg. 03).

Looking at the analysis records of India, it is evident that there was no Ex-post analysis performed to analyze the impact of executed laws, policies and safety interventions in practice to improve mine safety in recent years. Therefore, this research provides input to the safety analysis of Indian coal mines. “"Because mining is an ambiguous profession, our efforts to reduce hazards to an acceptable level by all available means must continue," says the Indian government. (PTI, 2019).

1.1 Research objective

India is the second-highest producer of coal crosswise the globe after China (Unwin, 2020). There are particular interventions to ensure mining safety that India regulates. What are the different levels of interventions, and how are these interventions executed? Are there any positive impacts of the interventions that are already in practice? All these types of questions need to be answered to ensure occupational safety in the Indian coal mines. The research includes

a study of various safety interventions practiced by other major coal producing countries with their impacts on occupational safety. Consequently, the main objective is **"to analyze the impacts of governmental safety policies and interventions on the occupational safety in Indian coal mines."** After the recent amendments by the government of Indian, risk assessments is now compulsory for every coal mine across India. Even though India has reduced the fatalities over the years, it is still a lot compared to other major coal-producing countries. Figure 1 shows the accidents in India as compared to the USA and Australia. It is clear that the number of fatal accidents in Indian coal mines is higher than in other coal-producing countries.

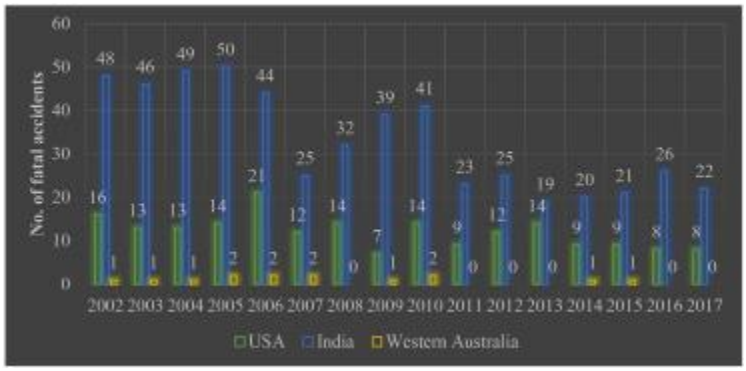

Figure 1: Number of fatal accidents

Source: (D. Tripathy & C. Ala, 2018)

Looking at the figure 1 it can be observed that by 2017 west Australia managed to attain 0 accidents in a year and USA managed to achieve a manageable situation by reducing the number to 8. However, India, managed to improve safety but still hold a large number of fatal accidents as compared to west Australia and USA. Therefore, to answer the research question, a preliminary research will be conducted to find interventions practiced by USA, China and Australia with proven positive impacts on the coal mine safety. So, by answering the research objective, the policymakers can consider the evaluation results to make amendments to the current safety measures and policies to improve occupational safety. The information gathered will benefit the government (DGMS) and the health ministry to understand the policy after its effects. This research will open a broad scope for further research in the safety interventions that are yet not practiced in Indian mines but have a proven positive impact.

1.2 Research question

Research questions are a systematic way to approach research problem. To reach the desired analysis, the research will follow one main research question and three sub-question. The main aim of the research will be achieved by answering the main question which is:

“What impact do the mining policies/ safety intervention methods have on the occupational safety in Indian coal mines?”

This report develops three sub-questions. These three sub-questions will aid the researcher to answer the main research question.

Q1: What is occupational safety? What are the safety intervention methods used by other major coal producing countries? What are their impacts (theoretically) on occupational safety?

Q2: What are the safety interventions adapted by the Indian coal mines? What are their impacts on mine safety?

Q3: What impact will the unimplemented interventions will have on the occupational safety if those practices are implemented in the Indian coal mines?

The first sub-question intends to collect information about the various interventions that are practiced across the globe to increase coal mine safety/occupational safety. Once, all the data is gathered, it will be a foundation to the second sub-question. With the help of data gathered by the preliminary research, questions will be constructed to gather data for sub-question 02.

The second sub-question directs the research to the actual case object on which the research is focused, i.e. Indian coal mines. The safety intervention identified in the previous section will now be analyzed for Indian mines to see which of the interventions listed in the literature are implemented in Indian mines with their overall impact on occupational safety. The third sub-question will open scope for further research and sum up the overall impact that is created due to the absence of safety interventions on occupational safety in the Indian coal mines.

1.3 Research relevance

Societal relevance

Coal mines are a huge source of employment in India. Every year lakhs of workers get employed in coal mines. Knowing that Mining is a risky profession, people work to feed their families. This research contributes to finding the reason behind the impacts of safety in Indian coal mines and improving occupational safety. The societal relevance is to improve safety and reduce fatalities in the Indian coal mines.

Scientific Relevance

With its increasing coal production, India has made much difference in the Indian economy, imports and exports and technological headway in the mining business. Many researchers have shown several reasons for accidents in the Indian coal mines. No one explicitly reflected policies in force and their consequences on worker safety. There is a

gap to be covered to reach the desired goal of safer work environments. The researcher fills in the knowledge gap by doing an Ex-post analysis and unrolls a broad scope for new research.

Management of Technology relevance

Mining is a popular and traditional business in India, and an MOT outlook helps build vital research and provide critical suggestions to policymakers. Throughout the entire course, several subjects have been learnt that helps to keep the research on track.

Subjects like Social and scientific values (MOT 1442) - helps to identify critical values of stakeholders and keep a scientific approach towards the research. Inter and Intra organizational decision making (MOT 1451) - This course helps the researcher understand why (in this particular case of worker safety in Indian coal mines) the Indian government made specific decisions/laws/policies and helps to make proper recommendations to policymakers. Research methods(MOT 2312) This is one of the essential subjects as it provides knowledge of structuring reports, clear research objectives, the appropriate approach to research questions and selection of methodological framework to answer the research question. The last one is preparing the master thesis (MOT2004) - Learnt a proper way of preparing a literature review. All these aspects are the essence of research.

1.4 Report structure

The researcher follows an IMRaD method for writing the research report (Sollaci & Pereira, 2011). This method assures a well-organized flow of research and simplifies revisiting any data within the paper. This method is also suitable if the researcher wants to publish the paper as this is a universally accepted format for presenting scientific findings. In all, the report contains six chapters. Figure 4.1 lays a plan on which the chapters connect.

Chapter 01- Introduction. In this chapter, the reader will come across the background of the subject, the problem statement approaching the case, the research question clarifying the aim of the research and the report design.

Chapter 02 - The literature review. This chapter highlights the existing literature and findings related to the case. With the help of a literature review, a research/knowledge gap is identified.

Chapter 03- Methods. The chapter will develop a well-organized research approach for the reader. The researcher will use pre available literature such as news articles, scientific papers, Book articles, journals to collect relevant data on labor safety in Indian coal mines. Nevertheless, data from ten interviews using quota sampling, in addition to the paper literature, is used.

Chapter 04- Analysis. The researcher will analyze the data collected from news articles, research/scientific papers, Book articles, journals, pre-conducted interviews and the ten interviews for conclusions on the impacts of the policies.

Chapter 05- Results. This chapter will reflect on the analysis performed in chapter 04 by answering the main research question and the relevant arguments.

Chapter 06- Discussion & Conclusion. With a discussion on the decision made to conclude from the findings. A quick highlight on the strengths and limitations of the research with future scope of ten years of exploration. This chapter also includes the discussion on the recommendations by the interviewees.

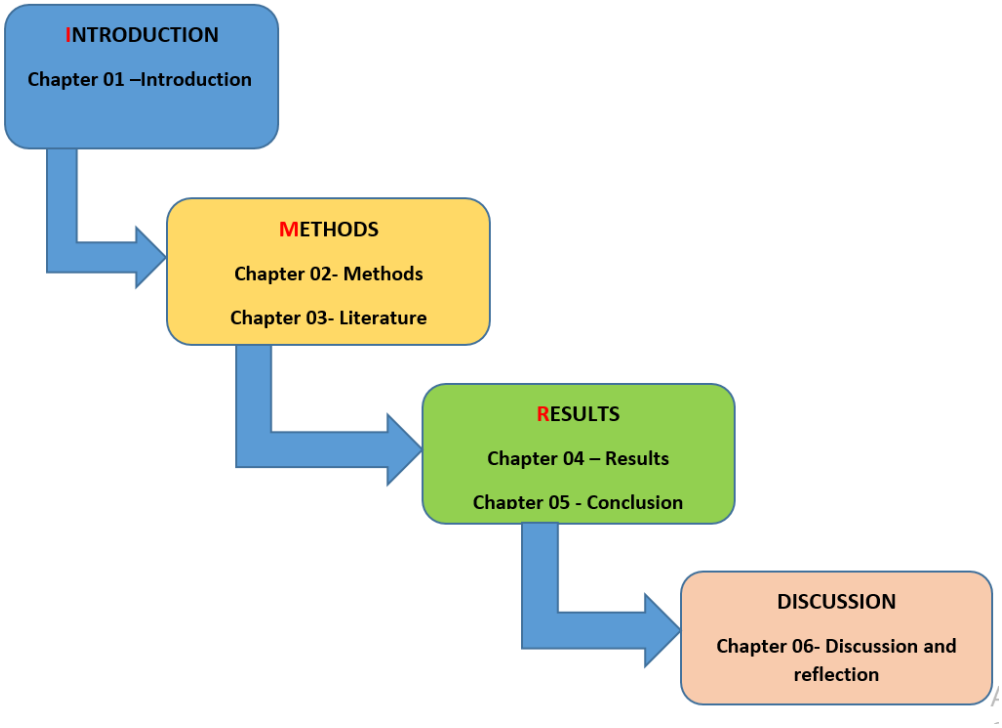

Figure 2: the report structure and content flow (IMRaD).

This page is intentionally left blank

CHAPTER 02 RESEARCH METHODS

This section of the report emphasis on the research method that will be used to carry out the research. The methods used to will be elaborated sub-question wise. The research was conducted through a qualitative methodology using 10 semi-structured. The research started with a general idea of occupational safety and impacts of safety interventions on occupational safety for major coal producing countries. The interviews were conducted with the experienced people in the field of mine engineering, human resources and Manager from Indian coal industry. Interviews are the best way to understand people's experience and day-to-day observations. The Interviewer used funnel approach to design questions i.e. from general question to specific questions.

2.1 Method Sub-question 01

The method used to answer sub-question one is the literature review. Secondary sources of data collection provide second-hand information and commentary from other researchers, articles, journals, books, or citations. A pre conducted interviews/ Interview transcript also works as second-hand data for the research. As a part of the research, the researcher is supposed to collect data to address a particular research problem identified. The collection of data can be for qualitative analysis or quantitative analysis. Quantitative analysis is mainly done where a lot of numerical pieces of evidence are preserved. For this particular research, the data collection is restricted to more qualitative.

Literature review is conducted using scientific data bases like Scopus, science direct, web-science and Google scholar. The relevant information is filtered using keywords such as: concept of occupational safety, what is occupational safety, what are the factors affecting occupational safety, what are the impacts of safety interventions on occupational safety, what are the safety interventions used by Chinese coal mines, impacts of behavior based programs on occupational safety etc. Using the keywords like "types of safety interventions", resulted in many papers. To sort relevant papers abstracts were used. The researcher read the abstracts and conclusion of the papers to see if the paper yield required content. After selecting suitable papers, snowballing effect was used. References were picked from the previous paper. Doing so was less time consuming and scientifically relevant.

2.1.1 Method of choice of interventions

To consider relevant interventions for this research, the following methods were used. A list of interventions was generated from the literature review. Similar terms or concepts were merged and listed as one. For example, safety audits and safety inspections are considered safety audits. The second method used for filtration of relevant interventions is the scope of research. For example, all the interventions aligned with health are excluded, like health checkups. And more safety-oriented interventions are included, such as equipment safety behavior interventions. The third method used for the inclusion of the interventions is based on the insights from the interviewees. After the

interviews, the interviewees confirmed that no other intervention is to be considered for the study, and the list of interventions is complete. And at last, the interventions for which enough empirical literature was found were considered for the study purpose.

The table below summarizes the global intervention selection and exclusion criteria for the study of impacts of the intervention on occupational safety in the Indian coal mines.

Table 1: Summary of the selection criteria for global interventions

Inclusion criteria	Exclusion criteria
Unique terms	Similar terms
Enough empirical evidence	Lack of empirical evidence
Factors confirmed by the interviewees	Factors not confirmed by the interviewees
Factors closely aligned with safety	Factors closely aligned with health or not closely aligned with safety

2.2 Method: sub-question 02

To answer the sub-question 02, interviews are used for data collection and those interviews are used to perform content analysis. The interview questions are framed using the literature review to answer sub-question 01.

2.2.1 Data collection method

A primary source gives you direct access to people closely associated with the Indian coal mines, either it is a worker or management or any political/government representative, i.e. the subject of your research (Mc leod, 2018). The nature of the specific events under study is discovered through data collection in qualitative descriptive studies. Thus, data collection entails semi-structured, open-ended, individual or focus group interviews that are minimal to moderate in length. (Hox & Boeije, 2005).

Primary sources are more trustworthy and convincible as evidence, but good research uses primary and secondary sources altogether (Mc leod, 2018). Therefore, the researcher will use both primary data collection and secondary data collection methods to answer the sub-question.

2.2.2 Interview structure

For this study researcher preferred semi-structured interviews. The questions for semi-structured interviews will be based on the literature review. The structure of the interview questions will follow the hierarchy of more generalized to specific. No questions will offend the interviewee or force the interviewee to answer personal questions. The interview questions are framed such that they are closely aligned with the purpose of research. The questions are mostly observational and experience based. Interviewer is flexible on the order of questions so as to extract more valuable information from the interviewee (Turner, 2016).

To study the impacts of interventions on occupational safety in the Indian coal mines. To maintain the confidentiality of the participants, the names are not revealed. The table below shows the list of participants with their designation. Different designations were selected to gather an overall perspective about the impacts of practiced and non-practiced interventions in the Indian coal mines.

Table 2: An over view of Respondents' Information

SR. NO	*RESPONDENT CODES*	*DESIGNATIONS*	*COMPANY*	*SECTOR*
1.	A	Deputy Manager	Coal India Ltd.	Public
2.	B	General Manager	Eastern Coal Field	Public
3.	C	Deputy Manager	Takrat India Pvt. Ltd	Private
4.	D	Personnel Manager	Central coal Field	Public
5.	E	Mine Engineer	Coal India Ltd.	Public
6.	F	Mine Engineer	Coal India Ltd.	Public
7.	G	Mine Engineer	Bharat cooking coal Ltd.	Public
8.	H	Human Resource Manager	BHR Pvt. Ltd.	Private
9.	I	Human Resource Manager	Hindalco	Private
10.	J	Mine consultant	MCD coal Pvt. Ltd.	Private

The respondents are coded as A, B, C, and D etc. By doing this, complete confidentiality with interviewees' name is achieved. The list of potential interviewees was generated before conducting interviews. In total 13 participants were shortlisted based on their designation and experience. Out of 13 participants, 3 participants did not show-up at the time of interview. The average time of interviews were ~ 32 minutes.

After conducting interviews with 10 participants, it was realized that no new information is needed, as a result, no interviews were conducted further for the study. After assigning the codes to the respondents, it works in the following

manner: There are four types of interventions that affects occupational safety. Some practices within the interventions might hold more significance than other.

The questions were asked in three phases depending on the designation the interviewee holds. Having diverse designation will enhance the generalizability of the data collected. The interviewees are not forced to answer any questions and have a complete right to deny answering at any point of the interview. The researcher picks to focus on the 'General interview guide' approach, which takes a mean spot and is moderately structured (Silverman, 2013).

2.2.3 Data processing method

The collected data needs to be processed before using it for analysis. The collected data from interviews will be processed in following manner: The interview recording (Only audio) will be transcribed using a software"Otter.ai". The transcripts generated are then drafted using the key points from the interview. This is done to remove inconsistencies from the data. The draft were sent to the respective interviewee's to read and sign the draft. By signing the draft, interviewee confirms the correctness of the data and authorizes the use of information for research. By doing this, the manipulation of the data is avoided. However the drafts are used for the sake of convenience of the researcher, it is equally important to make sure that the drafts are not prematurely reduced (McLellan et al., 2003).

2.2.4 Data analysis method

The method used is the content analysis. Content analysis is a suitable method of interpreting qualitative data and presenting it in quantitative manner. The main characteristic of the content analysis is the coding. The participants are assigned codes like A, B, C etc. The responses from the interviewees were coded into manageable content categories namely: management, technical, human & behavioral. After successfully coding the available data, selective reduction was conducted to focus on specific codes and patterns. The frequency of the repeated word and practices that were delivered by the participants were identified implicitly and explicitly.

2.3 Method: sub question 03

To answer sub-question 03, the similar method as of sub-question is used. First the data is collected using 10 semi-structured interviews. The data is processed and later analyzed using content (of the approved drafts) analysis method.

This page is intentionally left blank

CHAPTER 03 – LITERATURE REVIEW

This chapter focuses primarily on the research's theoretical foundation. Some previously conducted comparable studies are examined by comparing them to the actual case of Indian coal mines. The following sections will be discussed further down the road: 1.Different interventions used in other countries and their effects on occupational safety (theoretically). 2. A thorough examination of the safety interventions, including a hypothesis-based impact assessment. 3. Following the discussion of the significance of the Indian mines, a reflection on the robust framework of hypotheses and theoretical concepts will be presented. 4. A conceptual model, as well as its relationship to the research objective.

3.1 Safety interventions implemented by major coal producing countries

Occupational safety: Before going further to the safety interventions, it is necessary to understand the term occupational safety. In past years this term "occupational safety" is been defined by various scholars. Occupational Safety and occupational health are closely related but not the same. Occupational safety is concerned with the injury causing situations (Goetsch, 2019| Pg. 11). Therefore, for this particular research, the intervention that directly or indirectly affect the "injury - causing situations" will be chosen and the interventions closely related to the occupational health will not be taken into consideration.

Accidents in the workplaces, notably in the mining industry, are high (Bennett & Passmore, 1984). Constant efforts are taken globally to lessen the rate to zero. Accomplishing zero accidents is almost a utopia, but reaching a tolerable level of casualties is the goal of nearly every industry across the globe. A lot of safety practices and methods are adapted to increase Occupational safety. As observed in figure 1, countries like West Australia and USA managed to reduce the accident rates with increasing production. Therefore, it will be highly beneficial to find the interventions practiced by the other major coal producing countries.

3.2 Types of safety interventions

In this section, the researcher focuses on the types of safety interventions that are practiced within other coal producing countries.

Safety interventions

"Safety is a pre-condition for high productivity"(Swuste et al., 2010). Pg.03. A **safety intervention** is defined as an effort to transform how things are done to enhance safety. It could be any different plan, system, or initiative within the workplace designed to advance safety (Mazlina Zaira & Hadikusumo, 2017) pg.08**.** In this paper, four different interventions that are currently practiced by major coal producing countries are presented using figure 2.1. 1.

Management safety interventions. 2. Technology safety interventions. 3. Human safety interventions. 4. Human behavior safety interventions (Shakioye & Haight, 2010) pg.48.

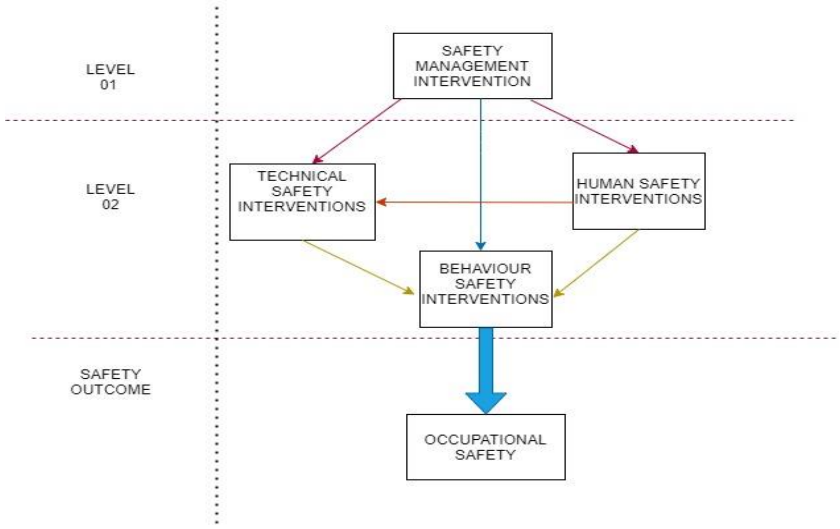

Figure 3: Integrated safety interventions.

The four interventions mentioned above can be categorized into 2 levels, level 0 and level 1 (refer figure 2.1). The levels are the indicators of the intra interventions impacts. Management safety interventions are categorized as level 01 intervention as management safety interventions leave a direct impact on the other three types of safety interventions. The arrows signify the impacts of these interventions on other interventions.

3.2.1Management safety interventions

All the interventions, laws and policies are written/initiated by the central government **(DGMS in the case of Indian coal mines)**. "Safety management is the backbone of worker/ occupational safety." (Teo & Ling, 2006).

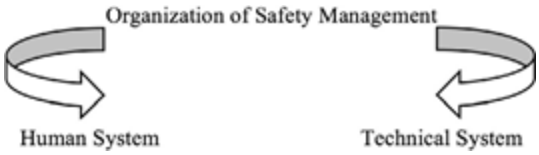

Figure 4: Safety management organization

Source: (Mazlina Zaira & Hadikusumo, 2017)

The figure 2.2 represents the organization of safety management systems. Organization of safety management holds equal portions of human safety and technology safety (Shakioye & Haight, 2010).

1. The necessary upgrades and maintenance of technology

Management has the requisite duty to look after the technological upgrades in the industry. Management should ensure that all demanded machines and equipment are up to the prevailing market bents and most suitable for the workplace (Garetti & Taisch, 2012). The reason why technological upgrades are regulated by the management (Hale et al., 2010) and not been governed under technical intervention is that it is managements responsibility to ensure if the instruments and machinery that is being used in mines is delivering required output.

In many countries several safety technologies are being adapted such as coal dust mitigations, methane control practices and proper planning for ventilation systems. Adapting the technology will increase worker safety and reduce unwanted incidences. Many of the countries are now using IoT to reduce manpower. Reduction of manpower results in reduction of accidents (Lööw & Nygren, 2019).

Impact: Implementation of upgraded technology provides advanced systems that reduces men power on field and hazardous places. Periodic maintenances of the equipment and systems reduces the risk of mishaps in workplace. Adapting advanced technologies have proven positive results in Chinese coal mines (Wang et al., 2012). Ex-ante studies have proven, based on the triple bottom line principle (People, Profits, Planet), that technology upgrade leaves a positive impact on occupational safety (Amponsah-Tawiah, 2013).

1. Management practices

Management needs to interact with their workers regularly. The interaction helps to prevent hazards due to worker negligence and uncertain responses. Accident prevention and safety performance also depend on worker engagement in the field (Wachter & Yorio, 2013).

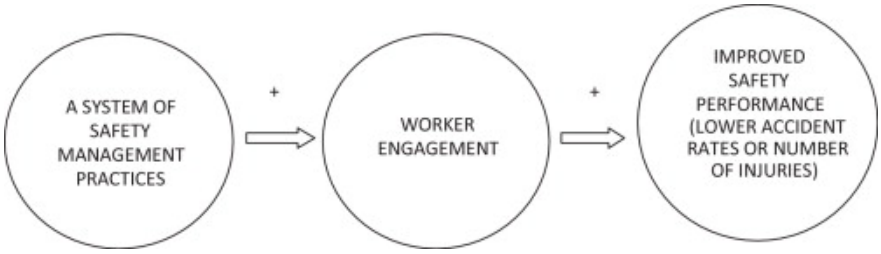

Figure 5: Worker management practices for safety.

Source:(Wachter & Yorio, 2014)

Worker engagement in safety will systematically lessen the chance of hazards from happening by spreading awareness amongst workers of their responsibilities and involved risks. Consequently, raised levels of worker engagement and a good rapport with the management/supervisor could be associated with improved safety performance (Ficher, 2012).

Impact: Based on a study by standards safety outcome (These are the safety standards pre-defined for a safety study in the USA mines), it can be said that the relation of worker and management i.e. a regular interaction of worker and management leaves a **positive** impact on occupational safety (Wachter & Yorio, 2014). An experiment conducted by the Gaertner serve as an evidence to the hypothetical assumptions that worker-management relations impact occupational safety. Gaertner compared five large coal mines where the worker-management relation are good with another five large coal mines where the worker-management relations are poor. Base on the annual average rates of Mine safety administration, the accident rates of the mines with good management –worker relations is almost half to that with poor worker-management relations (Wachter & Yorio, 2014| Pg.03).

Another experiment conducted by H. Peters also supports the hypothesis. Interviews of miners were conducted from 12 major coal mines. Out of 12 mines, 07 mines had a very low injury rate and 05 had very high injury rates. In the experiment, it was noted that the mines with low injury rates had a good management – worker relations. The management and workers shared a cooperative attitude (Peters, 1990).

3. Safety audits and safety rating

Safety audits are conducted regularly to avoid catastrophic losses at the workplace. In any industry, safety audits are conducted to analyze the current safety situation. The Hartford Loss Control Department (1998) demonstrated that an efficient safety audit is a medium that management can use to uncover safety and health issues when incidents happen (Brahmasrene & Smith, 2009). To be efficient, the audit must be supported by a responsible authority. Audits should be consecutive and regulated with the day-to-day procedures. An open-ended audit method is a tool by which management can achieve assessable data about the organization's safety and health programs. Regular safety audits help to identify the risk and streamlines the required actions which reduces the on field hazards. Even though audits are used to make safety evaluations, research has proven that too many audits affect safety adversely (Brahmasrene & Smith, 2009b).

On the other hand, the safety rating system i.e. international safety rating is not considered efficient in reducing the occupational risks. The main objective of the international safety rating is to identify the management work that has to be done to control injuries on field (Eisner & Leger, 1988| Pg. 06).

Impact: To observe the significant impact, the audit process should be continuous and not done just once. Similarly, too many audits in a time span shows relatively poor results on occupational safety (Brahmasrene & Smith, 2009). The impact of regular safety audits is considered positive on the worker and the occupational safety of the industry if

conducted in a proper scheduled manner. On the other hand, the international safety ratings (ISR) system is not effective with the occupational safety.

4. Safety supervision

Typically, a supervision system is implemented in response to accidents. Hazardous jobs like mining could be done under proper supervision. Every team of workers have supervisors allotted that monitors to only work but also workers safety behavior. In major coal producing countries like China where the death rate due to mine accidents was very high, implemented a supervision system policy to check impact on safety (Zohar, 2003). Not just the presence of a supervisor but the relation of mine supervisor with the workers also affects the safety (Su et al., 2019).

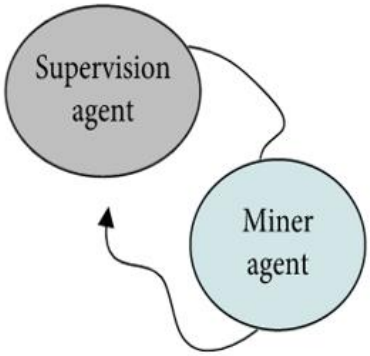

Figure 6: Information interaction between supervisor and workers

Source: (Nie et al., 2019)

In the figure 2.6, the interaction between the worker and supervisor is explained. This model is known as the interaction model. From supervisor agent the information is conveyed to the miner and the feedback goes from mine to supervisor (Nie et al., 2019). Even though the supervisor systems can be technology based, it is still classified as the human intervention as this Computable Miner Safety Supervision Model i.e. (CSMM) model is based on the thoughts the miner has while working like the salary that is paid, fear of encountering a risk while working etc. (H. Chen et al., 2016).

Impact: The supervision system is successfully implemented in Chinese coal fields. Referring to figure 2.8 below, China's Death rate per million tons was much higher till year 1999. After 1999 a considerable decrease in the China's death rate per million tons**.** The impact of supervision is dependent on the worker-management relationship**.** The

impact of supervision is positive on the worker safety as long as the relation between the supervisor and workers is good (Wachter & Yorio, 2014).

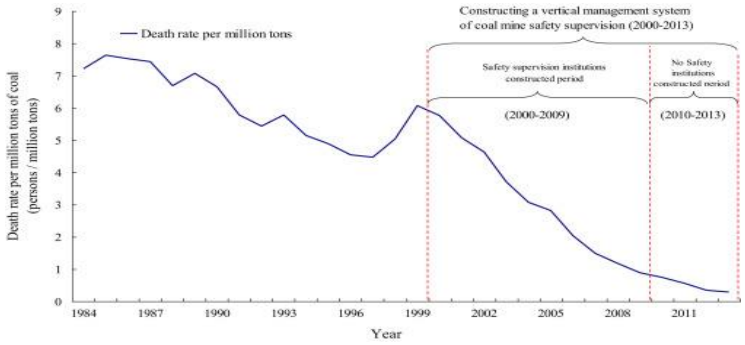

Figure 7: Death rate per million tons (DRPMT) of coal from 1984 to 2013 in China

Source: (S.-S. Chen et al., 2015)

These are the factors that are a part of human interventions on safety. Practicing these interventions will enhance safety and contribute to positive work environment. The hypothesis that are based on the Human safety interventions is: Human safety intervention has an impact on the occupational safety (Mazlina Zaira & Hadikusumo, 2017).

3.2.2 Societal safety interventions

The second type of intervention is the human safety intervention. This safety intervention is essential to the workers as it is designed to enhance their knowledge of workplace safety, motivate them, and develop a safe attitude while working in the field (Robson et al., n.d.). Human safety interventions are designed and implementation of interventions in social settings

1. Safety awareness & knowledge

Having safety rules and policies is not enough. It is very important to spread awareness amongst the workers about safety rules, regulations, habits and safety attitude while they work. Increasing employee safety conditions needs an awareness program to positive attitudes and behavior modification (Ünal et al., 2021). Safety can be promoted to workers (and production) via safety awareness, modifying risk behavior, safety and thinking, personal responsibility, leadership role, and personal commitment and values. Since safety is a people-intensive endeavor, "people-handling" skills must be improved. Employees follow management's stand (or what they perceive that attitude to be). Therefore,

supervisors set the safety tone and standards. They drive performance and are a crucial determinant of safety. Attitudes also reflect personal values (Kelley, 1996).

Education is a crucial aspect as it helps the workers to enhance the understanding of risks and safety requirements. Safety knowledge holds importance when occupational safety is considered (Fei & Anbi, 2011).

Impact: Workers on field when fully aware of the risk and safety rules, automatically reduces the risk of injuries and increases the occupational safety (Robson et al., n.d.). The impact of safety awareness, education and safety knowledge play a positive role in worker safety. A study has proven that the knowledge, education and awareness impacts safety in a positive way. (Nielsen, 2014).

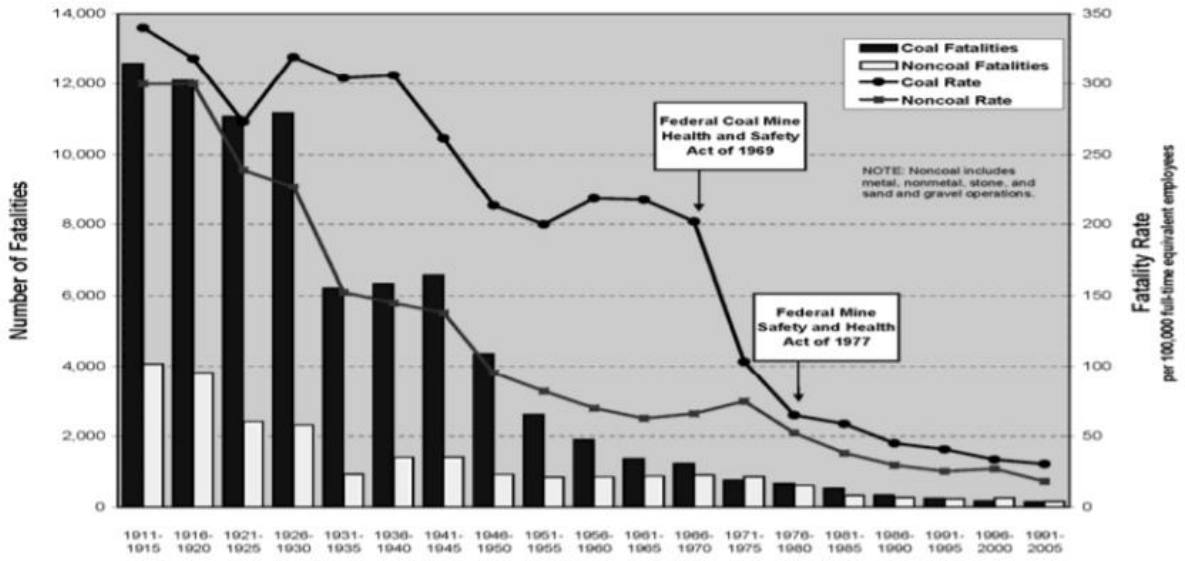

Figure 8: USA safety achievement – improving safety awareness

Source: (*2005 Home*, n.d.)

After improving mine safety awareness, safety education and training impacted USA mine safety positively. The fatalities in USA amongst the labor workers. However, the coal fatalities are higher than other fatalities. This also shows that coal mining is a more hazardous and risk profession than other mining industries.

2. Safety training

Training new workers as well as periodic training for regular workers will impact the accident figures and safety in mines. There are various methods that can be used for training workers.

Safety and health training techniques vary from passive, information-based techniques (such as lectures) to computer-based, programmed guidance and learner-centered, performance-based methodologies (e.g., hands-on

demonstrations). Lectures, which are among the least engaging methods of health and safety practices, are commonly used to present health and safety information. Other common passive techniques include videos and pamphlets, and also numerous types of written materials.(Burke et al., 2006).

The most engaging methods of safety and health training emphasize progressive knowledge development in various stages (Anderson, 1985) and the emphasizing principles of behavioral modelling. Observing a good example, modeling or practice, and feedback designed to modify behavior are all part of behavioral modeling. Hands-on demonstrations associated with behavioral simulations, which require active participation from the trainee, are also included in these methods. (Schofield & Dasys, 2010).

Impact: A significant reduction in the risk rate was observed after a time series experiment conducted by the implementation of safety training regulation by the US labor's mine safety department that if correct methods of training programs are scheduled and organized, it leaves a positive impact on the safety of workers and also enhances occupational safety and safety knowledge (Monforton & Windsor, 2010).

3. Safety awards, promotions and incentives

As mentioned in the previous sections, motivation is must for the workers to behave safely and adapt safety rules. This motivation can be given through various forms such as awarding the safety behaviors or money compensations and providing incentives for workers so they can work safely.

Money compensations cannot always be motivating. Digging deeper into the different aspects in which the monetary bonuses and awards affect safety will be a broader topic to cover for this research, hence, theoretical speaking, the bonuses and promotions are practiced to motivate workers and to develop a positive attitude towards safety.

Safety motivation and rewards improve working conditions and positively influence employees' attitudes and behaviors toward safety, resulting in fewer workplace accidents. The study used a questionnaire to conduct a survey among workers and employees to assess their perceptions of practices and self-reported safety knowledge, safety motivation, safety compliance, and safety participation.(Vinodkumar & Bhasi, 2010).

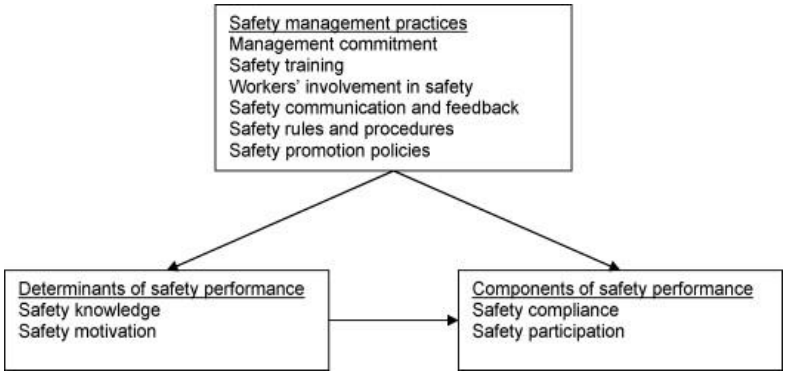

Figure 9: a hypothetical safety motivation model.

Source (Teo & Ling, 2006)

Impact: Referring to the figure 2.5, safety motivation is the determinants of safety performance. Studies have shown that safety motivation, awards and promotions influences work safety positively and also impacts the safety awareness and behavior positively (Teo & Ling, 2006).

Promoting workers so they attain peace of mind and work safely. China says a "win-win promotion." The figure below shows the decrease in fatalities and decreased injury rate in the city of Changzhi (S. Sun & Gai, 2014).

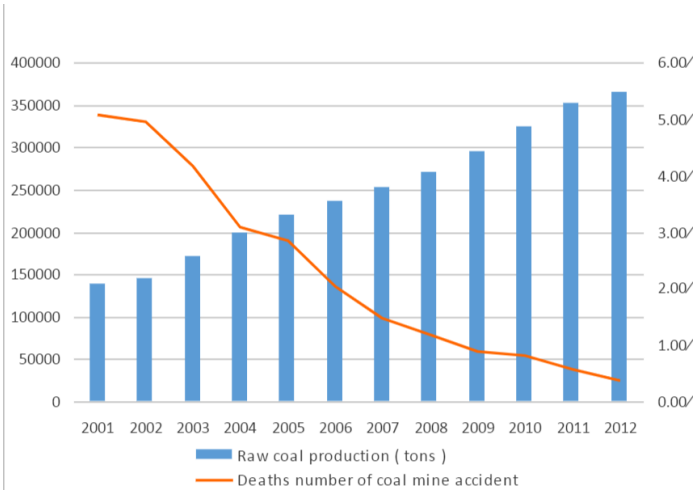

Figure 10: Decrease in injury rate after using promotion model- China

Another study by Psychology research shows that job satisfaction and commitment towards work are sign of worker motivations which can be achieved by awarding workers. The job satisfaction will indirectly affect the occupational safety (Sanjiv K. Nimbalkar, 2017).

3.2.3 Technical safety interventions

So far, the human safety interventions and management safety interventions have been discussed with hypothetical theories. The technical safety interventions affected by the management safety interventions will be discussed with theories contributing to occupational safety. The technical safety intervention includes making some organizational/infrastructural change (Robson et al., n.d.). A technical system forms a big part of the management intervention system that contributes to reducing occupational hazards (Shakioye & Haight, 2010). Following are the possible and impactful safety interventions that can be performed on the technical level.

1. Use virtual reality simulators

The working conditions of underground mines is usually complicated, and many mine works involve the operations of machinery. New miners with insufficient experience are vulnerable to work-related injuries (Yang et al., 2018). Virtual reality (VR) simulators is a new safety practice (Technology wise) that has proven positive impacts in Chinese coal mines (van Wyk & de Villiers, 2009). VR simulators were used in mines because there is a low chance of workers being educated or literature. To avoid hazards due to illiteracy or being uneducated (Squelch, 2001). Using simulators also affects the worker attitude and increases the worker safety behavior.

Impact: Installation of simulators have impacted safety positively for China and Africa. Simulators give easy practice to workers and boost their confidence. This in turn impacted positively on occupational safety/worker safety. Effective safety training is a must for ensuring mine safety. Virtual reality (VR) technology has the potential to improve training efficiency. (H. Zhang et al., 2019). In china, previously, only classroom trainings were provided. The results obtained from the classroom and had on field training did not give good results with respect to occupational safety (He & Song, 2012) . After implementation of VR Simulators for safety training, Chinese coal mines observed drastic dip in death rate per million ton of coal output even though the coal production kept increasing. The figure 11 shows the decrease of the death rate for one million tons of coal output after VR Simulator implementation in coal mines. It is also observable that with decrease of accident rate there is sharp increase in productivity of coal.

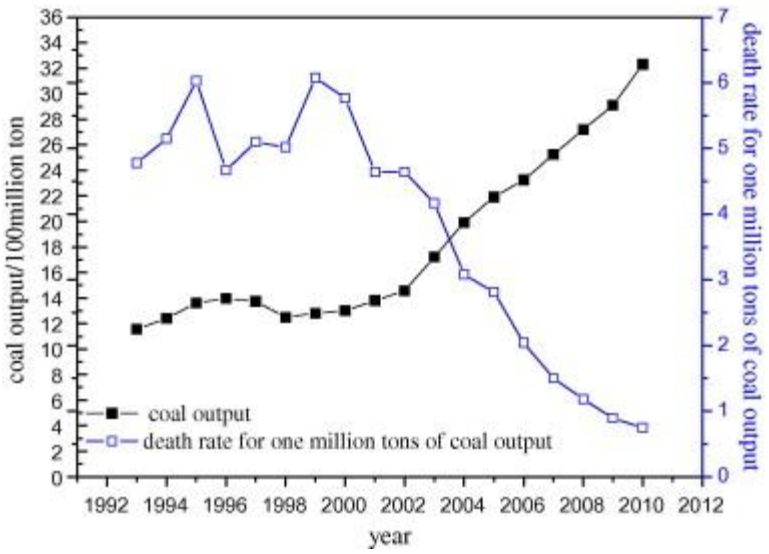

Figure 11: Chinese coal output death rate per million ton

2. Emergency response system

Self - escape issues

It is generally observed in mines that the rescue teams arrive in case of an accident but, the incentive for workers to escape from the mine themselves is the issue. I.e. the workers wait till the help arrives instead of moving out of the location themselves. This can be improved by training and education and well preparedness for emergencies (Nottinghamshire, n.d.).

Effective emergency response includes emergency measures, emergency capacities and contingency plans. Emergency measures. This process aims to eliminate or control the disaster at the early stage and prevent disaster from spreading to other nearby areas (Bing et al., 2014). We should set up emergency measures in coal mine enterprises based on the characteristics of the workplaces and organize relevant personnel to exercise emergency capacities on a regular basis. Emergency capacities provide trapped personnel with material support and self-rescue skills, which is extremely important in emergency rescue. Personnel emergency response development Training and education can help with this process. A contingency plan is a plan of action for potential accidents that includes a comprehensive contingency plan, a specific contingency plan, and a field disposal plan. (Onifade, 2021). Coal mining companies should develop specific contingency plans and field disposal plans for all types of potential accidents, as well as identify a responsible person throughout the accident process. Furthermore, coal mining companies must organize workers on a regular basis to learn and practice plans, as well as ensure that workers can move ahead normally when accidents occur.

Impacts: Researcher from the National Institute of occupational safety conducted interviews with 10 focus groups and individuals to gather data on effectiveness of response systems. They interviewed diverse groups and analyzed various situations such as mine fires, explosion and inundations. The study was conducted in south and east part of United States (Kowalski-Trakofler et al., 2010).

In 2007, the accident rate went up in the mine of US. When analyzed, it was identified that the emergency response systems had reoccurring issues. Later the framework of the emergency response system was rectified and a study was conducted to realize the impact of improved emergency response systems. From the interviews it was evident that accident and on field injuries have lowered to a considerable level (Kowalski-Trakofler et al., 2010). Interestingly, it was also realized that the worker training and trust impacts the emergency response systems and their impacts on occupational safety.

Another study conducted in Australian coal mines revealed that the lack of proper emergency response system was th e reason behind increased number of fatal accidents (Cliff & Grieves, 2010). Improving emergency response systems will impact the occupational safety in a desired way.

3. Risk management systems and warning control

The emergency response systems are used when an unwanted incidence has occurred. On the other hand Risk management systems and warning controls are digital equipment installed in mines to detect risks. According to the risk supervision features and the actual needs of safety products in the coal mine, the risk assessment systems are implemented. The system manages and controls the potential accident risks, hazard sources and human behavior risks (Qing-gui et al., 2012).

Risk management is the pre-analysis, clarity of vision, and restriction of risk, and also an administrative task of lowering the risk damage, which typically includes risk identification, risk assessment, risk control, and risk transference. (Liu & Luo, 2012). The purpose of risk identification is to determine the most likely risk type. Risk assessment primarily refers to the qualitative and quantitative analysis and information of various risk types; risk control is to reduce the occurrence likelihood and loss of risk, while the critical point is to redesign all criteria involving the output of risk mishap and increasing damage. (Ding & Zhou, 2013).

Impact: Based on a multi-level fuzzy general evaluation method, the study was conducted by an MPO (risk management research in China) specialized services risk evaluation model. For coal enterprises, a professional service risk management index system was established. (He & Song, 2012). The weights were determined using the Delphi and set-valued statistics-triangular undefined number methods, with the Jinjie Coal Mine in China serving as an example.

The nature of qualitative methods ensured the trustworthiness of the evaluation results. It was revealed that safety risks were the most critical, and that there were newly emerging risks such as contract risk and financial risk. Several

preventative measures were proposed based on the results of the Jinjie Coal Mine risk analysis: establishing and expanding risk management and warning control systems to improve occupational safety(Luo et al., 2019).

4. Use of IoT (Internet of Things)

By implementing IoT technology for adequate distant supervision, mine supervising trends, emergency response and accident investigation capabilities, and the situation of ensuring safety can all be improved. The term "intelligent safety supervision of coal mine" refers to using IoT technology by coal mines to communicate with mining workers and establish effective tracking systems and database systems, to achieve adaptive and early warning against accident risks through remote investigation, and to use data collected by sensors to aid in urgent situation rescue and accident investigative process.(Yinghua et al., 2012).

Impact: The figure below shows the IoT work flow to improve coal mine safety by reducing the risk of accidents in the underground coal mines.

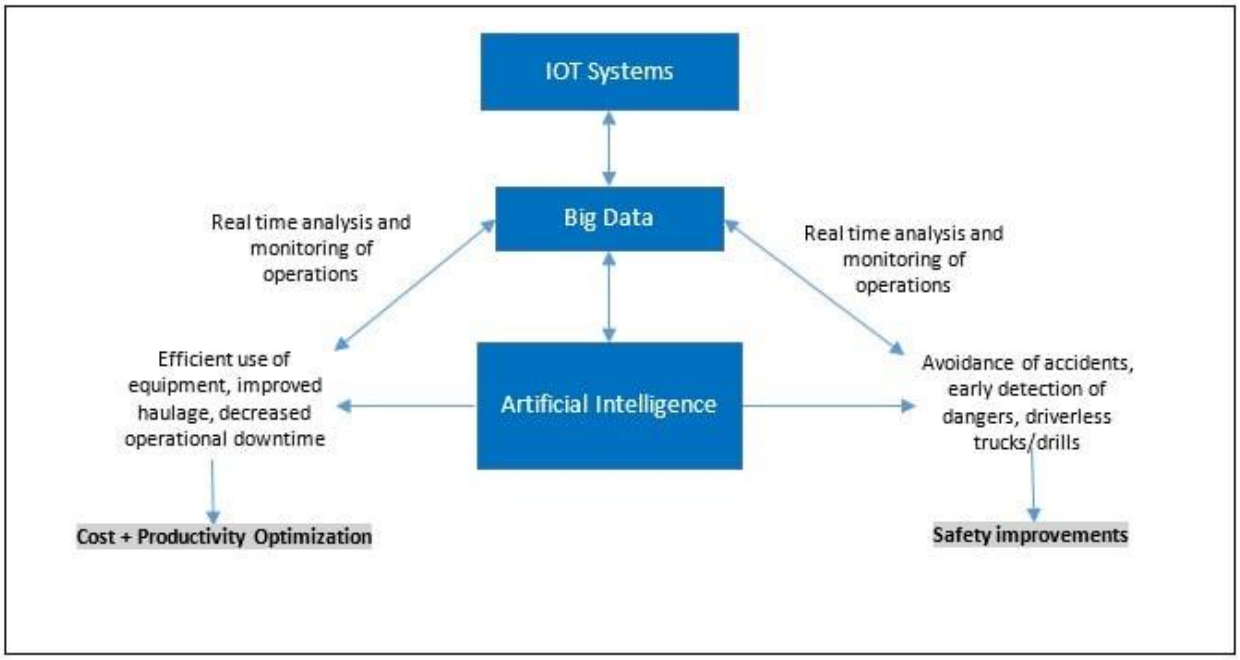

Figure 12: Flow chart of IoT in mining

Source (*Internet of Things (IoT) in Mining Industry | Infosys BPM*, n.d.)

IoT systems operate remotely and store data in big data units. The implementation has resulted into positive impacts on occupational safety. It is highly recommended to use IoT for smart supervision to avoid risk of accidents especially in underground coal mines. Internet of things allows for the prediction of potential risks in the mining industry. (E. Sun et al., 2012). The Brumadinho Dam disaster, a tailings dam of an iron ore mine in Brazil, occurred in January 2019 and resulted in a significant number of fatalities, is a recent example demonstrating the importance of IoT's use to increase mine safety.(Almeida et al., 2019). Use of Internet of Things offer sufficient assurance to enhance mine safety and is currently researched by many nations and implemented by Chinese coal mines (Molaei et al., 2020).

3.2.4 Behavioral safety interventions

Safety interventions are necessary to improve safety behavior and especially worker safety behavior (Zohar, 2003). Behavioral interventions are interventions that are intended to influence people's actions regarding their own safety. Studies have mentioned that inducing safety behavior interventions amongst all the other interventions, reduces accidents at the workplace and increases safety-related experiences (Cooper Ph.D., 2000). There are bases of scientific studies that show the positive impacts of safety behavior interventions on occupational safety.

1. Sharing of safety concerns

Sharing of safety concerns or previous experiences on local I.e., with the work force or on global level i.e. amongst the countries. The method of safety concerns is currently practiced in many other sectors like health care, mining and construction industries. Previous research has shown that nations are trying to share safety data across globe to foster occupational safety. It is shown by the researcher that sharing of safety concerns encourages safety leadership actions and hence, increases the occupational safety (Schulte, 2002).

Impact: In a time-lag study conducted in the United States nursing department with 586 nurses, reported that sharing of safety concerns and safety experiences resulted in lower injury rate in workplace and the nurses also reported overall improvement in the safety (Halbesleben et al., 2013).

2. Safety behavior norms

Safety behavior norms are directly associated with the safety leadership and actions. To find impact of safety behavior norms on the occupational safety, the most common method used by the researcher is the questionnaire. Safety norms have become an important contextual influence on the occupational safety (Fugas et al., 2021).

Impact: After conducting experiments to find impact of behavior norms on occupational safety, a major problem was noticed with behavior norms is that, after interventions are removed, the norms do not last for a long time. Constant attention and monitoring is required (Howe, 2017). In a questionnaire experiment conducted by the coal mining

industry in China, has proven impact of the behavior norms on occupational safety. The results also show that safety behavior is a favorable measure to promote worker safety (S. Zhang et al., 2017).

3. Behavior based safety programs

In the section above, it is theoretical evident that behavior norms play a vital role in safety. When accident rates were at peak, at first, engineering changes were adapted to reduce the occupational injuries. Later in time system changes were adapted to increase occupational safety. Still accident rate continues to grow. As the potential of other practices to increase occupational safety has exhausted, the focus has recently shifted to behavior based programs to reduce accidents at workplace (Hopkins, 2006).

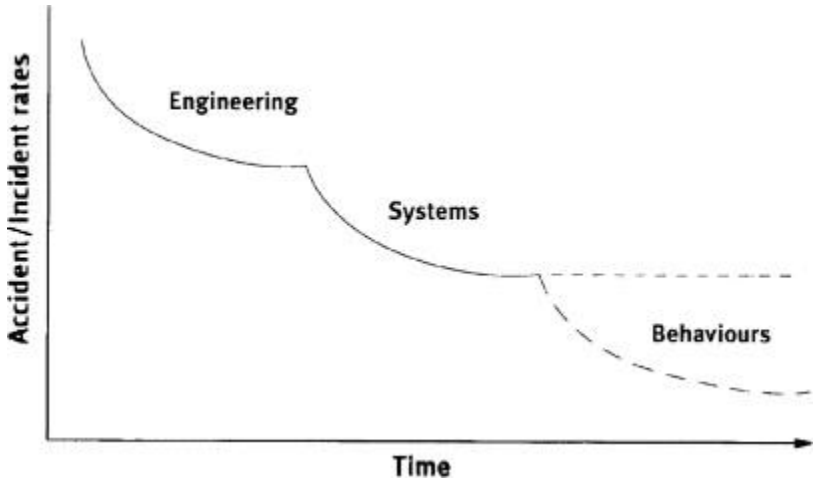

Figure 13: Focus on Behavior safety programs to reduce accident rates

A behavior based safety program to approach occupational safety is proposed by many researcher and has been found effectively improve occupational safety in different industry setting (Jasiulewicz-Kaczmarek et al., 2015).

Impact: A case study was conducted in Australian Manufacturing industry with high injury rate. After successful implementation of safety behavior program, it was noticed that many problems associated with the occupational safety were resolved as compared to other traditional methods (Clancy, n.d.).

The advancement of BBS (Behavior Based Safety) applications has been observed in a wide range of industries. The required appraisals of the BBS approach, as well as studies evaluating BBS interventions involving a cross-section of industrial sectors, provide evidence of this. (McAfee & Winn, 1989) 24 studies on the effectiveness of behavioral strategies were examined. They confirmed that all studies, without exception, demonstrated an improvement in safety performance by lowering injury rates and improving safety-related conditions. Similarly, Guastello investigated the

effectiveness of 53 accident prevention programmers, concluding, "Behavior safety techniques have the potential to be useful in a wide range of industries." (McAfee & Winn, 1989).”

3.3 The moderating effect

The literature review shows impacts of the interventions on occupational safety in major cola producing countries. The impacts are subjected to various moderating effects such as technological advancement (Chu et al., 2016)**,** language and culture (De Jesus-Rivas et al., 2016)**,** worker stress (Roberts & Grubb, 2014)**,** type of coal mine (Kulshreshtha & Parikh, 2002)**.** This study is focused on the impacts of safety interventions on occupational safety in the Indian coal mines. Therefore, the impact of moderating factors that influence the direct impact on occupational safety are not considered as the subject of study.

3.4 Conceptual model

Conceptual model is used to represent the concept reflected in the literature. In the figure below, the conceptual model represents the theoretical idea behind the impacts of safety interventions on occupational safety. It is evident the safety intervention 1. Management safety interventions 2. Technical safety interventions 3. Human safety interventions and 4. Behavior safety intervention have a direct and positive impact on occupational safety. The other factors, such as Implementation method, region/language & culture, worker characteristics (like worker stress), type of coal mine and technological progress moderates the effects of interventions on the occupational safety.

The conceptual model

The figure below presents the conceptual model. The model shows that the safety intervention have a direct and positive impact on occupational safety. The direct and positive impact is subjected to various moderating factors such as implementation methods, types of coal mines, worker characteristics and technological progress. Even though the moderating variables is not the subject of this particular study. The effects cannot be ignored.

The conceptual model represents the literature findings. The general safety interventions are implemented in four different levels. The specific interventions that fall under particular level of implementation is indicated in the conceptual diagram. For example, the equipment maintenance policy is an intervention implemented on management level. The implementation of these interventions in a particular mine is subjected to various external factors such as worker characteristics, region and culture, type of coal mine (open cast or underground)

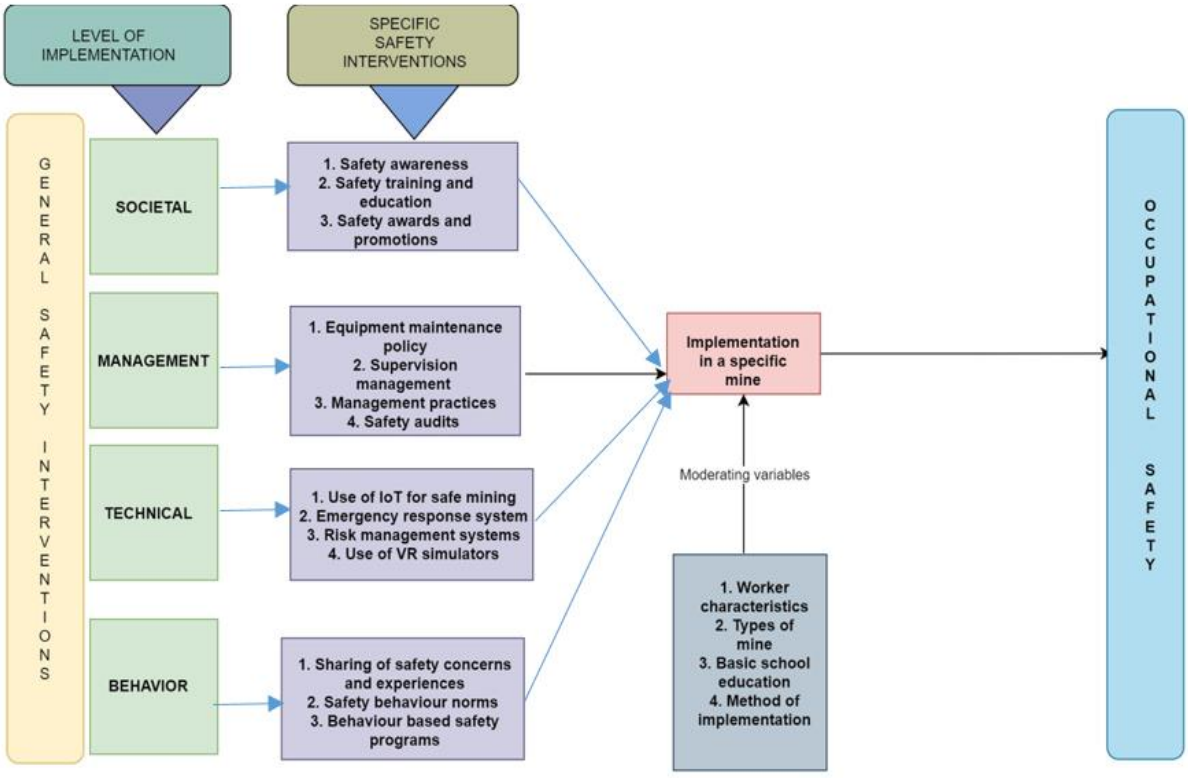

Figure 14: the conceptual model with impacts and theories.

This page is intentionally left blank

CHAPTER 04 RESULTS

"Qualitative data is often subjective, rich, and consists of in-depth information normally presented in the form of words. Analyzing qualitative data entails reading a large amount of transcripts looking for similarities or differences, and subsequently finding themes and developing categories." (Wong, 2008). This chapter focus on the results using content analysis method. Further down it analyzes the data to present results in a systemic manner such that it answers the sub-research questions.

4.1 Occupational safety in Indian coal mines

India, the world's largest democracy and a developing economy, has a population of more than 1.6 billion people. Out of this massive number, 63.6 percent are of working age, with more than 60 percent employed in the informal economy, primarily agriculture and services. The remaining 40% work in the organized sector, primarily in coal mining. Mining industries are rapidly expanding, as is the proportion of mineworkers in the workforce. (Pingle, 2012). Pg. 171.

Stakeholders are involved in the past, present, and future activities of companies. In India, the occupational safety and health (OSH) situation is complicated. Unprecedented growth and progress are accompanied by challenges such as a large unorganized workforce, the availability of cheap labor, public spending on safety, insufficient implementation of existing policies and interventions, a lack of reliable OSH data, a shortage of OSH professionals, stakeholder apathy, and infrastructure issues.

4.2 Results from the preliminary research

From the literature review, it can be concluded that, there are in total fourteen intervention practiced by other countries with positive and proven impacts on the occupational safety. The table below shows the fourteen interventions that are practiced by the other major coal producing countries.

Table 3: An overview of the interventions practiced by other coal producing countries.

SR, NO	*TYPE OF INTERVENTION*	*SUBJECT*	*CODE*	*SOURCE*
1.		Maintenance of the equipment	M1	
		Management practices	M2	
	Management	Safety audits and safety ratings	M3	(Swuste et al., 2010)
		Safety supervision	M4	

2.	Technical	Use Of IoT	T1	
		Emergency response system	T2	(Oyewole et al., 2010)
		Risk management system and warning control system	T3	
		Use of Virtual reality simulators	T4	
3.	Human	Safety awareness and knowledge	H1	
		Safety training and education	H2	(Shakioye & Haight, 2010)
		Safety awards and promotions	H3	
4.	Behavior	Sharing of safety concerns	B1	
		Safety behavior norms	B2	(Hadikusumo, 2017)
		Behavior based safety programs	B3	

4.3 Results from the empirical findings (Interviews)

This section of the report focuses on the findings from the data collected from interviews.

4.3.1 Impact of Management safety interventions

The management safety interventions in the Indian coal mines are analyzed for their impacts on the occupational safety. The results from the interviews are analyzed with the help of content analysis. The analysis is divided into two parts, each answering the sub question 02. The table below shows which of the interventions practiced by other major coal producing countries are currently practiced by Indian coal mines.

Table 4: The analysis of interventions practiced in Indian coal mines

Type of intervention	*Subject*	*Code*	*No. of respondents*
Management	Maintenance of the equipment	M1	7
	Management practices	M2	6
	Safety audits and safety ratings	M3	8
	Safety supervision	M4	8

In the table above the frequency of the positive responses is presented. During interviews if the respondent says that the intervention is implemented, it is counted as one. No respondent is counted twice for one intervention. The table above helps to identify the interventions that are sufficiently implemented in the Indian coal mines.

Now that it is clear that three interventions that are significantly practiced in the Indian coal mines, they can be further analyzed for their impacts on occupational safety. During the interviews, the interviewees were asked about the impacts of the currently practiced interventions in the Indian coal mines. The practices M1, M2 & M4 appears more significant and will be further analyzed for their impact on occupational safety. The gathered responses from the interviewees are presented in the table below. The responses represent the positive impact of the intervention on occupational safety.

Table 5: Impacts of the interventions on occupational safety in Indian coal mines

Type of intervention	Subject	Code	No. positive response
Management	Maintenance of the equipment	M1	7
	Management practices	M2	5
	Safety supervision	M4	5

The table explicitly delivers the impacts of the management interventions. The equipment maintenance is the most promising way to enhance occupational safety from a management perspective in the Indian coal mines. Most of the interviewees firmly agreed that maintaining the equipment regularly, impacts the occupational safety positively in the Indian coal mines. It is known from the study that Indian coal mines conduct weekly maintenance and all the maintenance are pre scheduled. Interviewee (C, D, and F) mentioned a loophole in the maintenance schedule that might impact occupational safety adversely. It is sometimes observed that the maintenance is only conducted if the machine needs urgent repairs, in other cases the maintenance is delayed.

Interestingly, the 3 respondents (C, D and F) that said that the equipment maintenance is done only when necessary were from northern coal fields. Therefore, it can be said that the maintenance equipment has a positive response on occupational safety in the Indian coal mines. The implementation of equipment maintenance schedules can be improved in Northern coal fields.

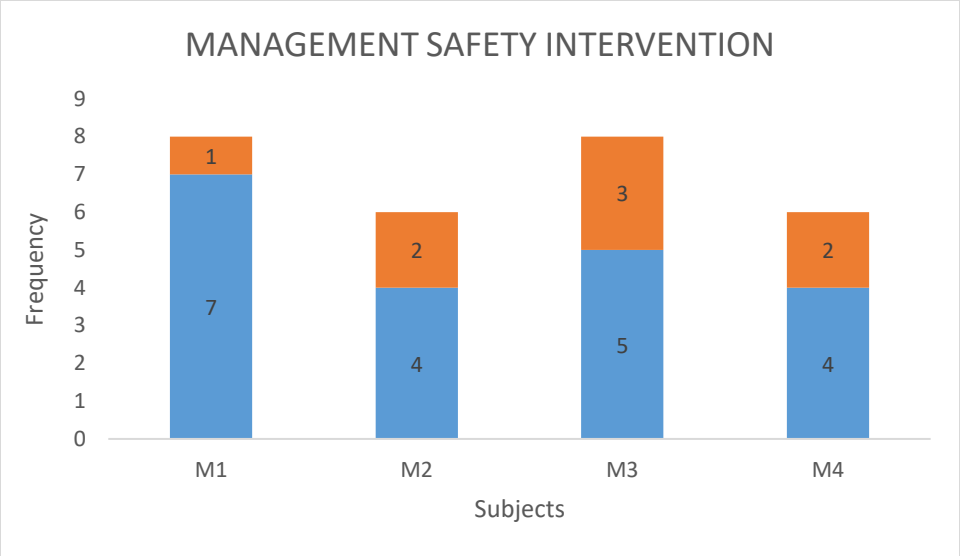

Figure 15: Frequency distribution of number of positive responses

Motivational activities for Management practices i.e. the worker-supervisor relation, is implemented in Indian coal mines. Interviewees claimed a positive impact on the occupational safety. Interviewee B &I said that there are regular sessions of worker-supervisor before the workers are deployed on field. Daily conversation between worker-supervisors strengthen the relation between worker and supervisor hence, workers work with more awareness for safety. The improved relation has impacted the occupational safety positively.

Safety supervision is very well adapted and implemented by the Indian coal mines. The interviewees (F and I) who did not completely agree with the proper implementation of supervision, referred to the lack of infrastructure for mine supervisors as the problem. Interviewee I said that there is lack of proper structures and shed for supervisors (Supervisors in Indian coal mines are called as Mine Sardars.) Due to lack of proper safety sheds, supervisor tend to leave the field and take up a safe place far from the mines. The study also reflects an interesting insight that constant supervision creates tension and pressure amongst the workers and increases the chance of unwanted incidents (said by F and I).

4.3.2 Impacts of Technology safety intervention

For this, the data from the approved drafts will be used. For every respondent with positive response/ or completely agrees that the intervention is practiced in Indian coal mine will be counted 1. The total number of positive responses for each subject is represented in the table below:

Table 6: An overview of interviewees' response

Intervention	*Subject*	*Code*	*No. of respondents*
Technical	Use Of IoT	T1	8
	Emergency response system	T2	7
	Risk management system and warning control system	T3	6
	Use of Virtual reality simulators	T4	8

From the table above, it is explicit that IoT is not at all implemented in Indian coal mines. The table shows the interventions implemented in the Indian coal mines. In the second part of analysis, the researcher analyze the impacts of the implemented interventions. The practices T2, T3, T4 look more important and will be further analyzed for their impact on occupational safety. The table below shows the response rate of the interviewees concerning the impacts of the interventions on occupational safety.

Table 7: Impacts of the interventions on occupational safety in Indian coal mines

Type of intervention	Subject	Code	No. positive response
Technical	Emergency response system	T2	5
	Risk management system and warning control system	T3	5
	Use of Virtual reality simulators	T4	6

The table above shows the frequencies of subjects/parameters of technical interventions. Frequencies are based on the number of times the subject is addressed by the respondent. No interviewee can be counted twice for one subject. The bar graph below shows the comparison of the frequency distribution of the positive responses by the interviewees.

Interviewees strongly believed that technological upgrades and advancement plays important role in improving occupational safety. Unfortunately, technology advancements are not efficiently achieved by the Indian coal mines. The major problem with the implementation of the technology is availability of electricity 24/7.

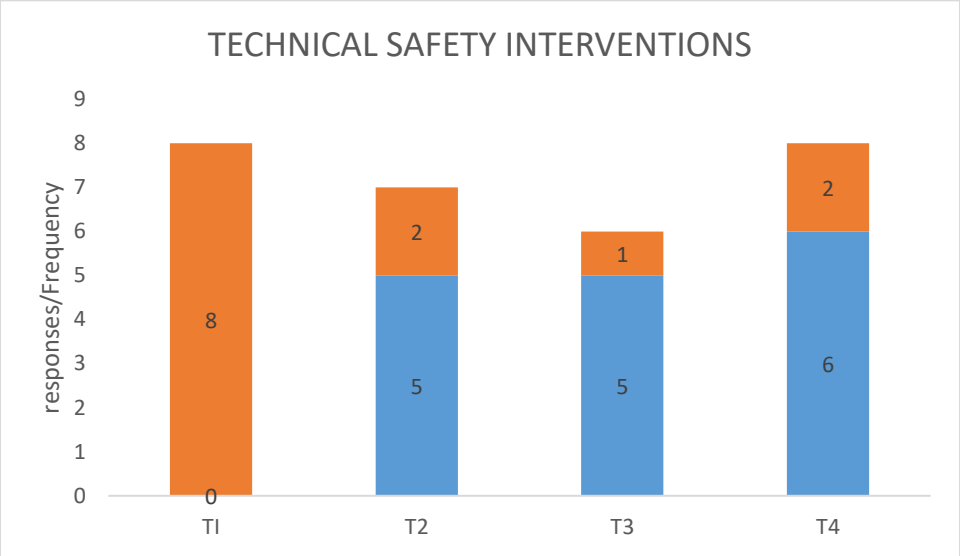

Figure 16: Overview of Frequency distribution of interviewees' responses – technical interventions

The emergency response systems (T2) is impactful and contributes to occupational safety in Indian coal mines positively. Respondents who believed that the emergency response systems are fully implemented, claims positive impact and at most efficiency of the system. On the other hand the systems have a scope of improvement with responsive systems. The reason for lack of effectiveness of the responsive system is due to old and inappropriate mine infra-structure. Interviewee J, who is a part of rescue team believes that the responsive systems have developed and improved over years in the Indian coal mines. The response time has improved from couple of hours to 35-40 minutes approximately. There is still a scope of improvement as the response time is ~10 minutes in other coal producing countries.

Risk management and warning control systems create positive impact on the occupational safety. The respondents (B, E, J, I and G) claimed positive impact of the emergency response and risk control. The other responses believed that the warning control systems are outdated and needs upgrades. The interviewees who said that the systems are well implemented, claim effective results on occupational safety. Interviewee (A) mentioned that the systems are manually operated and needs proper automation. When further discussed, it is clear that the mine infra-structure is a problem and cannot be resolved any time soon due to lack of proper investments by the Indian government.

Another trend in the mining industry worldwide is the use of Virtual Reality simulators. Referring to chapter 02, the use of VR simulators for worker training in mining industry has a positive impact. In Indian coal mines, the use of the virtual reality simulators is increasing and contributing to occupational safety positively. The study confirms the extensive use of VR simulators in the Indian coal mines. However, the interviewees (A and J) reported no significant difference in the occupational safety. When discussed, they said that the simulators are available and a good initiative but, operating these simulators is not easy and most workers face difficulty in understanding the operations of the

simulators. Installation of the simulators is effective but not efficient as it consumes electricity. Also, additional training session have to be conducted before workers could get a hand on the simulators.

4.3.3 Impacts of Societal safety interventions

Human interventions plays an important role in enhancing occupational safety. As mentioned in the previous sections based on the literature findings there are three most promising interventions practiced by other coal producing countries. In this section, the analysis is done in two parts. The first part will analyze which of these practices are currently implemented in Indian coal mines. The table below shows the responses from the interviewees with frequency of the responses.

Table 8: An overview of the responses from interviewees

Intervention	*Subject*	*Code*	*No. of respondents*
Societal	Safety awareness and knowledge	S1	7
	Safety training and education	S2	7
	Safety awards and promotions	S3	8

The table represents the percent of positive respondents with their frequencies. The interviewees who believed that the impact of particular intervention is positive, is counted for one. No interviewee is counted twice for one subject.

Table 9: An overview of responses for positive responses

Intervention	*Subject*	*Code*	*No. of respondents*
Societal	Safety awareness and knowledge	S1	5
	Safety training and education	S2	6
	Safety awards and promotions	S3	6

The bar graph below helps compare the frequency of responses from the interviewees.

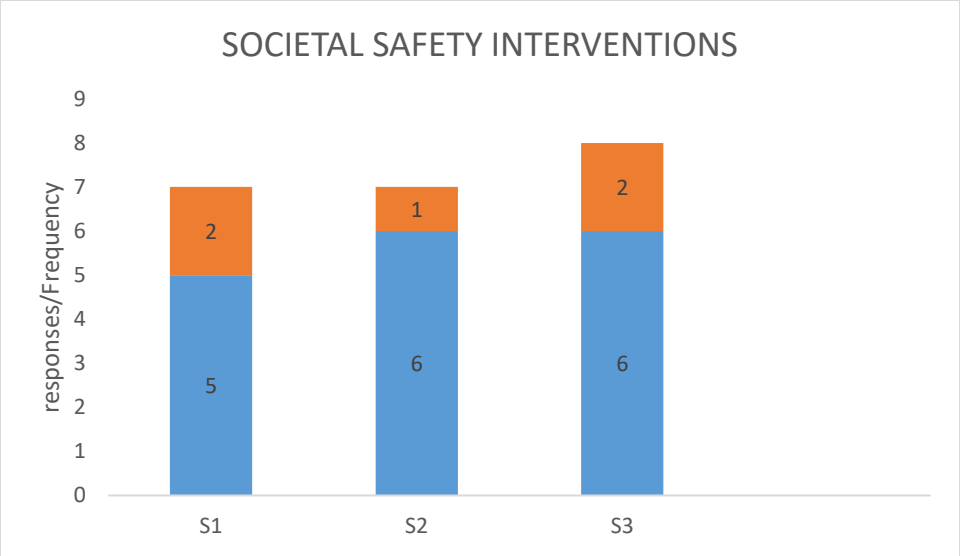

Figure 17: The frequency distribution of interviewee responses

The table above shows the response rate of positive incentives. The study shows that the education and training is implemented well in Indian coal mines. The respondents who agreed with the implementation of the intervention, believed that the impact of safety awareness is positive. However, interviewee I mentioned that the safety awareness needs more innovative method of implementation to increase safety awareness. Even though the government of India is constantly taking efforts spread awareness amongst the workers, but impact on occupational safety is not that noticeable. Here the concern regarding the method of implementation is significant.

Safety training is important for new entrants as well as pre-working employees. Respondents firmly believe that there is a huge scope of improvement for training process and assessment methods. Interviewee G also highlights on the fact that there are no before-after assessments done. It is important to see what a worker knows before giving training and a post assessment to see what difference has training made to the safety knowledge of worker and his skills. Doing assessments will enhance the impact on occupational safety positively. Interviewees also raised a concern with contract workers. The workers that work on the contract bases are difficult to train. There should be better training plans and procedures to leave a positive impact on occupational safety especially with the contract based workers.

Safety awards and promotion is looked upon as a motivation to work safely and be aware of the hazardous situation on field. The impact of awards and promotion on the occupational safety in Indian coal mines is positive. A good number of respondents agreed that the intervention is implemented in Indian coal mines and impacts occupational safety positively. However, the interviewees (E and D) firmly said that the awards and promotions have adverse effect on the occupational safety. The interviewees expressed the concern of wrong motivation. With their experience, they observed that workers tend to work safely only when they are watched or award week is round the corner. This doesn't really fulfill the motive to awarding workers for their safety awareness and knowledge. This also raised a concern of stress amongst the workers for promotions.

4.3.4 Impacts of Behavior safety interventions

Behavior safety intervention are different from human safety interventions. The intervention that make positive difference in the behavior of the workers are categorized as behavior interventions. The behavior interventions that are practiced in Indian coal mines are identified using interview data. The overview of the responses given by the interviewees is summarized in the table below:

Table 10: An overview of the responses from interviewees

Intervention	*Subject*	*Code*	*No. of respondents*
Behavior	Sharing of safety concerns	B1	8
	Safety behavior norms	B2	7
	Behavior based safety programs	B3	8

From the table above, it is clear that the interventions are not that significant in the Indian coal mines. Sharing of safety concerns is an intervention started by Chinese coal mines and shows outstanding results on occupational safety.

Out of the number of respondents who were asked, the following table shows the positive responses with reference to the positive impacts on occupational safety.

Table 11: overview of positive responses

Intervention	*Subject*	*Code*	*No. of respondents*
Behavior	Sharing of safety concerns	B1	0
	Safety behavior norms	B2	2
	Behavior based safety programs	B3	3

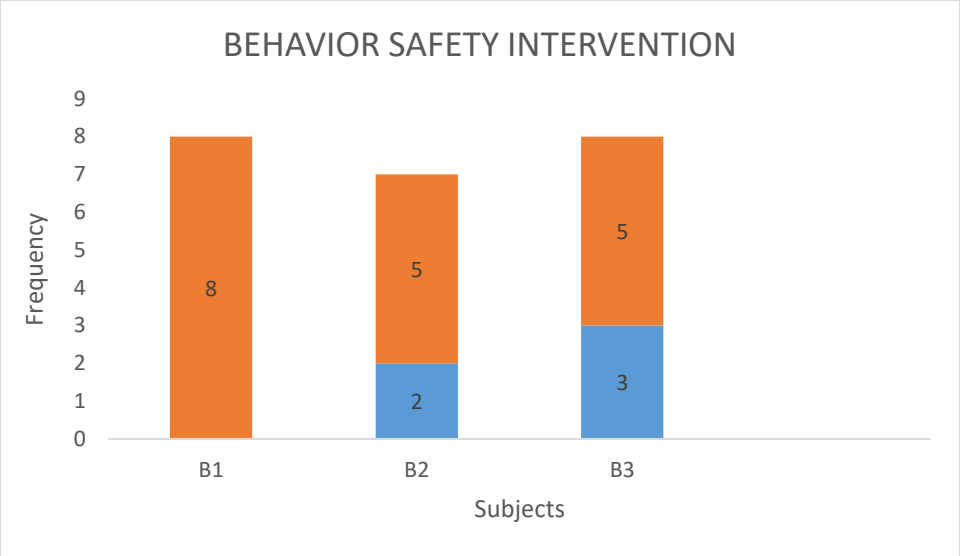

Figure 18: Overview of the responses from interviewee

In the next section, an analysis of unimplemented interventions/ less significant interventions in the Indian coal mines is conducted. The data used for analysis of unimplemented interventions on occupational safety is gathered from the interviewees.

4.4 Impacts of the less important & unimplemented interventions in the Indian coal mines

So far this research shows the interventions that are globally practiced by other coal producing countries. Later with the help of literature gathered, it is observed that the impacts of the fourteen global interventions is positive on occupational safety. Now it is also interesting to know what impact will the unimplemented or interventions with low rate of implementations will have on occupational safety if implemented in appropriate manner? To answer this a content analysis was conducted. The table below shows the frequency of the response from the interviewees. The interviewees were explicitly asked about the impacts of the intervention if they were in practice. For every positive response a count is registered. No interviewee is counted twice for same subject.

Table 11: An overview on positive responses from interviewees

Sr.no	*Intervention*	*subject*	*Number of positive responses*
1.	Management	Safety audits	3
2.	Technology	Use of IoT	6
3.	Behavior	Sharing of safety concerns	8
		Behavior safety norms	6
		Behavior based safety programs	7

The table represents the number of positive responses. The number of positive responses indicates the number of respondents that believed in positive impact on occupational safety. The bar graph shows the comparison between different responses. There are 5 interventions out of 14 which are not at all implemented in Indian coal mines or have a very low significance. To see what impacts these interventions have on occupational safety in the Indian coal mine if they were implemented in desired manner, a content analysis is conducted.

Until now, it is clear from the previously built literature and findings from the interviews that the interventions that are implemented in Indian coal mines have a positive impact on occupational safety. However, a few interviewees claimed that impacts are not as expected.

M1: Safety audits are conducted in the Indian coal mines but needs better implementation as suggested by the interviewees. 3 interviewees (D, F, and H) said it will be impactful if the audits are conducted in regular manner. Audits in Indian mines are scheduled regularly on three different basis, monthly, annually and in 5 years assessments. These are more of an on paper schedules than actual implementations. Also, the method of audits needs to change. For some mines, people work safely or manages to keep every aspect within guidelines only before the audits. When the interviewees were asked about the possible solution to improve audit systems, it was recommended to have surprise visits. This will improve the audit quality and enhance occupational safety.

T1: Use of IoT is increasing in many countries. The interview responses shows that the use of IoT in Indian coal mine will affect occupational safety positively. However, they explicitly mentioned the concern of infrastructure. IoT will need extensive supply of continuous internet and electricity. It is impossible for Indian mines to implement it right away. Even though the implementation of IoT is not possible, interviewees still believed it to be a good change and suggested implementation of IoT for increasing occupational safety.

B1: Sharing of safety concerns amongst workers has improved occupational safety adequately in Chinese coal mines. An idea of implementing this practice was positively supported by the interviewees. The other two interviewees somehow hesitated to answer this question as they regard this to be very personal. Sharing the safety concerns within workers is a bit frowned upon by the management. Closely analyzing the responses from the other interviewees who agreed with the sharing of safety concerns as a good idea, believed in the fact of "learning from others experiences/mistakes." Interviewees with on field work experience shared that talking to each other about the hazards and threats on field reduces mind pressure and therefore impacts occupational safety positively.

B2: Safety behavior norms are beneficial with respect to occupational safety (theoretically). 3 interviewees (B, G, I) said that behavior norms are implemented in Indian coal mines. Interestingly, the interviewees were from private coal sector. The interviewees who claimed the absence of behavior norms being practiced, believed that the impact of the behavior norms will be positive on occupational safety. The reason for which these practice will be effective was not well expressed by the interviewees as they had no much idea about the exact implementation of the intervention.

B3: Behavior based safety programs is an initiative taken by the Indian government to improve safety. It was clear from the interviewees' responses that the initiative taken to increase occupational safety need a lot of improved method of implementation. The behavior based safety programs should be implemented in such a way that the programs have a positive impact on worker behavior. While exploring a bit into the aspect of implementation, the researcher noticed the concern for basic school education. When the question regarding basic school education/educational qualification were asked, an abstract concept was revealed. The lack of basic school education and inappropriate method of implementations are significant moderating factors affecting occupational safety in the Indian coal mines.

Next section of the report elaborates on the additional findings of the research.

4.5 Additional findings

In this section the two additional findings will be discussed using similar method of content analysis. The data used for content analysis is gathered from the interviewees' responses. The data collected from interviews is based on the conceptual model explained in chapter 02.

During interviews, it was noticed that interviewees had some concern regarding the education of the workers. As a researcher, the relation of basic school education's relation with occupational safety is analyzed. During interviews, it was known that no mines in India have educational qualification for workers. This affects the occupational safety.

Interviewees expressed the concern of lack of educational qualification amongst mine workers. When asked about the impact of education on mine safety, the study findings shows that having basic school education/ minimum educational qualification, impacts occupational safety positively.

The reason why education is necessary is that it makes workers more confident to use technology and handle machinery. This enhances the occupational safety on field. Also, having proper education makes it easy for workers to understand training and instructions on field.

Referring to the literature and findings till now, the impact of the interventions is positive on occupational safety in Indian coal mines. Then what makes Indian mines unsafe as compared to other major coal producing countries? Carefully analyzing the responses from the interviewees, it can be said that India needs to improve the method of implementation of interventions. The methods should be more interactive and engaging for workers.

4.6 The empirical model for Indian coal mines

The empirical model is based on the findings and results in the previous chapter. This empirical model is based on the occupational safety in the coal mines. The figure below

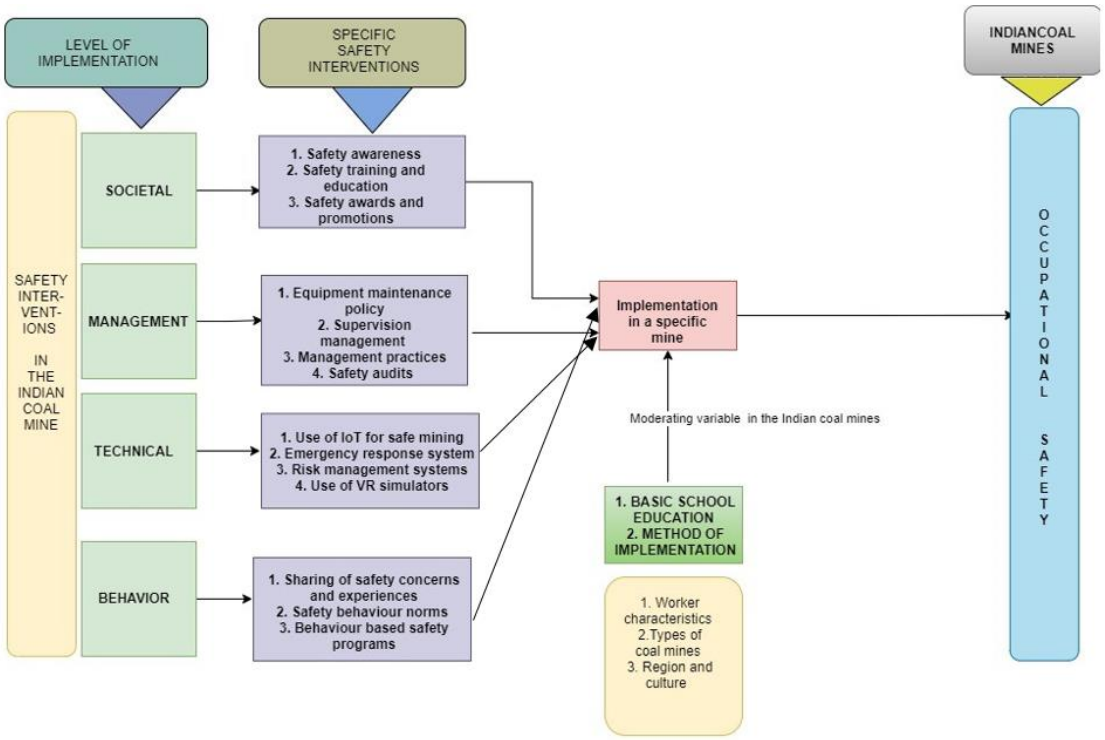

Figure 19: The empirical model of occupational safety in the Indian coal mines

Figure 19 depicts the empirical model developed from the research findings. The interventions in safety have a direct impact on occupational safety in Indian coal mines. Furthermore, the study finds that a lack of basic education and the current method of implementing interventions are major moderating factors affecting occupational safety in Indian coal mines. Because the study's primary goal was to identify the effects of safety interventions on occupational safety rather than the moderating variables, this could be a good research topic for the future.

This page is intentionally left blank

CHAPTER 05 CONCLUSION

In such demanding industry where growth is the only future, it is highly important to maintain safety at workplace. The Indian government and DGMS (Directorate general of Mine Safety) are taking constant efforts to improve occupational safety. It is well said that the safety is the key to high productivity. Therefore, it is necessary for industries like mining to take care of the mine workers and do enough to make them aware of the safety regulation and develop safety attitude. This study aims to identify the impact of safety interventions on occupational safety in the Indian coal mines. The chapter presents the key conclusions from the literature review and from the interviews.

5.1 Concluding points from theoretical findings

Before analyzing the impacts of safety interventions on occupational safety, as a researcher it is advisable to understand what occupational safety is and determine other factors that affect occupational safety. Occupational safety is associated with the injury-causing situations and is different from occupational health. Apart from the safety intervention, factors such as- language and culture, technological progress, method of implementation, worker characteristics and type of coal mine affects occupational safety.

The study lists 14 safety interventions that are practiced or researched by other major coal producing countries. The study also identifies their impacts on occupational safety. Theoretically, the interventions impact the occupational safety positively. The impact shows decrease in the number of workplace injuries and fatal accidents after successful implementation of the safety interventions. Using the theory, a conceptual model is constructed. The model serves as the base for empirical findings.

5.2 Concluding points from empirical findings

The empirical findings are presented in 3 parts. The first part refers to the interventions that are practiced in the Indian coal mines and are important. The second parts addresses the impacts of interventions that are not yet practiced in the Indian coal mines or interventions that are not important. The third part reflects on the additional findings of the research.

The view of occupational safety from a business lens portrays workers as a valuable resource in the mining industry. The Indian government fosters various initiatives such as campaigns, laws, policies etc. to achieve occupational safety.

Results from the study conducted, *basic school education* and *methods of implementation* of the interventions are significant moderating factors for occupational safety in the Indian coal mines. In the Indian coal mines, the mining equipment are maintained on regular basis impacting occupational safety positively. Smooth functioning of the equipment lessen the risk of malfunctioning and therefore contributes to occupational safety. Management practices have become important to encourage occupational safety. The worker & supervisor (mine sardar) relation in the Indian

coal mines is not great but workable. From the responses gathered, audits are more of an on-paper thing and is not much impactful. Instead some innovative suggestions include surprise visits and surprise audits to ensure enhanced safety in the coal mines.

Another frequently mentioned problem by the interviewees during their interviews is the *"lack of proper mine infrastructure."* The Indian coal mines have been following the same structure from past 30 years. This is also one of the prime reasons why much of the technological advancement is not possible in the Indian coal mines like use of IoT for supervision. When further discussed, the changes in mine infrastructure will cost Indian government a lot and Indian government in not in a position to release budget for structural upgrades.

Another thing that can be interestingly noticed is that, in the world of technological progress, Indian coal mine follows traditional ways of communication and responsive systems. Even though the currently used technology is outdated, the impacts are positive as the technology in use is compatible with the old infrastructure.

Behavioral interventions are more popular amongst the coal producing countries like China, USA& Western Australia. The impacts of behavior interventions are proven either by research or experiments. Unfortunately, those interventions are not yet fully practiced in the Indian coal mines. India has improved occupational safety over the decade, however Indian coal mines still have a huge scope of improvement as compared to other major coal producing countries. Indian government is constantly taking efforts to reduce injury causing situations and improve occupational safety.

In coming years, India's coal production is predicted to grow constantly. As the production increases the export increases which will also increase the demand for occupational safety. Referring back to chapter two, in the preliminary findings it can be observed that the countries that managed to improve occupational safety, also improved their production over the years.

India is not that far from achieving occupational safety. However researcher recommends to continue research on the possible and effective interventions to increase occupational safety. Many countries are still researching on the impacts of different safety practices and their impacts on occupational safety. As a researcher it is also advisable to research with different sample sizes and various populations to ensure the research study outcomes.

5.3 Key understanding

Safety intervention are implemented in four different levels in the Indian coal mine. In India, the absence of behavior safety intervention is evident. The study also revels the reason for the lack of behavior implementations and that is the lack of basic school education amongst the workers as well as unsuitable methods of implementation. The other interventions like use of IoT for safe mining techniques is not implemented in the Indian coal mine due to the fact that India is not ready to supply 24/7 electricity to the mines. Not only this but the mine infra structures are too old to support new technology. Unfortunately, it not possible for Indian government to renovate the mine structures due to insufficient funds.

This page is intentionally left blank

CHAPTER 06 DISCUSSION AND FUTURE SCOPE

The chapter is based on the previous chapters and provides with the relevant discussion. The chapter will first discuss the results of the study followed by the empirical model and concludes with the interview methodology and future scope of the research.

6.1 Scientific contribution & Reflection

6.1.1 Scientific contribution

From a scientific perspective, research is an important component for development. The study, not only portray high societal value but also holds scientific relevance. As mentions before in the chapter 02, there is no literature that explicitly presents the impacts of intervention on occupational safety in the Indian coal mines. This study provides three scientific contributions 1. The impacts of currently implemented interventions in the Indian coal mines. 2. The impact of intervention that are not yet implemented. 3. The significant moderating factors causing the impact on occupational safety in the Indian coal mines.

6.1.2 Personal reflection

India is known for its rich and highly diverse culture. The different cultures leads to different worker characteristics. The coal mining laws are centrally covered by the directorate general of mine safety. Any firm, public or private, is supposed to follow the rules and regulations defined by the government of India. This the main reason why the interventions such as training and awareness methods impact positively a certain region more than the other.

This study provides very valuable insights to the managers and mining company owners as they can now think about implementing training modules in multiple languages. More interactive methods depending upon the region and cultural practices. Another concern with the coal mine in India is that most of the workers lack education. In Indian coal mines, workers belong to below poverty line. Government of India should consider some reasonable schemes to provide basic education to workers. With this study, it is evident that basic education impacts the occupational safety adversely.

Method of implementation is a significant moderating factor affecting occupational safety in Indian coal mines. As a researcher, it is agreeable that one method cannot give same results with the entire population. This marks a significant point of improvement with occupational safety. Experimenting with different methods of implementations will help to boost safety attitude and enhance occupational safety.

6.1.3 Limitations and research challenges

- The focus of the study is restricted to the coal mines in India. As the sample size is small and it is just a representation of the actual population.
- Gathering of primary data from the interviewees was a bit difficult. Coal mining is a political issue in India and completely regulated by Directorate General of Mine Safety. Interviewees hesitated to answer the question and a bit worried about the data privacy.
- As coal mining is a sensitive issue in India, it was also difficult to find and convince people to give an interview for academic purposes.
- Data processing was a bit challenging as the language was regional for 3 interviewees. So as to get exact information and English is not that common in India, the researcher had to interview in regional languages.
- Time difference was challenging as the researcher had to adjust with the interviewees shifts at the mines.

6.2 Recommendations

The study unfolds various recommendations. The study provides insights and relevant recommendations to owners or coal mines in case of private coal mines, to policy makers and in the field of scientific research. The table 12 lists all the possible recommendations. The recommendation for policy makers are stated by the interviewees.

Table 12: Recommendations

SR.NO	SECTOR	RECOMMENDATIONS
1.	Policy makers	1. The time to process safety equipment demand to be fulfilled with almost transparency and on urgent basis. The finding suggests that the demand fulfilment process at times affect the occupational safety. If the equipment are supplied on urgent basis, it will affect occupational safety positively. 2. It is advised to policy makers to visit mines and try to understand real time situation before framing policies. This recommendation by interviewees was given as it is was observed that interventions are sometimes not possible to implement for example the pollution control interventions. It will be more effective if the policymakers understand real time situations, they'll be able to frame interventions that are more effectively implemented.

		3. There should be a minimum age qualification for the mine workers. India witnesses a problem of child labor. To avoid this, the interviewees suggested to have more stronger and effective policies/interventions.
		4. There should be a policy that gives wages according to their safety behavior and exposure to risk. If this is the case then workers will be more careful and maintain safety norms while working. This recommendation is based on the observational data gathered from the interviewees.
	Business / company managers	1. To ensure proper provision for mine supervisors when on site. For example: safety shades. As from the findings it is evident that lack of mine infrastructure affects occupational safety adversely.
		2. To implement training modules in various language as per the workers understanding. Language is a barrier as Indian has a diverse language and culture. The interviewees observed difficulty with understanding of certain training modules as they are migrant workers. To have multiple language training will enhance safety.
		3. To adapt interactive ways of worker training like: sharing sessions. Lack of sharing safety concerns impacts occupational safety negatively. From the analysis it can be observed that sharing of safety concerns is effective way to improve occupational safety and is not yet implemented.
2.		
		1. It is recommended for researcher to maintain & ensure the integrity of the research processes. The study also recommends research institutes to follow fundamental values to foster responsible research.
		2. It is recommended for future research to identify the effect of the other moderating factors on the occupational safety in the Indian coal mines.
3.	Scientific	

6.3 Future scope

The study can be further researched for the impacts of basic education on occupational safety. This can validate the findings of this research outcomes. Researching about the different possible intervention implementation methods that

will enhance the positive impacts of the current interventions. The future of Indian coal mining is predicted to grow consistently. With growing production it will have a greater scope to research on the potential improvements resulted from this particular study on occupational safety in the Indian coal mines. The moderating factors identified in this study can be further verified and also, the impacts of other moderating factors can be studied that might impact the occupational safety in the Indian coal mines.

This page is intentionally left blank

BIBLIOGRAPHY

2005 home: U.S. Bureau of Labor Statistics. (n.d.). Retrieved September 1, 2021, from https://www.bls.gov/opub/mlr/2005/

Almeida, T. D., Costa Avalone, M., & Fettermann, D. C. (2019). Building blocks for the development of an IoT business model. *Journal of Strategy and Management*, *13*(1), 15–32. https://doi.org/10.1108/JSMA-07-2019-0130

Amponsah-Tawiah, K. (2013). Occupational Health and Safety and Sustainable Development in Ghana. *International Journal of Business Administration*, *4*(2), 74. https://doi.org/10.5430/ijba.v4n2p74

Anderson, J. R. (1985). Cognitive psychology and its implications. Freeman. *New York, NY*.

Bennett, J. D., & Passmore, D. L. (1984). Correlates of coal mine accidents and injuries: A literature review. *Accident Analysis & Prevention*, *16*(1), 37–45. https://doi.org/10.1016/0001-4575(84)90004-6

Bing, W., Zhengdong, X., Yao, Z., Yan, P., & Zhenjiang, Y. (2014). Study on Coal Mine Safety Management System based on "Hazard, Latent Danger and Emergency Responses." *Procedia Engineering*, *84*, 172–177. https://doi.org/10.1016/j.proeng.2014.10.423

Brahmasrene, T., & Smith, S. (2009). The Influence of Training, Safety Audits, and Disciplinary Action on Safety Management. *Journal of Organizational Culture, Communications and Conflict*, *13*.

Burke, M. J., Sarpy, S. A., Smith-Crowe, K., Chan-Serafin, S., Salvador, R. O., & Islam, G. (2006). Relative Effectiveness of Worker Safety and Health Training Methods. *American Journal of Public Health*, *96*(2), 315–324. https://doi.org/10.2105/AJPH.2004.059840

Chen, H., Feng, Q., Zhu, D., Han, S., & Long, R. (2016). Impact of rent-seeking on productivity in Chinese coal mine safety supervision: A simulation study. *Energy Policy*, *93*, 315–329. https://doi.org/10.1016/j.enpol.2016.02.054

Chen, S.-S., Xu, J.-H., & Fan, Y. (2015). Evaluating the effect of coal mine safety supervision system policy in China's coal mining industry: A two-phase analysis. *Resources Policy*, *46*, 12–21. https://doi.org/10.1016/j.resourpol.2015.07.004

Chu, C., Jain, R., Muradian, N., & Zhang, G. (2016). Statistical analysis of coal mining safety in China with reference to the impact of technology. *Journal of the Southern African Institute of Mining and Metallurgy*, *116*(1), 73–78. https://doi.org/10.17159/2411-9717/2016/v116n1a11

Clancy, J. (n.d.). *1 Behaviour-Based Safety: A Case Study Illustrating a Successful Approach.*

Cliff, D., & Grieves, J. (2010). *Improving emergency management in underground coal mines*. 8.

Cooper Ph.D., M. D. (2000). Towards a model of safety culture. *Safety Science*, *36*(2), 111–136. https://doi.org/10.1016/S0925-7535(00)00035-7

D. Tripathy, & C. Ala. (2018). *Identification of safety hazards in Indian underground coal mines | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.jsm.2018.07.005

De Jesus-Rivas, M., Conlon, H. A., & Burns, C. (2016). The Impact of Language and Culture Diversity in Occupational Safety. *Workplace Health & Safety*, *64*(1), 24–27. https://doi.org/10.1177/2165079915607872

Ding, L. Y., & Zhou, C. (2013). Development of web-based system for safety risk early warning in urban metro construction. *Automation in Construction*, *34*, 45–55. https://doi.org/10.1016/j.autcon.2012.11.001

Eisner, H. S., & Leger, J. P. (1988). The international safety rating system in South African mining. *Journal of Occupational Accidents*, *10*(2), 141–160. https://doi.org/10.1016/0376-6349(88)90028-4

Fei, D., & Anbi, Y. (2011). Safety Education Based on Virtual Mine. *Procedia Engineering*, *26*, 1922–1926. https://doi.org/10.1016/j.proeng.2011.11.2385

Ficher. (2012). *Fisher: Integrating human performance concepts into... - Google Scholar*. https://scholar.google.com/scholar_lookup?title=Integrating%20human%20performance%20concepts%20into%20processes%2C%20procedures%2C%20and%20analysis&publication_year=2012&author=R.%20Fisher

Fugas, C., Melia, J., & Silva, S. (2021). *The "is" and the "ought": How do perceived social norms influence safety behaviors at work? - PsycNET*. https://psycnet.apa.org/doiLanding?doi=10.1037%2Fa0021731

Garetti, M., & Taisch, M. (2012). Sustainable manufacturing: Trends and research challenges. *Production Planning & Control*, *23*(2–3), 83–104. https://doi.org/10.1080/09537287.2011.591619

Goetsch, D. L. (2019). *Occupational safety and health for technologists, engineers, and managers* (Ninth edition). Pearson.

Halbesleben, J. R. B., Leroy, H., Dierynck, B., Simons, T., Savage, G. T., McCaughey, D., & Leon, M. R. (2013). Living up to safety values in health care: The effect of leader behavioral integrity on occupational safety. *Journal of Occupational Health Psychology*, *18*(4), 395–405. https://doi.org/10.1037/a0034086

Hale, A. R., Guldenmund, F. W., van Loenhout, P. L. C. H., & Oh, J. I. H. (2010). Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. *Safety Science*, *48*(8), 1026–1035. https://doi.org/10.1016/j.ssci.2009.05.006

He, X., & Song, L. (2012). Status and future tasks of coal mining safety in China. *Safety Science*, *50*(4), 894–898. https://doi.org/10.1016/j.ssci.2011.08.012

Hopkins, A. (2006). What are we to make of safe behaviour programs? *Safety Science*, *44*(7), 583–597. https://doi.org/10.1016/j.ssci.2006.01.001

Howe. (2017). *Howe: A union critique of behavioral safety—Google Scholar*. https://scholar.google.com/scholar_lookup?hl=en&publication_year=1998&conference=ASSE+Behavioral+Safety+Symp.&author=J.+Howe&title=A+union+critique+of+behavior+safety

Hox, J., & Boeije, H. (2005). *Data collection*. file:///C:/Users/hp/Downloads/hox_05_data+collection,primary+versus+secondary.pdf

Internet of Things (IoT) in Mining Industry | Infosys BPM. (n.d.). Retrieved September 3, 2021, from https://www.infosysbpm.com/blogs/sourcing-procurement/iot-in-mining.html

Jasiulewicz-Kaczmarek, M., Szwedzka, K., & Szczuka, M. (2015). Behaviour Based Intervention for Occupational Safety – Case Study. *Procedia Manufacturing*, *3*, 4876–4883. https://doi.org/10.1016/j.promfg.2015.07.615

Kelley, F. R. (1996). Worker psychology and safety attutudes: `. *Professional Safety*, *41*(7), 14.

Kowalski-Trakofler, K. M., Vaught, C., Brnich, M. J., & Jansky, J. H. (2010). A Study of First Moments in Underground Mine Emergency Response. *Journal of Homeland Security and Emergency Management*, *7*(1). https://doi.org/10.2202/1547-7355.1652

Kulshreshtha, M., & Parikh, J. K. (2002). Study of efficiency and productivity growth in opencast and underground coal mining in India: A DEA analysis. *Energy Economics*, *24*(5), 439–453. https://doi.org/10.1016/S0140-9883(02)00025-7

Liu, G., & Luo, C. (2012). Analysis of the Safety Psychological Factors in the Coal Mine Safety Management. *Procedia Engineering*, *45*, 253–258. https://doi.org/10.1016/j.proeng.2012.08.153

Lööw, J., & Nygren, M. (2019). Initiatives for increased safety in the Swedish mining industry: Studying 30 years of improved accident rates. *Safety Science*, *117*, 437–446. https://doi.org/10.1016/j.ssci.2019.04.043

Luo, B., Zhang, J., & Li, Z. (2019). Service Risk Evaluation of the General Contract for Coal Mine Production and Operation: Case Study at Shendong Jinjie Coal Mine in China. *Mathematical Problems in Engineering*, *2019*, e7845756. https://doi.org/10.1155/2019/7845756

Mandal, A., & Sengupta, D. (2000). The Analysis of Fatal Accidents in Indian Coal Mines. *Calcutta Statistical Association Bulletin*, *50*(1–2), 95–120. https://doi.org/10.1177/0008068320000109

Mazlina Zaira, M., & Hadikusumo, B. H. W. (2017). Structural equation model of integrated safety intervention practices affecting the safety behaviour of workers in the construction industry. *Safety Science*, *98*, 124–135. https://doi.org/10.1016/j.ssci.2017.06.007

Mc leod, S. (2018, June 20). *Primary vs Secondary Sources | Explained with Easy Examples*. Scribbr. https://www.scribbr.com/citing-sources/primary-and-secondary-sources/

McAfee, B., & Winn, A. (1989). *The use of incentives/feedback to enhance work place safety: A critique of the literature—ScienceDirect*. https://www.sciencedirect.com/science/article/pii/0022437589900030

McLellan, E., MacQueen, K. M., & Neidig, J. L. (2003). Beyond the Qualitative Interview: Data Preparation and Transcription. *Field Methods*, *15*(1), 63–84. https://doi.org/10.1177/1525822X02239573

Molaei, F., Rahimi, E., Siavoshi, H., Ghaychi Afrouz, S., & Tenorio, V. (2020). A Comprehensive Review on Internet of Things (IoT) and its Implications in the Mining Industry. *American Journal of Engineering and Applied Sciences*, *13*, 499–515. https://doi.org/10.3844/ajeassp.2020.499.515

Monforton, C., & Windsor, R. (2010). An Impact Evaluation of a Federal Mine Safety Training Regulation on Injury Rates Among US Stone, Sand, and Gravel Mine Workers: An Interrupted Time-Series Analysis. *American Journal of Public Health*, *100*(7), 1334–1340. https://doi.org/10.2105/AJPH.2009.178301

Nie, X. X., Bai, C., & Zhang, J. (2019). Simulation Research on the Effectiveness of a Multiagent Mine Safety Supervision System and Its Verification. *Mathematical Problems in Engineering*, *2019*, e8457124. https://doi.org/10.1155/2019/8457124

Nielsen, K. J. (2014). Improving safety culture through the health and safety organization: A case study. *Journal of Safety Research*, *48*, 7–17. https://doi.org/10.1016/j.jsr.2013.10.003

Nottinghamshire, M. (n.d.). *** * *Chief Operating Officer, Mines Rescue Service Limited*.

Onifade, M. (2021). Towards an emergency preparedness for self-rescue from underground coal mines. *Process Safety and Environmental Protection*, *149*, 946–957. https://doi.org/10.1016/j.psep.2021.03.049

Oyewole, S. A., Haight, J. M., Freivalds, A., Cannon, D. J., & Rothrock, L. (2010). Statistical evaluation and analysis of safety intervention in the determination of an effective resource allocation strategy. *Journal of Loss Prevention in the Process Industries*, *23*(5), 585–593. https://doi.org/10.1016/j.jlp.2010.05.014

Peters, R. H. (1990). Management Practices Affecting Coal Mine Safety: What Do We. *Professional Safety*, *35*(6), 35.

Pingle, S. (2012). Occupational safety and health in India: Now and the future. *Industrial Health*, *50*(3), 167–171. https://doi.org/10.2486/indhealth.ms1366

PTI. (2019). *Coal production in India*. @businessline. https://www.thehindubusinessline.com/economy/coal-production-in-india-up-by-16458-mt-in-5-years/article30096595.ece

Qing-gui, C., Kai, L., Ye-jiao, L., Qi-hua, S., & Jian, Z. (2012). Risk management and workers' safety behavior control in coal mine. *Safety Science*, *50*(4), 909–913. https://doi.org/10.1016/j.ssci.2011.08.005

Roberts, R. K., & Grubb, P. L. (2014). The Consequences of Nursing Stress and Need for Integrated Solutions. *Rehabilitation Nursing*, *39*(2), 62–69. https://doi.org/10.1002/rnj.97

Robson, L. S., Shannon, H. S., Goldenhar, L. M., & Hale, A. R. (n.d.). *Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries*. 139.

Sanjiv K. Nimbalkar. (2017). Coal Mines Workers and Motivation. *Journal of Psychology Research*, *7*(03). https://doi.org/10.17265/2159-5542/2017.03.005

Schofield, D., & Dasys, A. (2010). The Use of Virtual Simulators for Emergency Response Training. *Journal of Emergency Management*, *8*, 45–56. https://doi.org/10.5055/jem.2010.0011

Schulte, P. A. (2002). Approaches to sharing occupational safety and health information on a global scale†. *American Journal of Industrial Medicine*, *41*(3), 210–216. https://doi.org/10.1002/ajim.10049

Shakioye, S. O., & Haight, J. M. (2010). Modeling using dynamic variables – An approach for the design of loss prevention programs. *Safety Science*, *48*(1), 46–53. https://doi.org/10.1016/j.ssci.2009.04.008

Silverman, D. (2013). *Doing Qualitative Research: A Practical Handbook*. SAGE.

Squelch, A. P. (2001). *Virtual reality for mine safety training in South Africa*. 8.

Su, Y., Cong, W., & Liang, H. (2019). The impact of supervisor–worker relationship on workers' safety violations: A modified theory of planned behaviour. *Journal of Civil Engineering and Management*, *25*(7), 631–645. https://doi.org/10.3846/jcem.2019.10439

Sun, E., Zhang, X., & Li, Z. (2012). The internet of things (IOT) and cloud computing (CC) based tailings dam monitoring and pre-alarm system in mines. *Safety Science - SAF SCI*, *50*. https://doi.org/10.1016/j.ssci.2011.08.028

Sun, S., & Gai, X. (2014). Discussion about Promotion of Coal Mine Safe Production Levels from Strengthening Labour Management. *Procedia Engineering*, *71*. https://doi.org/10.1016/j.proeng.2014.04.062

Swuste, P., Gulijk, C. van, & Zwaard, W. (2010). Safety metaphors and theories, a review of the occupational safety literature of the US, UK and The Netherlands, till the first part of the 20th century. *Safety Science*, *48*(8), 1000–1018. https://doi.org/10.1016/j.ssci.2010.01.020

Teo, E. A. L., & Ling, F. Y. Y. (2006). Developing a model to measure the level of construction site safety. *Building and Environment*, *41*(11), 1584–1592. Scopus.

Turner, D. (2016, February 17). *Designing a semi-structured interview guide for qualitative interviews*. Quirkos Blog. https://www.quirkos.com/blog/post/semi-structured-interview-guide-qualitative-interviews/

Ünal, Ö., Akbolat, M., Amarat, M., & Tilkilioğlu, S. (2021). The role of the human factor in occupational safety and health performance. *International Journal of Occupational Safety and Ergonomics*, *27*(1), 179–184. https://doi.org/10.1080/10803548.2018.1554932

Unwin, J. (2020). *Who are the top five coal producing countries in the world?* https://www.power-technology.com/features/top-five-coal-producing-countries-world/

van Wyk, E., & de Villiers, R. (2009). Virtual reality training applications for the mining industry. *Proceedings of the 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa - AFRIGRAPH '09*, 53. https://doi.org/10.1145/1503454.1503465

Verma, S., & Chaudhari, S. (2017). Safety of Workers in Indian Mines: Study, Analysis, and Prediction. *Safety and Health at Work*, *8*(3), 267–275. https://doi.org/10.1016/j.shaw.2017.01.001

Vinodkumar, M. N., & Bhasi, M. (2010). Safety management practices and safety behaviour: Assessing the mediating role of safety knowledge and motivation. *Accident Analysis & Prevention*, *42*(6), 2082–2093. https://doi.org/10.1016/j.aap.2010.06.021

Wachter, J. K., & Yorio, P. L. (2013). Human Performance Tools: Engaging Workers as the Best Defense Against Errors & Error Precursors. *Professional Safety*, *58*(02), 54–64.

Wachter, J. K., & Yorio, P. L. (2014). A system of safety management practices and worker engagement for reducing and preventing accidents: An empirical and theoretical investigation. *Accident Analysis & Prevention*, *68*, 117–130. https://doi.org/10.1016/j.aap.2013.07.029

Wang, F., Ren, T., Tu, S., Hungerford, F., & Aziz, N. (2012). Implementation of underground longhole directional drilling technology for greenhouse gas mitigation in Chinese coal mines. *International Journal of Greenhouse Gas Control*, *11*, 290–303. https://doi.org/10.1016/j.ijggc.2012.09.006

Wong, L. (2008). Data Analysis in Qualitative Research: A Brief Guide to Using Nvivo. *Malaysian Family Physician : The Official Journal of the Academy of Family Physicians of Malaysia*, *3*(1), 14–20.

Yang, X., Ren, T., Remennikov, A., He, X., & Tan, L. (2018). Analysis of Energy Accumulation and Dissipation of Coal Bursts. *Energies*, *11*(7), 1816. https://doi.org/10.3390/en11071816

Yinghua, Z., Guanghua, F., Zhigang, Z., Zhian, H., Hongchen, L., & Jixing, Y. (2012). Discussion on Application of IOT Technology in Coal Mine Safety Supervision. *Procedia Engineering*, *43*, 233–237. https://doi.org/10.1016/j.proeng.2012.08.040

Zhang, H., He, X., & Mitri, H. (2019). Fuzzy comprehensive evaluation of virtual reality mine safety training system. *Safety Science*, *120*, 341–351. https://doi.org/10.1016/j.ssci.2019.07.009

Zhang, S., Shi, X., & Wu, C. (2017). Measuring the effects of external factor on leadership safety behavior: Case study of mine enterprises in China. *Safety Science*, *93*, 241–255. https://doi.org/10.1016/j.ssci.2016.12.017

Zohar, D. (2003). The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups. *Journal of Organizational Behavior*, *23*(1), 75–92. Scopus. https://doi.org/10.1002/job.130

This page is intentionally left blank

APPENDIX

APPENDIX [A]

Table A: Evaluation questions

INTERVENTION CATAGORY	EVALUATION QUESTIONS
MANAGEMENT INTERVENTION	1. How long have you been working with coal India? 2. How frequently is the technology upgraded in Indian coal mines? Is it same for every mine across India? 3. How is the relation between workers and management? How frequently do they interact? 4. What impact does the relationship between management and worker have on occupational safety? 5. How efficient are the safety management systems in Indian coal mines? 6. What is the current impact of the safety systems? 7. Is there any need to change or amend the current policies? Why/why not? 8. Does Indian coal mines conduct safety programs? How impactful are these programs? 9. Is there any assessments conducted post safety programs? If yes, what is the impact on occupational safety? 10. What methods are used for accident investigation and analysis? Are these methods effective? Why/why not? 11. Are safety audits conducted? How effective are the safety audits?

	12. According to you, is it possible for India to achieve acceptable level of mine safety in coming 10 years? Why/why not? 13. Do you have any recommendations for policy makers? 14. What do you think is the overall impact of the current mine safety policies? 15. Are there any other factors affecting occupational safety in the Indian coal mines?
TECHNICAL INTERVENTION	1. India still use WSN i.e. Wireless technology for communication, how effective is the technology when safety is considered? 2. What are the methods used for methane control? Are those methods effective? 3. Is VR Simulators used for worker training? 4. How does the use of virtual reality simulators affect occupational/worker safety? 5. How effective is emergency response systems? 6. Is there any scope of improvement with emergency response systems? 7. How long does the rescue team take to arrive at the accident spot? 8. What impacts do current ERS have on worker safety? 9. Do we have a use of mine seal? If not, why? 10. Do you think using mine seal will help to improve work safety? 11. How effective is the warning control systems? 12. How frequently are the equipment maintained? 13. What impact does frequent maintenance schedule have on the worker safety? 14. Do you have any recommendations for policy makers? 15. What are the other factors affecting occupational safety in the Indian coal mines?

	16. What do you think is the overall impact of the current mine safety policies?
SOCIETAL INTERVENTIONS	1. Which safety awareness programs are conducted by the government in Indian coal mines? 2. Are these programs effective? 3. Are there any assessments conducted post training to see if the workers have understood the safety trainings? If not, do you think including these assessments will affect worker safety? Why/Why not? 4. Do we have regular mental health check-ups for workers? If yes, what are the impacts on safety? If not, do you think including them will affect safety positively? 5. To increase worker motivation, are they offered any pay, promotions or awards? What are the impacts? 6. Are workers in Indian coal mines motivated to work safely? If not, what can be the most effective strategy to motivate them? 7. Do you think worker motivation affects safety? Why/Why not? 8. According to you, does basic school education amongst workers will impact safety positively? 9. What are the other factors affecting occupational safety? 10. Do you have any suggestions or recommendations for policy makers? 11. What do you think is the overall impact of the current mine safety policies?
BEHAVIOR INTERVENTION	1. Does Indian coal mines practice sharing of safety concerns? 2. What is the impact of sharing safety concerns? 3. What will be the impact if safety concerns and experiences are shared regularly?

	4. Why are these practices not implemented in Indian coal mines?
ADDITIONAL FINDINGS	1. Do current interventions need changes? 2. If not, what is the problem with current interventions? 3. What can be done to improve the method of implementation? 4. What is the main reason for lack of implementation? 5. Is school education or educational qualification required to work in coal mines in India? 6. Having educational qualification will impact occupational safety positively. What are your views? 7. Does basic school education affects occupational safety? 8. Does government take any initiatives for worker education? 9. What are the other factors affecting occupational safety? 10. If education is provided to workers, what impact will the practice have on occupational safety?

This page is intentionally left blank

APPENDIX [B]

Draft layout for interviewees'

Delft University of Technology

Interviewee G profile: Human Resource

Date: 15th June 2021

Type of Interview: Semi-structured

Conducted by: A.P.Jahagirdar

Declaration: The interview has been conducted as a requirement for my thesis at the Delft University of Technology. The summary below is the key takeaways from the interview. The interview was conducted on the zoom and was recorded. The interviewee has given consent to conduct an interview and was not forced by the interviewer. With this, the draft is sent to the interviewee and will be signed to approve the content used for analysis to ensure no manipulation of input data.

Privacy statement: No personal information like name, age, gender, will be used in my research. The recordings will be deleted after the successful accomplishment of my research project. In case of privacy concerns, the interviewee can send me an email asking me to delete the interview right after the transcription is done.

Declaration by the interviewee: Hereby, I declare that I was not forced to give information by the interviewer. The information above is best to my knowledge and can be used for research.

Signature: