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Cause of the Numerous Open Pit Mine Equipment Accidents: A Case of X Mining Company

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Abstract: ***This study investigates the cause of the numerous open pit equipment accidents at X Mining Company (XMC) during the period January 2019 to December 2020. The motivation for this study came from the large number of equipment accidents occurring at the Mine despite the available safety and management interventions.XMC management expressed concern with the increased number of mining equipment accidents and several awareness meetings were held with the employees. However, no holistic research was conducted to identify the root cause of the accidents. It is for this reason that this study was conducted to better understand the contributing factors in mobile equipment accidents, assess available training interventions, propose new ideas if needed, and determine whether certain activities or systems at the Mine required receiving special focus.Self-administered questionnaires were used to collect data from Operators and Supervisors. Data from the questionnaires were meant to provide feedback relating to the causes and factors associated with the numerous Open Pit mobile equipment accidents at XMC. Specifically, 147 copies were administered to mobile equipment Operators and 21 to Mining Supervisors.In order to analyse the questionnaire with open-ended questions, particularly for the responses from Supervisors, thematic analysis was used. Quantitative data analysis was done using descriptive and inferential statistics, SPSS Version 20. Whereas, qualitative data were analyzed using thematic analysis. An inductive approach was used by allowing the data to determine the emerging themes using four steps i.e., familiarization, coding, generating themes and theme definition and naming. An ethnographic study was conducted as a way of consolidating and validating the questionnaire responses and this was augment by document review.The study concluded that, mining equipment accidents by Operators at XMC are due to bad pit condition. This came out as the most prominent risk factor for the numerous accidents at XMC and was found to be statistically significant at 5% significance level. The other aspects arising expressively from the study as contributing factors to the frequent equipment accidents at the Mine include, bad road condition, staff fatigue, poor staffing, motivation and production pressure. Finally, four significant recommendations were made.***

Keywords: Open Pit, Equipment Accident, Training, Equipment Operator, Simulator

1. Definition of Key Terms

Different studies present words or expressions that can have a precise meaning in a specified field of research that may not be easily understood by people not in that field, such words or expressions therefore, need explaining to the reader to ensure clarity. Most of the definitions in this study are site specific (XMC).

In this section, therefore, terms that may be beyond common langue to some readers have been defined.

Accident
An accident is an unfortunate incident that occurs unexpectedly and unintentionally, typically resulting in damage to property or injury to personnel. In most cases, accidents often happen because machine manufacturers, employers, and Operators ignore certain safety rules and procedures.

Open Pit Mining
Open-pit mining, also known as open-cast or open cut mining, is a surface mining technique of extracting rock or minerals from the earth by their removal from an open-air pit, sometimes known as a borrow. Open-pit mines are used when deposits of commercially useful ore or rocks are found near the surface. The mined material is moved by the use of various mining equipment.

Trainee
A person on a machine that has not yet been assessed as competent on a particular type of machine he/she is being prepared to operate.

Trainee with no Experience
Any person who has never operated a machine and/or does not possess sufficient experience to pass a competency challenge test.

Trainee with Experience
Any person who presents prior certificates of competency and can demonstrate operational competency and has sufficient experience to operate a machine safely with a reasonable level of skill.

Competent Operator
A person who has completed the required training and is assessed by an appointed assessor and deemed competent to operate a machine with minimum supervision.

On Crew Trainer (OCT)
A competent and capable Operator who is appointed by the Mine Manager and Training and Development Manager to conduct practical training on specific machines.

Challenge Test
An evaluation of a person's skills levelon equipment operation.

A Simulator
A simulator in this case is a training tool (virtual reality) that provides an imitation of a real-life process via a computer, in order to provide a lifelike experience to a trainee.

Equipment Breakdown
Equipment breakdown is a condition when a machine is prevented from functioning in a normal way due to a developed fault or faults.

Equipment Availability
Equipment Availability is a percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed and Hillon (2008) defines availability as the probability that a piece of equipment is functioning satisfactorily at a specified time, when used according to specified conditions, where the total time includes operating time, logistical time, active repair time, and administrative time. Pinto and Xavier (2001), on the other hand, describe availability as the ratio of possible working hours to calendar hours. It is an important indication for reliability analysis and calculated as;

$$\text{Availability} = \frac{\text{Run Time}}{\text{Plnned Production Time}} \times 100$$

Equipment availability is also referred to as Uptime.

Equipment Performance
Equipment performance is an evaluation of how well the equipment operates in relation to the set standards and calculated as;

$$\text{Performance} = \frac{\text{Ideal Cycle Time x Total Count}}{\text{Run Time}}$$

Skill
Skill is the ability to perform work in accordance with the set standards and in line with the learnt abilities. From thePrinceton's World Net (2018), a skill is described as the learned ability to carry out pre-determined results often with the minimum outlay of time, or both.

2. Introduction

In October 2020 during the Head of Department Performance Review meeting, a concern was raised over the increased number of mobile equipment accidents in the Pit. To mitigate this problem, it was concluded that, Operators who were involved in these incidences be retrained (refresher training). It was further recommended that, a safety awareness meeting be conducted by a Senior Mine official at the start of each shift. However, no detailed study was conducted to determine the main cause of the numerous equipment accidents at the Mine. It is for this reason that this study was conducted to better understand the contributing factors in mobile equipment accidents, assess available safety interventions, propose new ideas if needed, and determine whether certain activities or systems at the Mine required receiving special focus.

Self-administered questionnaires were used to collect data from Operators and Supervisors. Data from the questionnaires were meant to provide feedback relating to the causes and factors associated with the numerous Open Pit mobile equipment accidents at XMC. Specifically, 147 copies were administered to mobile equipment Operators and 21 to Mining Supervisors. The two questionnaires were different, but had a few common sections.

Questionnaires were developed in English and later translated by the Training and Development Department into the Local language, Arabic for easy understanding. On the other hand, responses were given in Arabic and translated into English. This was carried out to ensure that, language did not create a response barrier, which could dilute the level of responses and consequently affecting conclusions drawn. Data were first coded in two Code Books, one for the equipment Operators and the other for Supervisors. Quantitative data analysis was done using descriptive and inferential statistics, SPSS Version 20. Whereas, qualitative data were analyzed using thematic analysis.

In order to analyse the questionnaire with open-ended questions, particularly for the responses from Supervisors, thematic analysis was used. Thematic analysis was used as it was found to be a good approach to this research in trying to find out Supervisor's views, opinions, knowledge and experiences on the mobile equipment accidents. This was applied to a set of texts written by questionnaire respondents. In applying this method, data were closely examined to identify common themes in form of patterns and ideas that came up repeatedly. An inductive approach was used by allowing the data to determine the emerging themes using four steps i.e., familiarization, coding, generating themes and theme definition and naming.An ethnographic study was conducted as a way of consolidating and validating the questionnaire responses and this was augment by document review.

3. Background

XMC is an open cast mine with an average daily material movement of 80,000 tonnes. This material came from mining activities, which started from drilling all the way to the final damping of martial at designated sites.

Excavators loaded the material into various types and size of Dump Trucks. Loading areas, haul roads and dumpsites were kept clean to prevent damage to equipment, more especially rubber tyres, machine suspension components and other drive train parts. To clean these areas, equipment such as Dozers and Graders was required and on the other hand, Water Trucks were used for suppressing dust along driveways, loading and dumpsites.

Trained National employees operated all this equipment and the operator training was conducted at the Mine site by Mine trainers who were certified by the Mine Training and Development Department.

3.1 Training Process (initial trainee with no experience)

The equipment operator program took the following route from needs identification to final certification of the trainee:

Step 1: Training Needs Identification
Under normal conditions, training needs were identified during the annual training plan preparation process, which was conducted in the fourth quarter of each year. However, unexpected equipment operator shortfalls were anticipated and prompted training needs outside the set period.

Step 2: Training Announcement
The Human Resource Department prepared an advertisement and communicated to all employees on the Mine site as well as those from outside the Mine.

Step 3: Candidate Selection
The Human Resources and Mining officials selected andinterviewed the right candidate for training. It must however, be noted that, the Training and Development and Safety Department did not take part in the selection process.

Step 4: Theoretical Training
The selected candidate underwent a theoretical training depending on the equipment to be operated. This training took a day and at the end of the session, the trainee was examined. The trainee was given three attempts and if he/she did not make it on the third attempt, the trainee was given the next chance after six months from the date of the last attempt.

Step 5: Simulator Training
If the candidate was successful in the theoretical training, he/she proceeded to the simulator-training phase. However, this applied to Dump Truck and Excavator Operators only. The training ran for twenty (20) hours for Dump Truck Operators and ten (10) hours for Excavator Operators.

Step 6: Controlled Area Training with OCT
The trainee was assigned to a Mining Training Officer who observed the trainee operate the equipment for a specified period to ensure the trainee grasped the minimum equipment operating techniques. This period ran for;
1) 10 hours for Excavator and Roller operator training
2) 20 hours for Grader, Wheel Loader, Bull Dozer and Wheel Dozer training
3) 25 hours for Haul Truck operator training

This was a full practical assessment on the machine.

Step 7: Practical Training with Competent Operator
Upon successful completion of step 6, the trainee was placed under the observation of a competent Operator for a period of:
1) 10 hours for a Roller trainee Operator
2) 200 hours for a Haul Truck trainee without a valid 3rdto 5th Grade National Driver's license
3) 140 hours for a Haul Truck trainee with a valid 3rdto 5th Grade National Driver's license
4) 180 hours for Grader, wheel Loader, Excavator, Bull Dozer Wheel Dozer Operator trainee

For accountability purposes, the trainee logged in on a daily basis all the training hours in a special logbook, which was signed off by the competent Operator. The practical training for the Dump Truck Operators was conducted in both day and nightshift.

Step 8: Final Practical Assessment
After successfully completion of step 7, the trainee was tested by an appointed Assessor. If the trainee was found not to be competent on three attempts, he/she was withdrawn from the training stream and could only resume the practical training after six months from the date of the last attempt.

From this stage, the successful trainee was certified and authorized to operate equipment under no or minimum supervision.
All trainees went through the general Mine induction before commencing any form of equipment operating training.

3.1.1 Training Process (trainee with previous experience)

A trainee with previous experience was referred to as any person who provided proof of training and could successfully demonstrate his/her skills before the assessor by passing through a challenge test. If the trainee scored 60% and above, the gap was identified and he/she proceeded to a gap filling training by completing the following hours of training as shown in Table 2.1.

Table 2.1: Training Schedule

Equipment Type	Simulator Training (hrs.)	Controlled Area Training (hrs.)	Normal Working Area (hrs.)
Roller	N/A	5	10
Haul Truck	5	5	10
Grader	N/A	5	10
Wheel Loader	N/A	5	10
Bull Dozer	N/A	5	10
Secondary Excavator	5	5	10
Primary Excavator	5	5	10
Backhoe	N/A	5	10
Wheel Dozer	N/A	5	10

After successfully completing this program, the trainee was certified and authorized to operate the equipment with no or minimum supervision. However, if the candidate scored less than 60%, he/she was either rejected or redirected to start from basic training.

In a situation where a competent equipment Operator had to switch to operate a different type of machine classified under his area of operation/competence, but in which he/she had not been fully trained, the Operator was taken throughstructured familiarization training. The duration of this training ranged from five (5) to ten (10) hours simulator training and five (5) to twenty (20) hours in a formal working area.

3.2 Mobile Equipment Accident Statistics

Different types of heavy equipment is used for mining operations in the pit and Operators of these machines undergo formal equipment operating training provided by the XMC. However, despite going through operator skills training and the several safety and management interventions, mobile equipment accidents still occurred at the Mine. The data for the mobile equipment accident frequency rate at XMC during the period 2019 – 2020 as provided by the Safety Department are shown in Figure 2.1.

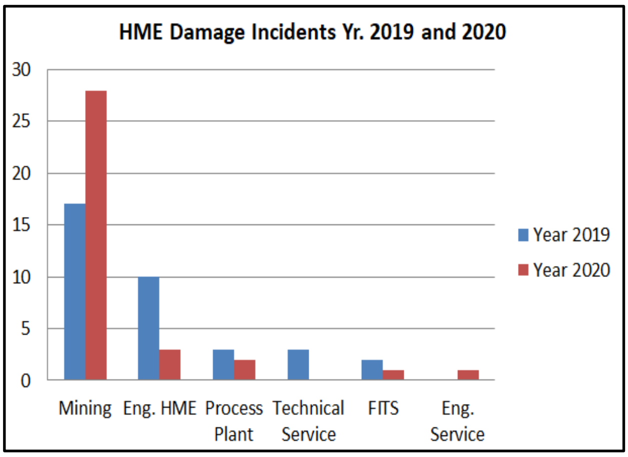

Figure 2.1: Mobile Equipment Accident frequency

In 2019, seventeen (17) mobile equipment accidents were recorded against twenty eight (28) in 2020. The accident trend from 2019 increased exponentially with time, with most of these accidents occurring in the morning as seen from Table 2.2

Table 2.2: Mobile Equipment Accident Time (shift)

Time	A	B	C	D	E	F
From	6:00	9:00	12:00	15:00	18:00	21:00
To	9:00	12:00	15:00	18:00	21:00	0:00

Count of Time 2	Column L						
Machine	**A**	**B**	**C**	**D**	**E**	**F**	**Grand Total**
Compactor / Roller			1				1
Haul Truck 775	1	1	2	1	3		8
Haul Truck 789		2	2	1		2	7
Dozer						1	1
Excavator		1					1
Fuel Truck					1		1
Grader	1						1
HIAB		1					1
LV	3			1	1	1	6
MMU	1						1
MT95H Haul Truck		1			1		2
Primary Excavator	1		1	2			4
Grand Total	**7**	**6**	**6**	**5**	**6**	**4**	**34**

It was however, interesting to note that, a majority of operations outside XMC equally experienced a higher number of accidents during the morning hours. Table 2.3 (adopted from: Sengupta and Mandal) is used as an illustration to show such similarities.

Table 2.3: Shift-wise Breakup of Indian Coal Mine Accidents

Company	Undergound			Open Cast			Surface		
	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3
ECL	67	33	59	9	3	9	21	6	10
BCCL	82	53	64	21	8	11	22	10	16
CCL	17	18	13	19	17	19	22	10	16
NCL	NA	NA	NA	13	4	8	4	0	4
WCL	43	24	19	12	4	8	6	4	4
SECL	52	23	25	15	10	8	13	8	9
MCL	2	5	3	6	0	6	9	1	3
NEC	4	3	3	2	0	1	0	0	0
Total	267	159	186	97	46	70	97	39	62

As seen from Table 2.3, the majority of accidents from different Mines in India occurred during the morning hours.The Indian coal miners worked in three shifts: 8 a.m. to 4 p.m. (shift 1), 4 p.m. to midnight (shift 2) and midnight to 8 a.m. (shift 3). XMC on the other, run two shifts, 6 a.m. to 6 p.m. (shift 1) and 6 p.m. to 6 a.m. (shift 2).

When an accident occurred at XMC, a Flash report was circulated around the Mine giving a summary of the occurrence. This document contained, the date and time of the accident, severity, location, circumstances leading to the accident and immediate action taken. Photos were presented where possible.

Later an investigation team was formed, comprising of the Departmental head, Safety personnel and other relevant stakeholders. This team carried out an investigation into the accident and after determining the root cause, mitigation measure were suggested and communicated to the employees through Toolbox meetings.

The loading areas and haul roads were found to be in a relatively good condition. The hauling route did not have major slopes, though in certain areas the maximum downhill reached 10%.

Haul Road

1) Width – the majority of the roads were wide with few tight corners
2) Spillage – noted, moderate to high risk of tyre cuts and aggression
3) Undulation – low to moderate
4) Sharp turns – two (2) sharp turns were observed on the road, though not significant
5) Water – not significant, reasonably dry
6) Size of surface material – 5 to 50mm

Loading area

1) Spillage – loose gravel ranging from 5mm to 35mm
2) Undulation – active undulated ground
3) Payload distribution – load along center of the machine and concentrated to the front of the machine
4) Loading point layout – moderately wide loading area. However, it required the machine to reverse and maneuver
5) Surface condition – dry
6) Size of surface material – aggregate 5 to 50mm

The effect of lateral acceleration was observed in a number of areas, more especially around the turns to the dumping areas. Lateral acceleration is the force that 'throws' a moving vehicle sideways during a turn. However, Operators were cautioned to reduce the vehicle speed when approaching such regions.

In summary, mobile equipment being one of the high-risk machines on the Mine, a number of safe work procedures and systems were in place to ensure safety of both equipment and personnel.

4. Statement of the Problem

The Mine used various types and size of mobile equipment from drilling to hauling of material to designated damping sites. However, the Mine experienced a number of equipment damage through machine accidentsand this situation became a major concern to the Mine Management in that it put both equipment and personnel at risk. To commence mitigating the problem, management immediately asked the Training and Development Department to initiate retraining of all the equipment Operators who were involved in these incidences and the Mining Department was requested to hold a safety awareness talk during each start of shift during toolbox meetings. This meeting was to be chaired by a Senior Mining official.

Nevertheless, no in depth study was conducted to investigate the cause of the numerous mobile equipment accidents at the Mine to enable Management and other stakeholders take appropriate action to correct the situation, though certain interim measures to minimise accident occurrences were instituted.

However, it must be noted that, mobile equipment accidents are not only unique to XMC.Zainalabidin, Kecojevic, Komljenovic and Groves (2008) conducted a study on Mine equipment accidents and concentrated on risk assessment for Loaders and Dozers using MSHA accident data from 1995 to 2006. This study determined that, the most frequent hazards for Loaders involved failures in following adequate maintenance procedures and failures of machine components. For Dozers, the most common hazard involved failures to identify adverse site conditions.

5. Literature Review

It is always important to conduct a literature review when carrying out a study in order to determine what is known on the topic, how well this knowledge is established and where future research might best be directed.However, though various studies have been conducted on general mine accidents, little attention has been given to the specific causes of mobile equipment accidents in open pit Mines.As such, there has beenvery little literature to review in this area of study and to this effect; theories that are closely related to the area of study were reviewed and used to frame questionnaires.

6. Theory Review

Theories are developed for the sake of explaining, forecasting and mastering phenomena such as associations, events and behavior. They generalize about observations and consist of interrelated rational sets of ideas and models, which may help, direct a study. Wacker (1998:362) advises that, theory building in research seek to find similarities across many different domains to increase its abstraction level and importance.Therefore, the following theories areselected to help understand certain behaviours and characteristics of personnel, equipment, environment and other related systems and processes at the Mine:

1) Motivation Theories
2) Training Theories
3) Human Capital Theory
4) Production Theory
5) Ausubel's Theory of Meaningful Learning

These theories refers to various bodies of ideas or sets of principles on which specific practices or systems are based.

6.1 Motivation Theories

Motivation may be defined as those forces within a person which push or propel him to satisfy elementary needs or wants. This theory is reviewed in order to determine the extent to which motivation could haveinfluenced the performance of employees and how performance can in turn be linked to how the employees manage equipment they are entrusted with.

6.1.1 Maslow's Hierarchy of Needs theory

Abraham Maslow (1954:75) believed that, man was naturally good and argued that individuals possessed a continuously growing internal drive which has great potential. His theory involves five categories of motives organised with lower-level needs on the bottom, which must be satisfied first, before the higher level needs could come into effect. It was, therefore, necessary to investigate how various human needs specified by Maslow could affect the equipment Operators in their day to day activities

6.1.2 Herzberg's Motivation Hygiene Theory

Herzberg's motivation hygiene theory also known as the two-factor theory focuses on the sources of motivation, which are relevant to the achievement of work. This theory prompted the study to understand how the need to achieve certain objectives such as production targets could influence the performance of equipment operators.

6.1.3 McClelland's Need for Achievement Theory

The theory implies that, when a need is strong in a human being, its effect may motivate the person to use behaviour, which may lead to satisfaction of the need (this may be coupled with different levels of anxieties). The central theme of McClelland's theory is that, needs are learned through adapting to one's environment and since needs are learned, behaviour which is rewarded tends to recur at a higher rate.This need assisted the study to determine whether some Operator behaviours aimed at achieving certain targets could influence normal operations. Could equipment Operators be taking short-cuts in order to meet their daily targets?

6.2 Training Theories

Training is the formal and organised modification of behaviour through learning, which transpires as a result of, instructions, education, development and planned experience. Therefore, Learning theories are conceptual frameworks that describe how information is absorbed, processed, and retained during learning. Additionally, they are an organized set of principles explaining how individuals acquire, retain, and recall knowledge.Various theories such as Situated Learning or Cognition Theory,Constructivism and Experiential Learning Theoryas well as Action Theory were reviewed to have an in-depth understanding of the nature of the training system at the Mine. The individual theories made it possible for the study to investigate the content of the equipment Operator training offered at the Mine in order to identify any shortfalls or areas requiring special attention.

6.3 Human Capital Theory

Human capital theory is based on neo-classical theories of labour markets, education and economic growth. It takes for granted that, workers are productive resources and endeavours to find out whether highly trained employees are more productive than other workers. On the other hand, Garcia (2005:1691) explains that, as employees do not obtain considerable pay increases due to increased productivity after attending specific training sessions, they are not motivated to finance their own training requirements. This point was of great interest to the study as it brought up a question of the impact remunerationcould haveon the equipment Operator'sperformance.Further, the content of this theory led the study into considering the need for a National driver's licence in the selection process of equipment Operator trainees.

6.4 Production Theory

The theory of production explains the principle by which a business decides how much to produce (output) and how much of each kind of labour, raw material, equipment etc., that it employs (inputs or factors of production) in order to produce such output. Robert (2016:4) narrates that, the various decisions a business enterprise makes about its productive activities can be classified into three layers of increasing complexity, decision, profitable quantities and the most profitable size of equipment

The production Theory directed the study into finding out whether decisions such as management 'push ' to make up lost production existed and if it did, the impact this could have on the behaviour of Operators.

6.5 Ausubel's Theory of Meaningful Learning

This theory relies heavily and explicitly on repetition in several ways such as the perpetuation of dissociability, which indicates that, without repetition "specific items of meaningful experience tend to gradually undergo obliterative subsumption". The more one does something, the more one becomes conversant with it. During one of the Heads of Department meetings, a point was raised to retrain Operators who were involved in equipment accidents. The concepts of this theory contradicted the decision by XMC in that, the expectations from the theory would be such that, the more the equipment Operators worked continuously with their machines, the more experienced they were expected to become in operating this equipment. Though, the contrary may apply, 'doing the same thing repeatedly breads monotony'.

In summary, these theories assisted in designing the questionnaires as they provided critical information relating to workplace and worker characteristics, training and the interaction of the factors of production. It should nevertheless, be noted that, other theories may apply to this study, however, the selected theories are found to be more closely related to the subject under investigation. Additionally, time, would be a limiting factor if more theories were to be reviewed.

7. Methodology

Self-administered questionnaires were used to collect data from Operators and Supervisors. Data from the questionnaires were meant to provide feedback relating to the causes and factors associated with the numerous Open Pit equipment accidents at XMC. Specifically, 147 questionnaire copies were administered to 147 Dump Truck Operators and 21 to Mining Supervisors, with a response rate of 100%. The two questionnaires were different but had a few common sections.

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Data were first coded using the two Code Books referred to as I and II for the Operators and Supervisors respectively. There were 147 questionnaire copies for the Operators and 21 for Supervisors. Quantitative data analysis was done using descriptive and inferential statistics, SPSS Version 20. Whereas, qualitative data wereanalyzed using thematic analysis.An ethnographic study was conducted as a way of consolidating and validating the questionnaire responses and this was augment by document review.

In order to analyse the questionnaire with open-ended questions, particularly for the responses from Supervisors, thematic analysis was used. Thematic analysis was used as it was found to be a good approach to this research in trying to find out Supervisor's views, opinions, knowledge and experiences on the causes of mobile equipment accidents. This was applied to a set of texts written by questionnaire respondents. In applying this method, data were closely examined to identify common themes in form of patterns and ideas that came up repeatedly. An inductive approach was used by allowing the data to determine the emerging themes using four steps i.e., familiarisation, coding, generating themes and theme definition and naming.

8. Findings

This part of the report provides a summary of the results obtained on the characteristics of the respondents. It begins by providing a summary of the characteristics of the respondents, the occurrence of equipment accidents and some important factors that might be related to occurrence of equipment accidents.

8.1 Characteristics of Participants

In this part of the report, we focus on the characteristics of the respondents by summarizing the socio-demographic profile, the work-related profileand type of machine operated.

8.2 Socio-demographic characteristics

Most (30%) of the respondents were aged 50 years while the minority (17.1%) fell in the age bracket of 20 – 29 years of age (Table 7.1).

Further, as indicated in Table 7.1, (69.5%) of the respondents had a history of driving before they becamemining equipment Operators. Only a few (30.5%) had no history of driving before they became an Operator. These results suggest that, more than half of the respondents were experienced drivers. In fact, the results also indicate that, more than 50% of those with a history of driving had an experience of at least 5 years.

It is also observed that in this sample, more than a quarter (30%) of the respondents had a 3rd grade National driver's license whilst the rest had none (20.8%), 2nd grade (16.2%), 4th grade (23.1%) and 5th grade (10.0%) (Table 7.1).

Table 7.1: Characteristics of the Respondents

Variable	Category	Frequency	Percent
Age Group	20 - 29	24	17.1
	30 - 39	36	25.7
	40 - 49	38	27.1
	50 and Above	42	30.0
History of Driving Car Before Becoming Operator	Yes	98	69.5
	No	43	30.5
Length of Driving Before Becoming Operator	1 to 2 years	17	15.7
	3 to 5 years	22	20.4
	Above 5 years	69	63.9
Grade of National Driver's License	None	27	20.8
	2nd	21	16.2
	3rd	39	30.0
	4th	30	23.1
	5th	13	10.0

8.3 Work-related characteristics as Operator

Majority (38.1%) of the workers enrolled in this study had a work experience at XMC of 4 – 7 yearswith more than 3 quarters (75.9%) having received less than 12 months of training. Additionally, more than half (62.3%)of the workers had worked as operators for more than a year at XMC. It is also interesting to note that, most (43.1%) of the respondents were level 3 Operators at XMC (Table 7.2).

Table 7.2: Work-related Operator Profile

Variable	Category	Frequency	Percent
Work Experience at XMC	1 to 3 years	36	26.9
	4 to 7 years	51	38.1
	Above 7 years	47	35.1
	Total	134	100.0
Length of Training as Operator	Years	20	15.0
	Months	101	75.9
	Weeks	4	3.0
	Days	8	6.0
Operator Level	Level 1	41	29.9
	Level 2	33	24.1
	Level 3	59	43.1
	Level 4	4	2.9
Length of Service as Operator	Years	81	62.3
	Months	39	30.0
	Weeks	4	3.1
	Days	6	4.6

8.4 Work-related Profile of Supervisors

The study also identified a few characteristics among Supervisors and it is found that, the majority (38.1) of the Supervisors had worked at XMC for more than 7 years whilst only a few (4.8%) had worked as Supervisors for more than 7 years.

Table 7.3: Work profile of Supervisors at XMC

Variable	Category	Frequency	Percent
Length of Time at XMC	1 to 3 years	7	33.3
	4 to 7 years	6	28.6
	Above 7 years	8	38.1
Length of Time as Supervisor	1 to 3 years	11	52.4
	4 to 7 years	9	42.9
	Above 7 years	1	4.8

8.5 Type of Machine Operated

Sixty three percent (63%, 88/140) of the workers enrolled in this study indicated that, they had operated more than one type of machine (Figure 7.1). Figure 7.1 provides more detail on the frequencies concerningthe type of machine used by an Operator at XMC.

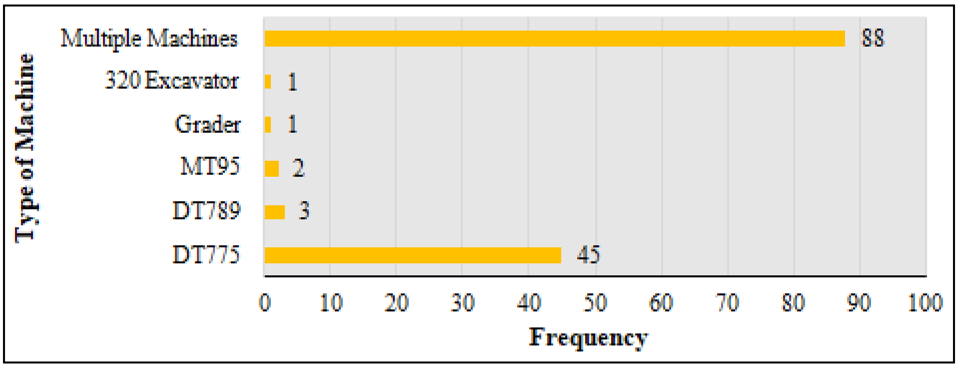

Figure 7.1: Type of Machine Used by Operator at XMC

8.6 Occurrence of Accidents, Frequency and Temporality

This section presents the views of the equipment Operators and Supervisors on the frequency of mining equipment accidents at XMC.

8.6.1 Among Operators

Figure 7.2 indicates that, accident occurrence received the highest scores on strongly agree (25) and agree (65) compared to any other question. Furthermore, the figure shows that, some workers agreed that, accidents did happen during the night (46) and day shift (34) at XMC. However, it is important to note that, very few strongly agreed to accidents happening during the day (7) and during the night (7) (Figure 7.2).

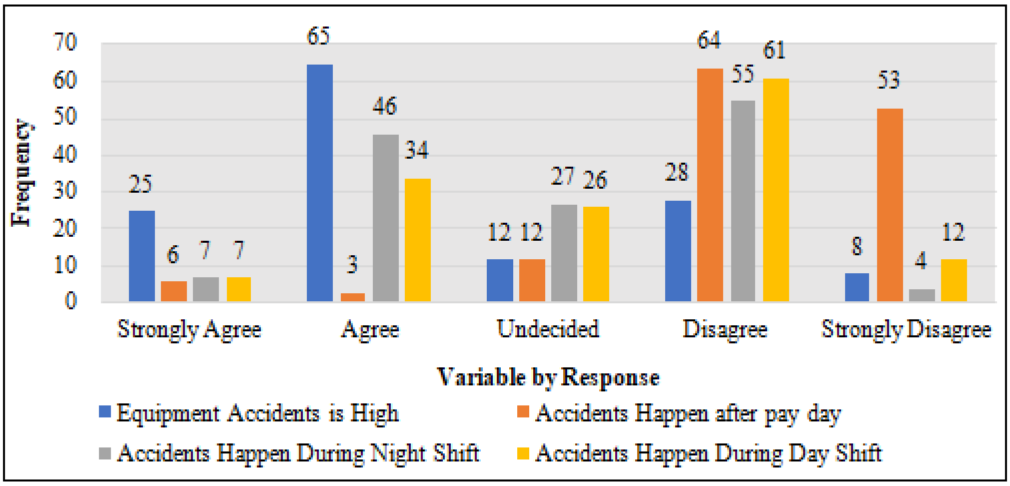

Figure 7.2: Accident Occurrence Frequency by Response among Operators

8.6.2 Among Supervisors

It is observed that, occurrence of equipment accidents scored high on both agree (6) and strongly agree (12) among Supervisors. More details are provided in Figure7.3.

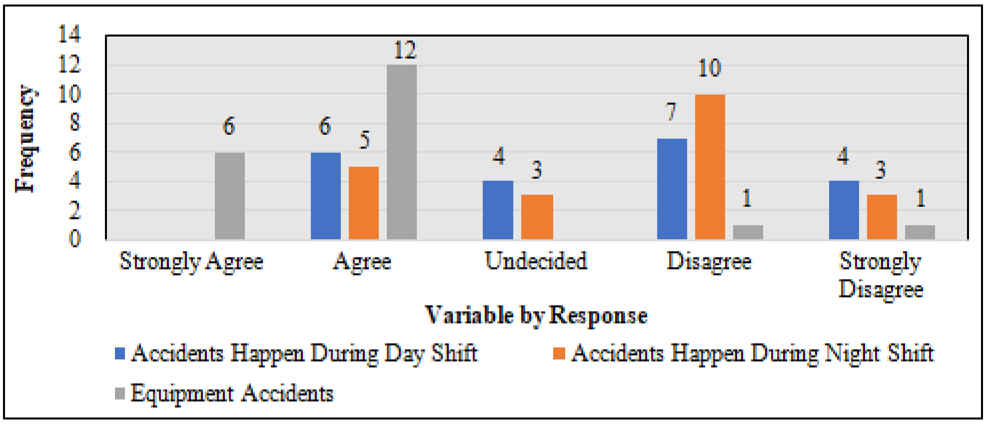

Figure 7.3: Accident Occurrence Frequency by Response among XMC Supervisors

8.7 Reasons and Risk Factors for Equipment Accident Occurrence

This section presents the views of employees on the risk factors behind accident occurrences.

8.7.1 Risk Factors for Equipment Accidents at BMSC According to Operators

The workers at XMC were asked a series of questions to identify possible reasons for the occurrence of equipment related accidents. From the findings obtained, it is observed that, most of the respondents agreed that road conditions (35.9%), production pressure (37.8%) and Operator fatigue were some possible reasons for accident occurrence at XMC among the Operators. However, some mixed responses were observed on each of these variables. Additionally, most of the respondents disagreed to the fact that low motivation (43.1%), female operators (52.5%), male operators (44.9%), older people (46.4%), young people (48.2%), poor communication (46.9%) and rough approach from Superiors (36.6%) contributed to equipment accident. More details in Table 7.4.

Table 7.4: Risk Factors for Equipment Accidents at XMC according to Operators

Variable	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Road Conditions	24 (16.9)	51 (35.9)	7 (4.9)	45 (31.7)	15 (10.6)
Production Pressure	23 (16.1)	54 (37.8)	16 (11.2)	38 (26.6)	12 (8.4)
Operator Error	18 (12.7)	38 (26.8)	31 (21.8)	41 (48.9)	14 (9.9)
Operator Fatigue	32 (22.7)	54 (38.3)	14 (9.9)	35 (24.8)	6 (4.3)
Bad Attitude of Operators	8 (5.7)	30 (21.3)	22 (15.6)	58 (41.1)	23 (16.3)
Poor Communication	18 (12.6)	18 (12.6)	17 (11.6)	67 (46.9)	23 (16.1)
Young People	10 (7.2)	14 (10.1)	15 (10.8)	67 (48.2)	33 (23.7)
Older People	6 (4.3)	3 (2.2)	12 (8.7)	64 (46.4)	53 (38.4)
Male Operators	3 (2.2)	12 (8.7)	19 (13.8)	62 (44.9)	42 (30.4)
Female Operators	4 (2.9)	4 (2.9)	18 (12.9)	73 (52.5)	40 (28.8)
Low motivation	18 (13.8)	33 (25.4)	13 (10)	56 (43.1)	10 (7.7)
Rough Approach	19 (14.5)	35 (26.7)	19 (14.5)	48 (36.6)	10 (7.6)

8.7.2 Risk Factors for Equipment Accidents at XMC according to Supervisors

The Supervisors at XMC were asked a series of questions to identify possible reasons for the occurrence of equipment related accidents. It is observed that, most of the respondents disagreed that road conditions (43%), production pressure (43%), poor communication (40%), younger people (40%), older people (42.1%), female operator (65%) and rough approach (38.1%) were some possible reasons for accident occurrence at XMC among the operators. However, most of the Supervisors agreed that Operator error (47.6%), Operator fatigue (42.9%), bad attitude of operators (42.9%), male Operators (40%) and low motivation (40%) contributed to equipment accident. More details in Table 7.5.

Table 7.5: Risk Factors for Equipment Accidents at XMC according to Supervisors

Variable	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Road Conditions	0 (0%)	8 (42%)	2 (11%)	9 (47%)	0 (0%)
Production Pressure	2 (9.5%)	5 (23.8%)	3 (14.3%)	9 (42.8%)	2 (9.5%)
Operator Error	4 (19%)	10 (47.6%)	4 (19%)	3 (14.3%)	0 (0%)
Operator Fatigue	4 (19%)	9 (42.9%)	3 (14.3%)	3 (14.3%)	2 (9.5%)
Bad Attitude of Operators	5 (23.8%)	9 (42.9%)	4 (19%)	3 (14.3%)	0 (0%)
Poor Communication	5 (25%)	2 (10%)	2 (10%)	8 (40%)	3 (15%)
Young People	0 (0%)	4 (20%)	4 (20%)	8 (40%)	4 (20%)
Older People	0 (0%)	2 (10.5%)	5 (26.3%)	8 (42.1%)	4 (21.1%)
Male Operators	0 (0%)	8 (40%)	3 (15%)	5 (25%)	4 (20%)
Female Operators	0 (0%)	0 (0%)	2 (10%)	13 (65%)	5 (25%)
Low motivation	2 (10%)	8 (40%)	4 (20%)	3 (15%)	3 (15%)
Rough Approach	2 (9.5%)	2 (9.5%)	6 (28.6%)	8 (38.1%)	3 (14.3%)

8.8 Effectiveness of Measures to Prevent Equipment Accident Occurrence

Views from respondents on the effectiveness of measures put in place to minimize equipment accidents are presents in this section.

8.8.1 Effectiveness of Measures to Prevent Occurrence According to Operators

The findings in this study also clearly show that, a number of measures have been put in place to prevent accident occurrence at XMC. It is observed that most of the respondents in the study agreed that, most of these measures were implemented effectively. For instance, it is observed that, the majority (52.7%) indicated that, meetings focused on operational safety and not administrative, training and assessment was adequate (48.3%), supervision was adequate (50.4%), toolbox meetings discussed safety concerns (45%) and the National driver's license was made a pre-requisite (35.2%). Similar observations are made with strongly agree, which was only second to the frequencies obtained on the agree response as shown in Table 7.6.

Table 7.6: Effectiveness of Measures Put in Place to Reduce Equipment Accident Occurrence at XMC According to Operators

Variable	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Meeting Focus on Operational Safety and Not Administrative	38 (29)	69 (52.7)	11 (8.4)	10 (7.6)	3 (2.6)
Training and Assessment Adequacy	54 (37.8)	69(48.3)	5 (4)	13.0 (9.1)	2 (1.4)
Adequacy of Supervision	34 (24.1)	71 (50.4)	9 (6.4)	23 (16.3)	4 (2.8)
Toolbox Meetings Discuss Safety Concerns	53 (41.1)	58 (45)	4 (3.1)	11 (8.5)	3 (2.3)
Making National Driver's License a Pre-requisite	39 (30.5)	45 (35.2)	8 (6.3)	25 (19.5)	11 (8.6)

8.8.2 Effectiveness of Measures to Prevent Occurrence According to Supervisors

The study found that, the majority (43%) of the respondents agreed to the fact that, training and assessment was adequate to reduce accidents among Operators at XMC. Furthermore, most (48%) of the Supervisors indicated that, they thought supervision was adequate to contribute significantly to the reduction of equipment accidents at XMC.

Table 7.7: Effectiveness of Measures Put in Place to Reduce Equipment Accident Occurrence at XMC According to Supervisors

Variable	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Training and Assessment Adequacy	8 (38.1%)	9 (42.9%)	3 (14.3%)	1 (4.8%)	0 (0%)
Adequacy of Supervision	4 (19%)	10 (47.6%)	3 (14.3%)	4 (19%)	0 (0%)

8.8.3 Associations Existing Between Accident Occurrence and Risk Factors for Equipment Accident Occurrence

A test was conducted to determine significant associations existing between accident occurrence and certain risk factors presented in the study.

Associations Between Equipment Accident Occurrence and Risk Factors for Accident Occurrence According to Operator's Responses

Fisher's exact test was performed for bivariate analyses to determine significant associations existing between accident occurrence and some of risk factors included in this study. The results obtained indicated that, only road conditions had a significant impact of accident occurrence (p-value < 0.05). The respondents who agreed to accident occurrence at XMC were more likely to also agree that road conditions contributed to equipment accidents happening. However, the rest of the other risk factors had no significant association with equipment accidents happening (p-value > 0.05). Further details are provided in Table 7.8.

Table 7.8: Associations Between Equipment Accident and Selected Risk Factors

		Equipment Accidents Happen: Agree	Undecided	Disagree	P value
Accidents Due to Operator Error	Agree	38	3	13	0.234
		70.4%	5.6%	24.1%	
	Undecided	21	4	5	
		70.0%	13.3%	16.7%	
	Disagree	27	4	18	
		55.1%	8.2%	36.7%	
Road Conditions	Agree	52	3	16	0.040
		73.2%	4.2%	22.5%	
	Undecided	2	2	3	
		28.6%	28.6%	42.9%	
	Disagree	35	7	17	
		59.3%	11.9%	28.8%	
Accidents Due to Production Pressure	Agree	50	4	18	0.355
		69.4%	5.6%	25.0%	
	Undecided	8	3	5	
		50.0%	18.8%	31.3%	
	Disagree	28	5	13	
		60.9%	10.9%	28.3%	
Accidents Due to Operator Fatigue	Agree	58	6	19	0.418
		69.9%	7.2%	22.9%	
	Undecided	8	2	4	
		57.1%	14.3%	28.6%	
	Disagree	19	4	12	
		54.3%	11.4%	34.3%	
Bad Attitude of Workers	Agree	25	2	9	0.255
		29.1%	16.7%	26.5%	
	Undecided	13	5	4	
		15.1%	41.7%	11.8%	
	Disagree	48	5	21	
		55.8%	41.7%	61.8%	

Table 7.8: Associations between Equipment Accident and Selected Risk Factors (Continued)

		Equipment Accidents Happen: Agree	Undecided	Disagree	P value
Poor Communication	Agree	23	1	8	0.076
		71.9%	3.1%	25.0%	
	Undecided	9	5	3	
		52.9%	29.4%	17.6%	
	Disagree	55	6	24	
		64.7%	7.1%	28.2%	
Young Operators	Agree	16	0	6	0.388
		72.7%	0.0%	27.3%	
	Undecided	10	2	2	
		71.4%	14.3%	14.3%	
	Disagree	58	10	26	
		61.7%	10.6%	27.7%	
Older Operators	Agree	6	0	6	0.342
		50.0%	0.0%	50.0%	
	Undecided	11	2	3	
		68.8%	12.5%	18.8%	
	Disagree	67	10	25	
		65.7%	9.8%	24.5%	
Female Operators	Agree	4	0	4	0.487
		50.0%	0.0%	50.0%	
	Undecided	14	1	3	
		77.8%	5.6%	16.7%	
	Disagree	67	11	28	
		63.2%	10.4%	26.4%	
Male Operators	Agree	8	1	5	0.921
		57.1%	7.1%	35.7%	
	Undecided	13	2	4	
		68.4%	10.5%	21.1%	
	Disagree	63	9	25	
		64.9%	9.3%	25.8%	
Low Motivation	Agree	31	4	12	0.497
		66.0%	8.5%	25.5%	
	Undecided	6	2	5	
		46.2%	15.4%	38.5%	
	Disagree	43	4	15	
		69.4%	6.5%	24.2%	
Rough Approach from Mine Officials	Agree	32	4	14	0.722
		64.0%	8.0%	28.0%	
	Undecided	14	2	3	
		73.7%	10.5%	15.8%	
	Disagree	35	3	17	
		63.6%	5.5%	30.9%	

8.8.4 Associations between Equipment Accident Occurrence and Risk Factors for Accident Occurrence According to Supervisor's Responses

Table 7.9provides the results obtained after performing bivariate analyses for equipment accident responses compared to responses on several risk factors among Supervisors. The results obtained indicated none of the selected factors had a significant association with equipment accident at XMC.

Table 7.9: Association between Equipment Accidents and Selected Risk Factors among Supervisors

Variable	Category	Equipment Accidents Happening: Agree	Equipment Accidents Happening: Disagree	P value
Accidents Due to Operator Error	Agree	11 84.6%	2 15.4%	1.000
	Disagree	3 100.0%	0 0.0%	
	Undecided	4 100.0%	0 0.0%	
Road Conditions	Agree	7 87.5%	1 12.5%	1.000
	Disagree	8 100.0%	0 0.0%	
	Undecided	2 100.0%	0 0.0%	
Accidents Due to Production Pressure	Agree	6 85.7%	1 14.3%	1.000
	Disagree	9 90.0%	1 10.0%	
	Undecided	3 100.0%	0 0.0%	
Accidents Due to Operator Fatigue	Agree	10 83.3%	2 16.7%	1.000
	Disagree	5 100.0%	0 0.0%	
	Undecided	3 100.0%	0 0.0%	
Bad Attitude of Workers	Agree	11 84.6%	2 15.4%	1.000
	Disagree	4 100.0%	0 0.0%	
	Undecided	3 100.0%	0 0.0%	

Table 7.9: Association between Equipment Accidents and Selected Risk Factors among Supervisors (Continued)

Variable	Category	Equipment Accidents Happening: Agree	Equipment Accidents Happening: Disagree	P value
Poor Communication	Agree	6 85.7%	1 14.3%	1.000
	Disagree	9 90.0%	1 10.0%	
	Undecided	2 100.0%	0 0.0%	
Young Operators	Agree	3 75.0%	1 25.0%	0.678
	Disagree	10 90.9%	1 9.1%	
	Undecided	4 100.0%	0 0.0%	
Older Operators	Agree	2 100.0%	0 0.0%	1.000
	Disagree	10 90.9%	1 9.1%	
	Undecided	4 80.0%	1 20.0%	
Male Operators	Agree	8 100.0%	0 0.0%	0.626
	Disagree	6 75.0%	2 25.0%	
	Undecided	3 100.0%	0 0.0%	
Low Motivation	Agree	8 88.9%	1 11.1%	1.000
	Disagree	5 83.3%	1 16.7%	
	Undecided	4 100.0%	0 0.0%	
Rough Approach from Mine Officials	Agree	4 100.0%	0 0.0%	0.684
	Disagree	8 80.0%	2 20.0%	
	Undecided	6 100.0%	0 0.0%	

9. Qualitative Analysis of Supervisors' Responses

A qualitative study was conducted to explore and provides deeper insights into the area of study. This method was incorporated in order generate some form of hypotheses as well asto further investigate and understand the level and implication of the quantitative data.

9.1 Steps followed in the Analysis

Step 1: Familiarisation
The step involved getting to know the data and reading the open-ended responses from Supervisors and initial notes were taken.

Step 2: Coding
This involved coding of the data. In this context, coding means writing down text. Phrases or sentences were written down in coming up with labels or "codes" to describe their content.

Step 3: Themes Generating
Themes were generated on the basis of the codes.

Step 4
The themes were defined and named.

9.2 Causes of Accidents Data Coding

Response extracts are presented in Table 8.1 and respective codes developed.

9.2.1 Code Development

Table 8.1: Causes of Accidents Data Coding

Response Extract	Codes
Production pressure Pressure and fatigue Working for 5 weeks, operators feel fatigued Fatigue Sometimes struggle meeting productions Lack of focus and concentration	Staff Pressure and fatigue
Loading point floors are supposed to be even, but there is shortage of auxiliary Supporting machines Very poor condition Some roads are above gradients Some junctions are not traffic friendly Conditions not appropriate for Dump Trucks Narrow road	equipment, hence Poor Road Conditions.
Pit conditions are not good Narrow dumps especially bottom pit ramps	Bad pit ramps conditions
Understaffing No incentive for good work but for bad operator behaviour Re-shifting Male operators are impatient More supervision is required Low motivation operators less concentration. Comfort of the Dump Trucks Rough approach sometimes convey instructions without calm	Staffing, motivation and poor conditions
Accidents happen any time When they work alone, they operate in their on ways Most happen in night shifts Accidents happen both night and day time Both night and day time shifts	Time of accidents

9.2.2 Themes Generation

After analysing the codes, patterns among them were identified, and gave rise to themes. Table 8.2 shows five themes that were generated.

Table 8.2: Turning Codes into Themes

Codes	Theme
Staff Pressure and fatigue	Staff fatigue
Poor Road Conditions	Poor road conditions
Bad pit ramps conditions	Poor pit conditions
Staff motivation and poor conditions	Poor staff motivation
Time of accidents	Night and day time

This shows that, the analysis has answered the research question of: What are the main causes and risk factors of mobile equipment accidents at XMC? In this case, it can be stated that, according to the Supervisors' views, mobile equipment accidents by Operators are due to staff fatigue, poor road and pit conditions, poor staffing and motivation. These accidents happen during both day time and night time.

The Supervisors further suggest that, in order to address this problem, the following should be done: Training in both theory and practical; Change of mind-set of operators; Ramp widening; More supervision is required and in particular in form of Standard Operating Procedures (SOP).

Questionnaires Reliability Coefficients

The Cronbach's Alpha reliability coefficient for the Operators was 0.648 and for the Supervisors it was 0.538 as shown in Table 9.1. Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered a measure of scale reliability. These values imply that the Operators' questionnaire has an acceptable level of reliability, but for the Supervisors, it required some adjustments.

Table 9.1: Cronbach's Alpha Values

Group	Cronbach's Alpha	Items (N)
Operators Reliability Statistics	.648	27
Supervisors Reliability Statistics	.538	31

The formula used in SPSS for Cronbach's alpha was:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}} \quad \text{......1}$$

Where:
N = the number of items.
$\bar{c}$ = average **covariance** between item-pairs.
$\bar{v}$ = average variance.

The Supervisors' Cronbach's Alpha coefficient is low. There are many possible explanations to this and one of these could be the low number of questions. However, this did not significantly affect the level of outcomes.

10. Document Review

Through document review, it is observed that, there was a correlation between productionvolume andthe number of mobile equipment accidents. Figure 10.1 shows the trend of accident occurrence in 2019 and 2020 at XMC.

Paper ID: SR21126131012 DOI: 10.21275/SR21126131012

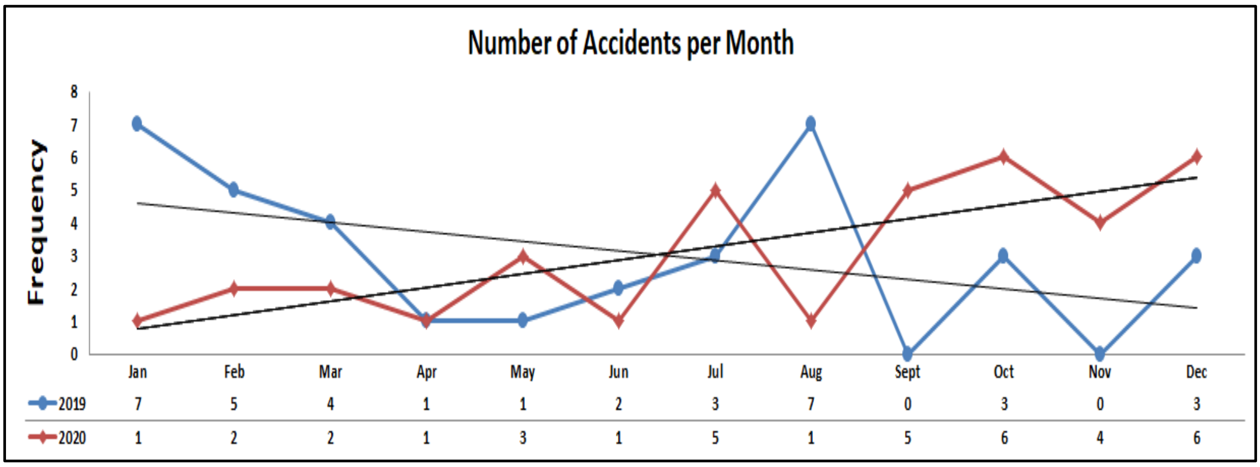

Figure 10.1: Material Movement for 2019 and 2020

In 2019, the equipment accident frequency took a downward trend, except in August where the number of incidents increased. In 2020, the number of accidents was exponentially high. Figure 10.2 shows the production profile for the two (2) years, 2019 and 2020.

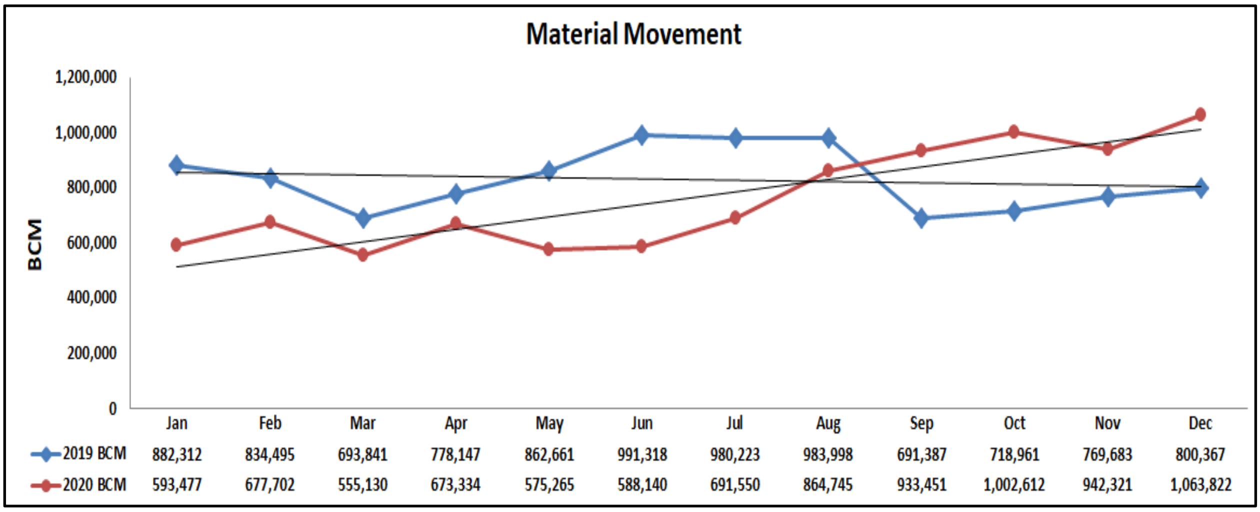

Figure 10.2: Material Movement for 2019 and 2020

From January 2019 production assumed a downward trend until March 2019 when production started to improve. However, in August 2020, a sudden drop in output was again noted all the way to the end of the year. In 2020, production maintained a rising steady state, producing an average of 593,477 BCM in January to 1,063,822 by the end of the year, though a slight deep in material movement was observed from April 2020 to August 2020. Never the less, the general trend of material movement in 2020 was positive.

The interpretation of the data in the two (2) figures, Figure 10.1 and 10.2shows that, there is a strong correlation between production output and the number of equipment accidents at XMC during the years reviewed.

From this result,it may be deduced that, it can be more accurate to determine the number of equipment accidents based on the amount of material movement, say accidents per million tonnes moved. Basing the number of accidents on man-hours can equally give a more accurate representation of accident statistics more especially where a comparison between years is concerned. Thus, the number of accidents per man-hours.

It is further observed that, most equipment accidents occurred during morning hours. Some of the Operators spoken to complained that, they did not have enough sleep due to noise at night from their colleagues who did not sleep in good time. The point of fatigue came out prominently from questionnaire responses, though not as much as the state of road and pit conditions. Sleep deprivation can have serious implications on the performance of equipment Operators. Figure 10.3 shows some of the effects of sleep deprivation (Created by: Dr. Galatia, 2021).

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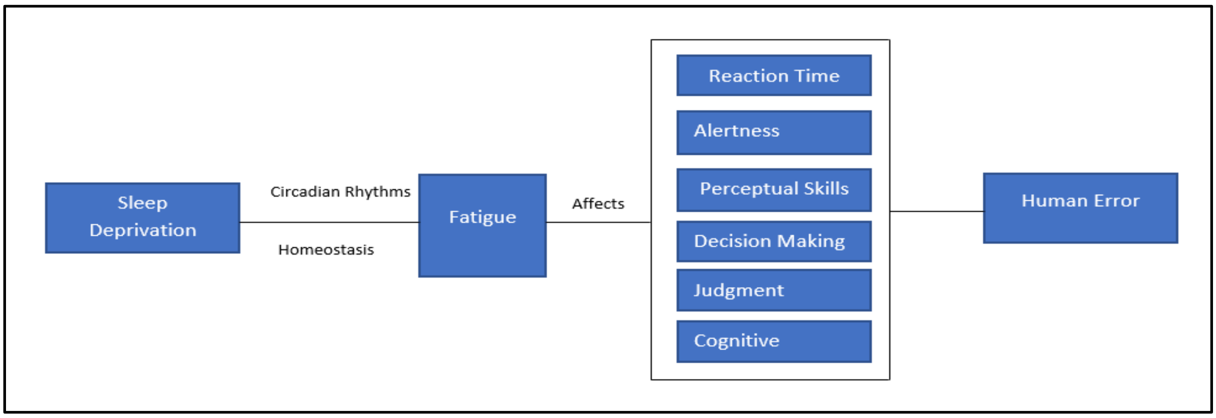

Figure 10.3: Effects of Sleep Deprivation

11. Operationalization of the Concept

This section discusses the operationalization of the concept of sleep deprivation in relation to the study context in basic terms. Other studies have given a wider perspective of the effects of sleep deprivation, measurement and consequences of fatigue to equipment Operators.Oslo (2014) has defined fatigue in detail and how it affects the safety performance of human transport Operators.

Sleep Deprivation
Sleep deprivation is the condition of not having sufficient sleep and it can be either chronic or acute and may vary widely in severity. A chronic sleep restricted state adversely affects the brain and cognitive functions. The pattern of life led by the equipment Operators can cause circadian rhythms to be out of synchrony and this is likely to cause these individuals to have sleepless nights. Subsequently, if this condition is not checked on time, itcan cause an imbalance in homeostasis leadingto such conditions as tiredness and mimic fatigue symptoms.

Fatigue
Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional character of the condition depends on the form, dynamics and context of exertion. The context of exertion is described by the value and meaning of performance to the individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions. The fatigue condition results into changes in strategies or resource use such that original levels of mental processing or physical activity are maintained or reduced. Therefore, as indicated earlier, equipment Operators need to always check their life pattern to avoid drifting into unnecessary fatigue, which may affect their concentration and judgement during working hours.

Managing fatigue may not only be the responsibility of the equipment Operator, but management inclusive. Management should take interest in knowing the activities of its employees and also monitor and measure how much work each worker is given. In certain organizations, though not noticed at XMC, Operators are trained in multiple tasks (multi-skilling). Though this phenomenon may prove to be cost effective, it has serious implications if not well managed as it may lead to task-overload. Task overload may adversely affect the Operator's effectiveness and lead to errors in executing tasks.

Reaction Time
Fatigue can cause an equipment Operator to have a slowed response (reaction) due to such effects as wake state instability, which is caused by pulls between motivation to stay awake and sleep drives. The outcome of this condition is that, normal performance at one moment is followed by severe decrements in performance the next. This state is likely to result into the equipment Operator making errors as he/she operates the machine.

Alertness
A person under fatigue may seem to be aware of the surrounding, but in ensconce, his mind could be 'switched off' and could react suddenly and without caution to any alerting situation. A good example can be, a Truck Operator who is in a loading queue, if not in a clear state of mind, he can suddenly move the machine controls and cause an accident. While backup alarms on machines are meant to offer warning to pedestrians and other equipment Operators, equipment accidents still occur when reversing. Among other factors, this is due to not being alert to the activities within the work environment.

Perceptual Skills
Perceptual skills involve the ability to organize and interpret the information that is seen and give it meaning. Our eyes send large amounts of information to our brains to process every single second. If our eyes are sending us the proper information in a way that makes sense, the brain can then process it, thus allowing us to form thoughts, make decisions, and create action. However, when a person is taking action/operating under fatigue, his eye-brain coordination may result in wrong decisions or reactions. Such a condition can have serious implications on equipment Operators.

Decision Making
Decision-making skills involve the ability to solve problems quickly and efficiently. To develop these skills, one must have good attention to detail, the ability to analyze and show resourcefulness when facing a challenge or obstacle. Poor decision making by an Operator working under stress or fatigue can lead to serious errors.

Judgment
Judgment is a mental ability, which determines a person's decision-making capability, and his/her ability to come to a sensible conclusion on a certain matter when he/she needs to choose from a multiple of options. A stable state of mind is required in making good judgment and on the other hand, an unstable mind is likely to cause serious mistakes. Various things are responsible for making poor judgement of which fatigue in individuals is one of them. Every time an Operator is on a machine, he/she needs to make good judgment as the pit environment has a series of obstacles to manage. During loading for example, both the Digger and Truck Operator must make good judgement of each other's position and maneuver.

Cognitive
Cognitive skills and knowledge involve the ability to acquire information, often the kind of knowledge that can easily be tested. A person experiencing cognitive decline, due to fatigue, may end up with a declining ability to draw conclusions. This can lead to one making hast decisions which may not be well though through and in the case of an equipment Operators, this can lead into serious errors and subsequently, accidents.

12. Ethnographic Study

As a way of validating the questionnaire responses.The Operator training program was reviewed and later, the HME Engineer and the Training and Development Supervisor observed the activities in the pit as well as dumpsites. The two drove alongside the operators in the pit without disclosing their presence. This was after going through the training package, including the simulator. The major findings were:

Operator Trainee Selection
From the Operator selection point of view, it was noticed that, Training and Development as well as Safety Department did not take part inthe selection process. The two departments are key to the training of equipment Operators. Their input in selecting the preferred candidate is significant as theyconstantly interact with trainees of different background. This interface, gives them an upper hand in understanding and interpreting certain unique attributes and behaviors in learners.

Simulator Training
The simulator-training period was not sufficient. Performing several scenarios on the simulator can help the trainee further understand the operations of the machine and learn more about the environment he/she was going to face.A properly designed simulator program should be well spread (time) to allow trainees to answer the question, "If I do this, what happens?" It should provide the Operator trainees with an opportunity to test out different scenarios to see what works and to understand how they arrived at the right and wrong answers, this needs time and consistency. This trial-and-error approach gives trainees the knowledge and confidence they need to apply their new skills when they are released in the field.

The value of simulator training should be further enhanced by following up with a debriefing and coaching sessions. With the help of video recordings, the training sessions can be analyzed, errors identified, successes marked, and emotions or feelings that influenced the trainees can be discussed and corrective measures suggested.

Practical Training
The practical Operator training in the field was not adequate to give the Operator the competence to work independently.Operators were kept busy throughout the shift, maneuvering controls of their equipment and communicating with other Operators and the control room. They regularly met other traffic and had to stop at intersections to giving way to each other. This was a high task-load and needed a lot of concentration and experience, therefore, to master all these maneuverseffectively; an Operator required a considerable amount of time and guidance. The 200 hours, which may be convertedinto approximately18 days may not be adequate for the Operator to master these tasks and effectively deal with emergency or complicated circumstances.

Cabin Resource Management
There was no specific cockpit (Cabin) resource management training to detail the Operator on what not to do and what to do in demanding moments. In the field, Operators were faced with different challenges arising from technical faults with their equipment, such as loss of brakes, to giving way to irresponsible vehicle Operators who could not observe traffic rules. Additionally, pedestrians in the vicinity of machinesas well as rough terrain were some of the challenged Operators faced. As such, thereis need for a complete study module to equip an Operator on how to react when faced with such emergencies. This should also include making the operators appreciate the consequences of carrying things such as food, drinks, sharp objects and cell phones in the cabin while operating their equipment. During this program, a package of defensive driving should be incorporated, where practical near accident scenarios should be simulated. On the other hand, fitting machines like Dump Trucks with E-Lights (double cameras) to monitor both the cabin activities and the front of the machine could improve the behavior of Operators and minimize guesswork during accident investigations as these cameras could be replayed to observe previous activities.

Safety
Though the Mine had a number of safety and operating procedures,Operators did not follow some of them. Some Dump Truck Operators for example, did not follow the stipulated thinking distance. At the dumpsite, competition in tipping was observed, each Operator wanted to tip first. A traffic controller at all dumpsites could be a better option in controlling traffic. Spot checks by Supervisors or Inspectors may be required along the haul road to monitor the behavior of machine Operators. To a greater extent, observations from this study show that, supervision within the pit was not adequate.

Machine Interface
Crowding at loading points was observed. In certain areas, maneuvering to correctly position the Truck next to the

shovel was particularly a challenging task for Dump Truck Operators. Operators had to back up next to a moving digger. This operation was not easy as the Operators depended solely on two rear-view mirrors to perceive the position of the Truck relative to the shovel.Machine to machine collision can be avoided by introducing some innovative engineering controls such as proximity sensors (vehicle anti-collision) which should give warning once the machine gets close to another vehicle. Consequently, the engine of the moving machine should cut off when too close to the other machine or personnel. However, in the absence of these high-tech controls, collision of vehicles can be controlled by the use of reflective pegs positioned to demarcate points between vehicles. The other measure of significance is to introduce a one-way traffic where roadways appear to be tight or where congestion of vehicles apply.

As earlier stated, Dump Truck Operators sorely depended on the two rear view mirrors when reversing. It could be a good idea to install reverse cameras on all Dump Trucks to assist the Operators when reversing.

Support Equipment
The availability of the auxiliary equipment such as Dozers, Water Trucks and Graders was not adequate to support the effective maintenance of roadways as well as loading and dumpsites. Bad road and poor work sites conditions are a recipe for accidents as Operators maneuver to avoid bad spots. Therefore, the maintenance Department should ensure support equipment is made available at all times.

Switching of Machines
An element of negative transfer was observed among Operators. In certain instances, Operators had to switch between different Truck types. Inconsistent design of controls across these machines facilitates negative transfer. While this problem is likely to result into control errors (such as the use of the retarder) by Operators, a short session for an Operator to go through the controls of a different vehicle may improve the Operator awareness and minimize errors.

Radio Communication
In addition to machine control, the Operator also had to perform other tasks, which mainly involved communicating with other parties across the Mine such as pit control and various equipment Operators to exchange information or get instructions. These tasks, which can be categorized as communication and information management, involved the use of the radio. However, it was observed that, some of the communication was not work related and this conduct resulted into denying other Operators access to communicate work related information in time.

Visibility
The inability of Excavator Operators to see clearly around the area of operation could be a causal factor in accidents within the pit, more especially during loading operations. Most of the Excavator windows were found to be covered in dust from the pit. This condition was likely to impair the Operators visibility. As such, it can be a better option for the engineering department to procure a mobile high pressure washer to assist in cleaning the windows while carrying out routine checks on Excavators within the field.

13. Conclusion

The main objective of this study is to explore the cause of the numerous mining equipment accidents experienced at XMC and to better understand the contributing factors in mobile equipment accidents, assess available Operator training interventions, propose new ideas if needed, and determine whether certain activities or systems at the Mine required receiving special focus.

The most important finding to emerge from the two questionnaires administered (147 Operators and 21 Supervisors) is that, mobile equipment accidents by Operators at XMC are due to badpit condition. This came out as the most prominent risk factor for the numerous accidents at XMC and is found to be statistically significant at 5% significance level. The other aspects arisingexpressively from the study as contributing factors to the frequent equipment accidents at the Mine include, bad road conditions, staff fatigue, poor staffing, motivation and production pressure.

From the ethnographic study conducted, it has been discovered that, the duration of the Operator training is inadequate and that the training module does not incorporate the Operator cabin resource management training which is vital for the safety of the equipment Operator. Additionally, the two departments, Training and Development and Safety,donot take part in the candidate selection process. The two departments are well positioned to understand and interpreted humanbehaviour and attitude as they are always in constant interaction with trainees of various skills level.

14. Recommendations

This study was based on a detailed analysis of XMC in search of the causes of mining equipment accidents based on the operational practices in the Mine and using theoretical analysis. Therefore, some recommendations emerged from the findings:

1) The mining Department must come up with a study to assess the pit conditions and find ways of correcting the irregularities. Restricting certain routes in the pit area to one-way, can significantly help in decongesting some areas as well as providing enough space where roadways may be tight for heavy vehicles. On the other hand, the maintenance (HME) Department must equally put in place a strategy to ensure that, the minimum acceptable number of support equipment is always made available to mining.
2) Though the elements of fatigue and motivation received reasonable concern from the study, the root cause of these variables has not been conclusively identified and mitigated. Therefore, the mining Department needs to conduct a detailed investigation into the main cause of fatigue and low motivation for the equipment Operators. Additionally, the equipment operator’s job is repetitive. Repetitiveness of a task is bound to lead to monotony. Therefore, it may be important for Supervisors as well as Safety Officers to randomly talk to Operators about the

safety of their machine and the environment while in the field. This initiative may help to break Operator monotony and improve concentration.

3) It would be necessary to include the Training and Development as well as the Safety Department in selecting candidates for the equipment operator training.Since the two departments deal with human character on a daily basis, their skills can be significant in making good judgement. Their experience can help to view the weak and strong areas of the candidate and provide correct information about the positive or negative characteristics of the individual.
4) Gaps in the operator training can be assessed and extra modules developed where necessary. Incorporating cabin resource management training into the existing program will be a major milestone in improving the safety of Operators. Above all, the duration of the operator training should be reviewed as the study found out that, the time allocated to the equipment operator training was not enough.

It must also be noted with great care that, Mine management changes with time. As such, discrepancies may arise in recording accident statistics as each set of management may have its way of defining reportable accidents. If this is not properly understood, accident statistics may not be representative, more especially where comparison is required for various periods.

15. Limitations

Although this study considers the causes of mining equipment accidents at XMC, it falls short of analyzing the financial implication of the accidents. Therefore, future studies should consider empirically analyzing the impact of equipment accidents on the total cost to the company.

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