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Original article

Improving Remedial Measures from Incident Investigations: A Study Across Ghanaian Mines

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ABSTRACT

Background: Learning from incidents for accident prevention is a two-stage process, involving the investigation of past accidents to identify the causal factors, followed by the identification and implementation of remedial measures to address the identified causal factors. The focus of past research has been on the identification of causal factors, with limited focus on the identification and implementation of remedial measures. This research begins to contribute to this gap. The motivation for the research is twofold. First, previous analyses show the recurring nature of accidents within the Ghanaian mining industry, and the causal factors also remain the same. This raises questions on the nature and effectiveness of remedial measures identified to address the causes of past accidents. Secondly, without identifying and implementing remedial measures, the full benefits of accident investigations will not be achieved. Hence, this study aims to assess the nature of remedial measures proposed to address investigation causal factors.
Method: The study adopted SMARTER from business studies with the addition of HMW (H – Hierarchical, M – Mapping, and W – Weighting of causal factors) to analyse the recommendations from 500 individual investigation reports across seven different mines in Ghana.
Results: The individual and the work environment (79%) were mostly the focused during the search for causes, with limited focus on organisational factors (21%). Forty eight percentage of the recommendations were administrative, focussing on fixing the problem in the immediate affected area or department of the victim(s). Most recommendations (70.4%) were support activities that only enhance the effectiveness of control but do not prevent/mitigate the failure directly. Across all the mines, there was no focus on evaluating the performance of remedial measures after their implementation.
Conclusion: Identifying sharp-end causes leads to proposing weak recommendations which fail to address latent organisational conditions. The study proposed a guide for effective planning and implementation of remedial actions.

1. Introduction

Within the occupational health and safety practice, incident investigation is regarded as a major means of improving workplace health and safety, and it is highly embedded in organisations that practice safety management systems [1–3]. Even though most safety-conscious organisations adopt risk management practices to ensure safety, a risk management plan has the potential to fail as things do not always go as planned [4,5]. Thus, there must be a process to learn from failure to improve safety. Incident investigations are therefore implemented to ensure learning from past incidents to prevent future recurrence of the same/similar events with the overall objective of improving safety in the organisation [6]. Hence, reactive incident investigations complement proactive risk management. Generally, whenever an accident occurs within a sociotechnical system, an investigation of the accident is carried out to find weaknesses within the system that contributed to the accident and address those weaknesses to improve safety. Therefore, Incident investigations remain important to improving sociotechnical safety, which has been emphasised in the

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literature [2,6,7]. Even though incident investigation in practice consists of several stages with various activities, it generally consists of two major components [6,8].

First is the collection of data and its subsequent analysis to identify the causes that contributed to the incident. This initial stage is often followed by the identification of solutions (remedial measures), which, when implemented, can potentially address the identified causal factors. This indicates that the identification of causal factors and the identification of remedial measures are interrelated, and the outcome of the first (causal factor identification) is a necessary input for the next (identifying remedial measures) [6,9,10]. A review of the literature indicates that the identification of causes has seen considerable progress, unlike the identification of solutions to address the causes of the incident, which has not seen much progress. It was observed through the literature review that three specific progresses have been made in the search for causes, which have not translated to the identification and management of remedial measures. These three improvements are (1) a clear definition of the search for causes, including its stages and activities, (2) models/methods to guide and facilitate the search for causes and (3) analyses of past accidents and disasters to identify the causes.

For instance, several studies have focused on the identification of causes, describing clearly what constitutes that component, its stages, and the specific activities [2,8,9,11]. Drupsteen et al [8] have defined the process of investigating and analysing incidents to consist of four stages, including (1) reporting the incidents and their registration, (2) defining the scope and depth of the investigation, (3) collection of data and (4) analysing the data to find the cause of the incident. A similar process was defined by Jacobsson et al [11], who also recognised reporting as the initial stage in the search for causes, with the data analysis to identify causal factors being the last. Several other authors [2,10–12] recognised that reporting, data collection and data analyses are steps that must be followed in the search for causes, indicating consensus on what constitutes the first component of incident investigation, that is, the search for causes. Again, the models for the search for causes have undergone significant progress over the years, from the early simple linear models to the more recent complex interaction models [13–15]. Following the improvement in accident causation models, different accident investigation methods have also been developed, from those that focus on the proximate causes to those that focus on distal causes deeply buried within the complex nature organisation [16–19]. These advancements have contributed to the effective investigation of complex accidents, which are typical of sociotechnical systems that are systemic in nature, with several subtle interactions. Thus, regarding the methods available for searching for the causes of the incident, a broad range of options exist, and a selection can be made depending on the complexity of the incident under investigation. Moreover, within the literature, there have been investigations of major accidents to uncover the causes for learning. Such accidents include the BP Texas [20,21], Westray mine explosion [22], and Piper Alpha [23–26], among others. The investigation of such accidents and disasters has further contributed to the search for causes, bringing to bear the complex nature of sociotechnical systems. All these illustrate the growth in the initial component of the incident investigation process. However, as earlier emphasised, the later component of identifying solutions, even though it has seen improvement, the progress made does not correspond to that of the search for causes.

For instance, there has been narrow research attention on defining the steps that constitute the planning and implementation of remedial measures. Similarly, there has been limited focus on the analyses of the effectiveness of implemented remedial measures through post-implementation recommendations checks. Considering that the overall objective of an incident investigation is to improve safety, "the identification of causes remains inadequate unless it leads to the selection and implementation of improvements that address the identified weaknesses" [27]. Generally, within the literature, it has been reported that most organisations spend more resources on the search for causes in contrast to the identification of remedial measures [13,27,28]. Again, there have been calls to focus research on the identification and implementation of remedial measures as that remains important to the incident investigation process and safety improvement. Even though there has been research attention on the search for recommendations and analysis of recommendations, some limitations exist in those works. For instance, Stemn et al [27] evaluated the nature of remedial measures in the Ghanaian mining industry, including the existing process and practices for planning and implementing recommendations. Their research, however, relied on interviews, which has been criticised for having social desirability bias, in contrast to analysing actual investigation reports. Similarly, Rollenhagen et al [28] also studied the remedial action identification processes of two Swedish nuclear plants using interviews and analysis of the previous 106 investigation reports. Even though their research presents several meaningful contributions, it presented some limitations in terms of the number of reports analysed, the number of participating organisations and the domain specific. These suggest that the process of identifying and implementing remedial measures requires more focus and warrants more research attention. This research contributes to this area by evaluating the nature of remedial actions recommended to address the causes of accidents in the Ghanaian mining industry by studying actual investigation reports.

The research was formulated to present three specific contributions. The first was to analyse the nature of the problems that remedial measures were proposed to address to receive a general view of the causal factors identified from investigation across the mines. Secondly, the study sought to evaluate the nature of the remedial measures proposed to address the causal factors to obtain an in-depth understanding of recommendations resulting from incident investigations at the mines. Thirdly, based on the outcome analyses of the past remedial measures, develop a tool to support the evaluation of the effectiveness of remedial measures prior to implementation.

2. Materials and methods

2.1. Data used

Accident investigation reports were collected from seven large scale gold mines in Ghana (Table 1). The accident investigations were obtained from the individual mines by the researcher for a period of nine years, thus from 2012 to 2020. Six of the mines (A, B, C, D, E and G) are multinational companies, whereas Mine F is national. The reports obtained were pre-analysed and sorted based on the following criteria: (a) presents detailed information on the causal factors identified, and remedial/corrective action proposed to mitigate the identified causal factors, (b) the report is indicated closed and sign-off. Closed and signed-off means the proposed remedial measures from the investigation proceeding have been implemented. In all, 500 reports out of 701 met the stated criteria and were used in the study to assess the nature of remedial measures across the mines. Table 1 presents the summary of the reports used for the study.

2.2. Data analysis criteria description

The study adopts the acronym HMW-SMARTER for the report analysis. The HMW is used to analyse the causal factors, and

Table 1
Summary of reports analysed

Mine	# Of reports collected	# Reports considered	Average # of pages per report	Type of operation
A	216	151	6	Surface
B	152	97	9	Surface
C	90	56	13	Surface
D	97	90	8	Underground
E	29	28	8	Surface
F	59	30	13	Surface
G	58	48	3	Surface & Underground

SMARTER is used to analyse the proposed recommendations. The HMW is abbreviated from Hierarchical identification of the causal factors (H), mapping of the causal factors (M) and weighting of the causal factors (W) to determine each potential contribution to the failure. The "H" category looks at the classification of the causes identified, taking into account the levels within the sociotechnical system. The "M" studies the relationship between the various levels within the system, especially how upper levels influence happenings at the lower levels. During an incident investigation, several factors are identified as causes of the accident. Evaluation of the causal factor to identify each potential contribution enables targeted remedial measures to be proposed to address the causal factors to prevent the reoccurrence of the incident. The "W" assesses the identified causal factors' contribution to the event/failure.

Whenever an accident occurs within the mines, there are two objectives or sub-goal for carrying out investigations; (1) is to identify all possible causes and (2) to propose and implement remedial measures to prevent their reoccurrence. A popularised term, SMART, from the business field, has been proven effective for assessing the objective/sub-objective of a broader goal [29–31]. MacLeod [30] and Subrt and Brozova [32] added "*E*" and "*R*" to the management tool to become SMARTER. SMARTER stands for:

- Specific
- Measurable
- Attainable
- Relevant
- Trackable
- Evaluation of controls
- Reference

The remedial measure must be specific: The proposed remedial measure must state categorically which of the identified causal factors it seeks to address and the focus of the action within the sociotechnical system. In addition, the expected outcome of the activities planned should be communicated to all stakeholders and states who is to be responsible for the implementation of the proposed remedial measure. The action plan should also state where and when the measures should be implemented. Adequate specificity leaves no doubt about what precisely the proposed remedial measure seeks to achieve and makes it easy to trace and assess its effectiveness.

The remedial measures must be measurable: The effectiveness of remedial measures in addressing an identified failure within a system is measurable if it is quantifiable. With the saying "you can't manage what you don't measure" [20] establishing success criteria for remedial measure implementation will enable easy quantification and accurately measuring its performance. Specific measurement criteria help to know if the recommendation's target outcome has been accomplished and track its progress along the way.

The remedial measures must be attainable: During the planning of recommendations, it is important for safety practitioners to consider the feasibility of the proposed remedial measure taking into consideration the human capacity, capital and time. Proposing unrealistic recommendations results in frustration at the implementation phase.

The remedial measures must be relevant: Remedial measures with short-term relevance should be stated and how it features in the long-term plan to prevent the reoccurrence of the same or similar incident. To ensure effective use of the company's resources, implementations should target deficiencies at higher levels. This could be done by prioritising the remedial action, targeting organisational deficiencies which influence the operator at the sharp end to engage in unsafe behaviour.

The remedial measures must be trackable: The organisation should also have systems in place to track the progress of the implemented remedial action. The implementation of remedial measures should be time-bound. The planning phase should state the start time and the expected completion date for remedial measures implementations.

During the investigation and the planning stage, the performance of existing controls and the nature of the proposed remedial action should be evaluated: Evaluating the performance of existing controls will help the organisation know deficiencies within the defences and improve on them to prevent similar failures or events. The nature of the proposed recommendations, whether preventative, mitigative or supporting activity, should be indicated.

Recommendations from similar accidents should be reference during the planning of remedial actions: Studying similar events during remedial action planning and implementation helps the organisation to unlock lapses in the previous recommendation and improve on them to prevent a similar occurrence.

2.3. Data analysis procedure

The study adopts the *HMW-SMARTER* as the board theme for the analysis of the nature of proposed remedial measures from the mining sites (see Fig. 1). Subcategories under the board themes were generated from the initial analysis of the investigation reports and the study of similar works on remedial action planning and implementation in safety-critical domains [33,34]. Two analysts, experts in mine safety, were engaged in developing the assessment framework and analysing the reports. The analysis was conducted in two parts. First, study the characteristics of the causal factors using the HMW criteria. This was to help determine the level within the sociotechnical cited most as the causal factor of accident and whether the proposed remedial actions are focused on addressing the deficiencies within this level. Second, study the proposed remedial actions to ascertain if they are SMARTER enough to prevent the reoccurrence of the same or similar event within the mines.

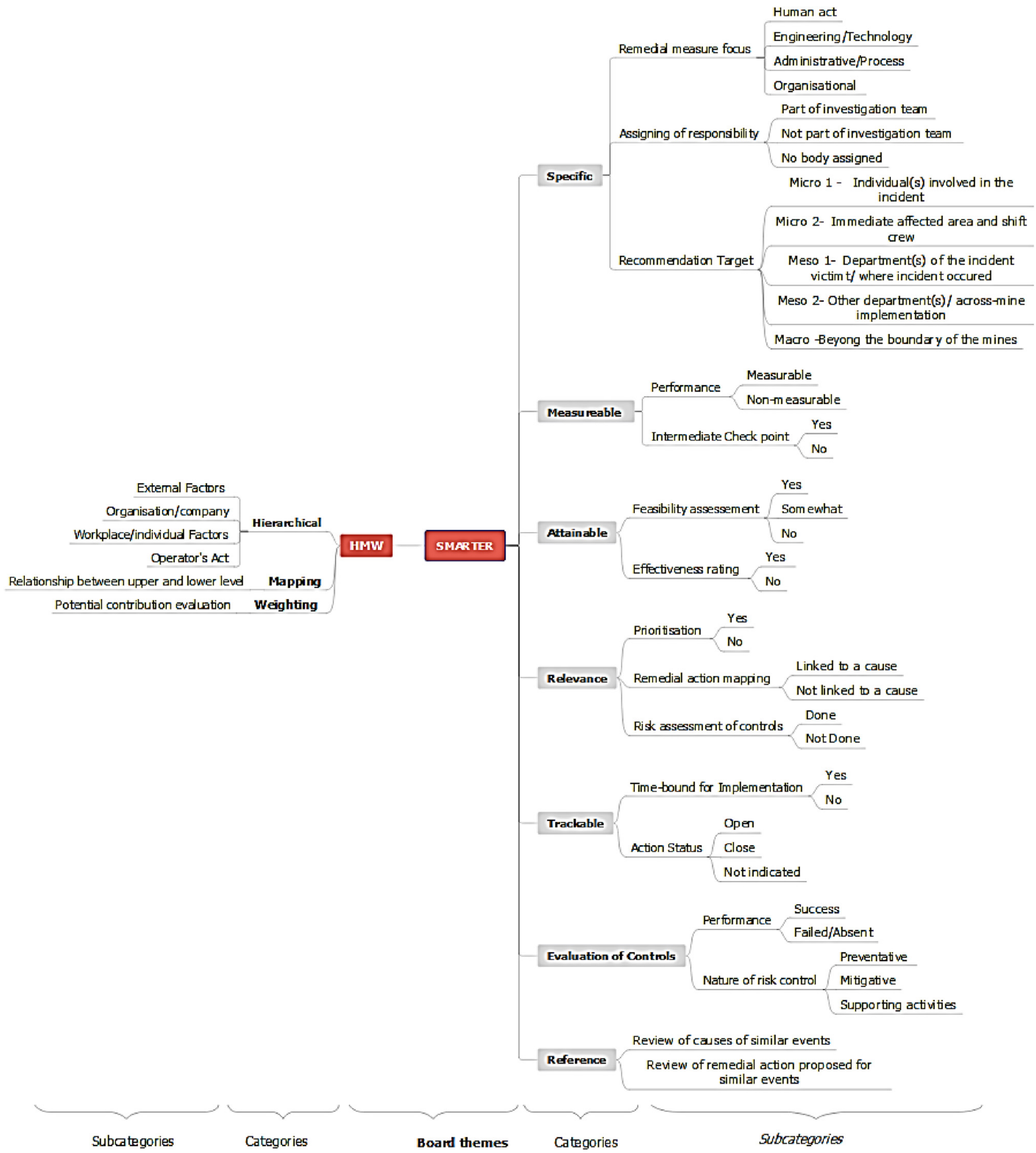

Fig. 1. Final coding framework for proposed remedial assessment.

3. Result

The study identified 1706 causal factors and 1849 remedial measures from 500 individual accident investigation reports. The causal factors were regrouped under four classes as presented in Table 2. Across all the Mines, the number of remedial measures proposed exceeded the number of causal factors identified except for Mine C. In all the cases, the search for causes of the accidents were restricted to the mine's boundary and, therefore, there were no citation of external influence as a causal factor. Accident analysis from other industries, such as marine and oil and gas, has established the influence of external factors such as government policy and regulations on accident occurrence [35,36]. During accident investigations, the Mines should take insight from this and extend the search for causes beyond the mine boundary. Across all the mines, individual/workplace factors were frequently identified as the cause of the accidents, followed by the operator's act, except Mine E, where organisational factors were mostly cited as the cause of accidents.

Considering the mines as a single organisation, 49% of the causes identified were workplace/individual factors, 30% were operators' acts, and 21% were organisational factors. For the operator's act category, the predominant causes identified were procedural

Table 2
Summary of HMW assessment from the reports

Board theme	Category	Mine						
		A	B	C	D	E	F	G
Hierarchical identification of causal factors	Operator's act	194	76	64	85	14	25	59
	Workplace/individual factors	293	163	94	112	40	74	63
	Organisational/company	41	108	58	19	52	43	29
Mapping of causes	Mapped	0	88	48	79	19	18	0
	Not-mapped	151	9	8	11	9	12	48
Weighting of causes	Weighted	0	269	170	0	0	0	0
	Not-weighted	527	77	44	215	104	141	149

non-compliance (15.50%), poor hazard perception/recognition (9.83%) and inadequate task assessment (9.30%). Under the workplace/individual condition, most of the accidents were attributed to inadequate supervision (7.78%), complacency (6.51%), congestion/restricted areas (5.24%) and defective equipment/tools (5.08%). Unsafe design/constructions (12.99%), inadequate work standards (10.54%) and poor safety culture (4.14%) were the most cited examples under the organisation factor category. Detailed information on the causal codes under each category is published [37], and interested readers can refer to it. In most of the cases, the causes identified were graphically represented, mapping the sequence of the event. This is particularly observed at Mine B (90%), C (85%), D (87%), E (68%) and F (60%) where the causes were mapped in most of the cases. Across all mines, only Mines B (78%) and C (79%) evaluated the extent to which the identified causes influenced the undesired events. Table 2 presents a summary of the *HMW* assessment of the cases.

Table 3 summarises the analysis of the remedial measures proposed to address the causal factors. Regarding the focus of the remedial measures across the mines, it was observed that the majority (886) of the recommendations were administrative, such as development/review of SOPs and information/communication of significant findings, except in Mine E, followed by human act in Mines C and D and Engineering/Technology in mines A, E and G. In Mine E, 44% of the remedial measures were focused on fixing organisational deficiencies, with the least focus on human acts (5.6%). In General, 48% of the proposed measures focused on administrative/processes, 22% on engineering/technology, 18% on human acts (focussing on the operator's behaviour or development, such as revoking of operator's licences, disciplinary action against the victim or reinduction and training) and 10% on organisational deficiencies. With the assigning of personnel to ensure the successful implementation of the measures, 57% were part of the investigation team, whereas 22% were not part of the investigation

Table 3
Summary of SMARTER analysis across all mines

Board theme	Category	Subcategory	Mine						
			A	B	C	D	E	F	G
Specific	Remedial measure focus	Human act	91	89	55	74	7	27	24
		Engineering/technology	115	89	44	43	38	40	42
		Administrative/process	364	102	80	155	25	99	61
		Organisational	4	68	6	4	55	19	29
	Assigning of tresponsibility	Part of investigation team	412	94	168	200	62	114	0
		Not part of investigation team	162	61	11	75	32	71	0
		No body assigned	0	193	6	1	31	0	156
	Remedial measure target	Micro 1	124	61	14	42	1	14	13
		Micro 2	230	95	83	106	31	47	53
		Meso 1	205	111	67	119	57	88	56
		Meso 2	14	80	21	9	36	36	34
		Macro	1	1	0	0	0	0	0
Measurable	Performance measurement	Specified	0	0	0	0	0	0	0
		Not-specified	574	348	185	276	125	185	156
	Intermediate checkpoint	Specified	0	0	0	0	0	0	0
		Not-specified	574	348	185	276	125	185	156
Attainable	Feasibility assessment	Yes	0	309	173	0	0	0	0
		No	574	39	12	276	125	185	156
	Effectiveness rating	Yes	0	309	173	0	0	0	0
		No	574	39	12	276	125	185	156
Relevance	Prioritisation	Yes	0	348	185	0	125	0	0
		No	574	0	0	276	0	185	156
	Cause -remedial action mapping	Link to a cause	0	0	0	0	0	0	0
		Not link to a cause	574	348	185	276	125	185	156
	Risk assessment	Done	0	0	0	220	0	0	0
		Not done	574	348	185	56	125	185	156
Trackable	Time-bound	Yes	550	323	185	214	86	177	0
		No	24	25	0	62	39	8	156
	Action status	Open	0	154	12	157	8	22	0
		Close	550	115	173	56	2	20	0
		Not indicated	24	79	0	63	115	143	156
Evaluation of controls	Performance	Success	0	80	40	0	0	0	0
		Failed/absent	0	87	45	0	16	14	0
	Nature of risk control	Preventative	5	34	8	10	14	13	20
		Mitigative	126	91	51	59	42	39	35
		Supporting activities	444	223	126	207	69	132	101

process. At mine G, assigning personnel to remedial measures was not indicated in all the cases, contributing greatly to the general 21% unassigned remedial measures. Across the mines, most of the remedial measures were directed at the department(s) of the incident or where the incident occurred (Meso 1) except at mines A and C, where the targets were at the immediate affected area or shift crew (Micro 2) as shown in Table 3. Across all the mines, only 2 of the recommendations were directed at addressing external influence. Overall, the results indicate that few recommendations (12.5%) are targeted at addressing mine system deficiencies/ external influence, which should be of great concern to management if they seek to prevent similar accidents within the mines. However, 14.5% of the recommendations were directed at human problems or behaviours, which is a positive indication that the mines have evolved from the traditional idea of addressing who went wrong to what went wrong.

Concerning the measurement of the performance of the remedial actions, a similar trend was observed across all the mines, as shown in Table 3. An intermediate checkpoint to assess the progress of the recommendations was not specified in all the cases, nor were criteria used to assess the overall performance of the remedial measures. Mine B (88.7%) and C (93.5%), in most cases, conduct effectiveness ratings and feasibility assessments on the recommendations and, based on the outcome, prioritise them to determine which one to implement first. Mine E also prioritise the proposed corrective action, but there is no indication of the criteria for the ranking. Across all the mines, the remedial actions were not linked to causes to indicate the particular causal factor a recommendation seeks to address. Except for Mine D, none of the mines evaluated the risk that would emerge from the proposed remedial measures upon implementation. 83% of the remedial measures were time-bound, with action status *open* and *closed* for 59.6% and 23% of the remedial measures, respectively. The state of 580 recommendations were not indicated in the reports. Most of the recommendations across all Mines were supporting activities (70.4%), which only enhanced the effectiveness of existing controls, with few being preventative (5.6%). Across the Mines, especially at Mine A and E, where the events are similar, there is no review of similar cases (past events and their proposed recommendation) during investigations (Table 3).

4. Discussion

Managing complex systems, such as the mining industry, regarding accidents is challenging. Accidents, if not prevented or properly managed, can affect the sustainability of the system if they do occur. In order to create a safe system, the mines have adopted several management practices, which have not effectively addressed this challenge. To build a safe and adaptable system, there must be a shift from “management” to “governance” of complex systems. Although an emerging paradigm, complex system governance exhibits high potential to solve complex systems challenges and improve its performance compared to complex system management [38,39]. Complex system governance presents long-term solutions, considering the system's viability. It is recommended that the mining setting join the development of the complex system governance field as it exhibits a high potential to address complex system problems.

Planning of recommendations is mostly influenced by the extent to which the Mines search for causes and what they accept as a cause of an accident [13]. Identifying sharp end causes leads to proposing weak recommendations which fail to address latent organisational conditions [33,40,41]. The Mines focused on the operator's act or workplace/individual conditions during the search for causes, with the nature of the recommendation to address these factors being administrative. Administrative recommendations mostly address human problems or behaviour but fail to address organisational latent conditions that influence individuals to engage in unsafe acts. Looking beyond the individual and his workplace would influence the planning stage of recommendation to focus on engineering/technological measures which could address latent organisational conditions. Mapping and weighting the causes assist the mines in making an informed decision on what level of the sociotechnical system to target to address the failure and which of the causes need much attention. Mines such as B and D, where there was a chronological sequence of the events/causes, recommendations were mostly targeted at the departmental level and sometimes across mine implementation. Targeting across mine implementation help to prevent similar event at different sections or departments. To ensure successful and timely implementation of the proposed remedial measures, it is important to assign the corrective actions to a member of the investigation team. Although most of the recommendations were assigned to a member of the investigation team, quite a number of the recommendations were not assigned or assigned to someone not part of the investigation team. In instances where the individual assigned is not part of the investigation team, she/he may not understand the level of importance assigned to a particular recommendation and the expected outcome of the corrective action upon implementation. This results in the inadequate implementation of the recommendation and also accounts for many recommendations with action status open or not indicated. Failure to assign the implementation responsibility to an individual present challenges in tracking the progress and the overall performance of the remedial measure.

With the popular saying “you cannot manage what you do not measure” from management studies [30], it is important to establish criteria to quantify the performances of the remedial measures to ensure accurate measurement. Without performance measurement, it is very difficult to determine whether the implemented corrective action yields the expected results. Across all mines, the cases are closed after the remedial measures are implemented. There are no systems to check whether the implemented corrective action addresses the problem identified during the investigation process. In some mines where the cases were similar, raise the question; Are the proposed measures effective? This question can only be answered through performance measurement.

After the recommendation has been proposed, it is left to management to decide on what and when to implement, taking into account time and the company's resources. If a conscious effort is not made, motivational biases, specifically strategy-based error, may occur at this stage. This happens when suboptimal recommendations are implemented [42], which can not prevent similar accidents but can only mitigate the situation for a certain period. To address motivational biases whiles saving the company's resources, it is very important to prioritise the remedial measures based on their ease of implementation, considering the available resources and their effectiveness in preventing future events. Cost-benefit analysis at this stage allows the company to explore alternate corrective measures and help the company make an informed decision on which of the recommendations to implement in the meantime while waiting for the economy to allow for the implementation of a permanent solution. The other mines could adopt the recommendation ranking system at Mine B and C to save the company's resources and adequately address the causes identified. Also, to address motivational biases at the implementation stage, there should be a third party, for example, the senior manager, who signs off to close investigations, to inspect the implemented recommendations to ensure that it is executed not according to the desire of the personnel assigned but to the expectation of the investigation team.

All the Mines fail to assess the risk introduced into the system by the remedial measures, which is a significant factor to consider in accident prevention and safety management [43]. In complex sociotechnical systems such as the Mining industry, introducing solutions leads to solving the problem and can also result in further problems [43]. Hence, when implementing solutions, it must be done in a way that minimises the introduction of other problems, systemic thinking must be followed during the implementation of remedial measures from accident investigations. Many accidents have been attributed to failure on the part of management to perceive the adverse effect of decisions and changes in technology [34,43]. Therefore, there should be an emphasis on the potential for the introduction of new risks due to the proposed remedial measures. Thus, implementing new remedial measures should themselves be risk assessed so that the potential of introducing new risks is minimised since elimination is often hard to achieved. Again, across all the Mines, there was no causes-remedial measure mapping; as a result, the remedial measures implemented do not address the significant causal factors. To prevent future accidents and render the system safe, remedial measures should address latent conditions with much influence on the event. Targeting significant latent organisational factors helps to mitigate the deficiency and prevent future failures. Most of the proposed controls were supporting activities instead of being preventative or mitigative.

Controls refer to implementations, either acts, objects or technological systems that prevent or mitigate losses, and their performance can be measured and audited [33]. Preventative controls either eliminate or minimise the exposure to the accident, whereas mitigative controls provide immediate protection against harm and restore the system to safe operation [33]. Majority of the recommendations were non-controls which are to ensure the effectiveness of risk controls that are absent or not effective in preventing failure within the system. Although supporting activities are essential and needed, the focus should be on mitigating or preventing the undesired event. It was observed that, across the participating mines, there was limited focus on analysing the performance of risk controls, and this was identified as a significant setback in the accident investigation process and required strengthening. Insights from other industries, such as aviation, indicate that evaluating the performance of risk controls during accident investigations adds value to the investigation process [44–46]. With the evaluation of risk controls, lapses within the barriers are revealed and corrected to prevent similar accidents. Evaluating the success of the risk controls can enable the organisation to replicate the controls at different sections of the organisation, contributing to improving the entire system rather than focussing on specific locations. Parallel to accident causation factors was obverse in the majority of the cases. This situation occurs when the Mines continue to address causes with the same recommendations, although they are not effective in preventing similar/same incidents [34]. This is attributed to lack of review of similar/same past events during the investigation proceedings. It is suggested that all the Mines should have a system in place to archive all incident documents, classifying them based on the nature and severity of the incident to enable easy retrieval during investigations.

4.1. Guide for effective planning and implementation of remedial measures

Wherever an accident occurs, past events should be glanced through to determine if a similar event has occurred before. This could be achieved through proper documentation of the incident reports, thus classifying them based on their nature, type and severity. Proper documentation makes referencing easy and safe time. If a similar event has been recorded, then the causes identified and recommendations proposed should be studied during data analysis and planning of recommendations. Causes identified should be presented in a hierarchical order under the board theme; external influences, organisational factors, workplace/individual factors and

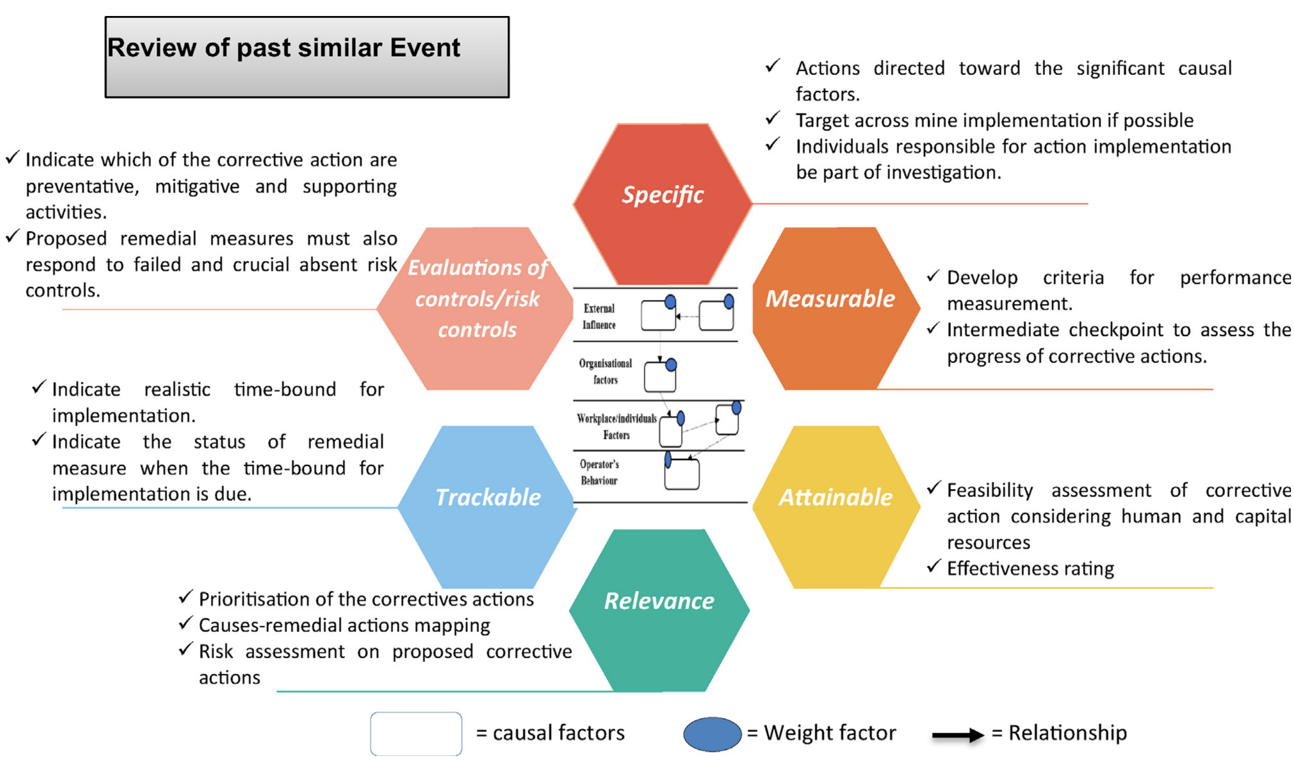

Fig. 2. *HMW-SMARTER* Model: A guide for effective planning and implementation of remedial measure.

operator's behaviour. The relationship between the causes should be indicated through mapping, such as AcciMap [47]. Finally, a weight factor should be placed on all the causes identified to determine the extent of influence of each of the causes of the accident.

The proposed recommendations should be SMARTER enough to address all the significant latent conditions within the sociotechnical system. The proposed remedial measures must be *specific*. The recommendations' focus and the implementation level should be clearly stated. Across Mines implementation is recommended as it helps to prevent similar events at different sections of the mine. Individuals responsible for implementing corrective actions should be part of the investigation process/team. Inadequate implementation of corrective action within the mines resulted from "limited/lack of collaboration between those making recommendations and those assigned implementation responsibilities" [33]. At the planning stage, the team should explicitly indicate, which recommendations are preventative, mitigative, and supporting activities. The proposed corrective actions must also respond to failed and absent crucial risk controls. The proposed remedial measures must be *measurable*. The mines should develop criteria to measure the performance of corrective measures when implemented. Intermediate checkpoints should be factor in the performance assessment criteria so that ineffective controls can be identified earlier and make changes or modifications. The proposed corrective action must be *attainable*. Feasibility studies should be conducted for the recommendations taking into account the company's resources and the effectiveness of the remedial measure in preventing future undesired events. Interim and long-term solutions should be clearly stated. The proposed remedial measure must be *relevant*. The remedial measures should be ranked to determine which ones to implement first based on their significance in addressing the identified problems. There should be a clear indication of which of the causes a particular corrective measure seeks to address. The level of uncertainty introduced by implementing the recommendations should be assessed and put measures in place to reduce it to an acceptable level. The proposed remedial must be *trackable*. Time-bound for implementation must be indicated for the recommendations, and it must be realistic. The status of the recommendation after the expected time for implementation should be indicated. If not implemented/open, factors hindering timely and successful implementation should be indicated. The guide is summarised in the *HMW-SMARTER* model shown in Fig. 2.

Conflicts of interest

The authors declare no conflict of interest.

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