Measuring resilience in the aviation industry: a case study of a South African Company

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Keywords

Safety management systems, accidents, incidents, safety-I, safety-II, Resilience engineering, Risk Assessment Grid.

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Abstract

For organizations operating in high-risk environments, resilience must be a top priority as a key component of their safety measures. In addition to applying Safety I principles, it is also crucial to implement Safety II principles to further improve resilience. This study examines the views of employees within the organization regarding four constructs of Resilience Engineering: the ability to respond, the ability to monitor, the ability to learn, and the ability to anticipate. The evaluation was conducted through an online survey instrument and the sample was drawn from the operational personnel population. Several tests were administered to characterize the sample, assess its reliability and validity, and conduct other analyses. The results indicate that while some elements of resilient performance are visible, the overall picture is that these elements need to be improved upon.

Introduction

The objective of the research is to assess the resilient performance of an organisation in the aviation industry to determine whether there are any visible signs of resilient performance, to identify the areas of improvement and to make recommendations accordingly. The reason for this is that the regulatory environment responsible for safety oversight is still heavily focused on the historical approach to safety management which includes retrospective analysis of accidents and incidents and counting errors (SACAA, 2011). Therefore, the study will be used to show the advantages of resilience engineering and how the adoption of this approach can enhance the management of safety.

The area of focus will be on the operations of the organisation because this is the primary contributor to the safety performance of the organisation, and consists of operational employees whose knowledge and experience will be relevant to this study. The assessment will review relevant aspects of the work done by operational personnel as these are the main drivers of the safety outcomes.

The operational element of the organisation includes both Air Traffic Services (which includes Air Traffic Controllers) and Operations technology (which are the technicians and engineers) however, this study will focus on the Air Traffic Services

part of operations to gain a good overall understanding of the operations of the organisation. This approach is important because the operational domain is key to the safety outcomes of the organisation.

The status of research around resilience proposes that the focus of safety management should be on understanding why things go right (Hollnagel et al, 2015) and for humans to be seen as the resources that are essential to ensure that the system is flexible and resilient as opposed to being seen as the problem. Resilience Engineering (RE) acknowledges that the world has become complex and that cause-and-effect logic cannot be the only explanation for unwanted outcomes. (Hollnagel et al., 2015)

RE as a theory became prominent following the Columbia space disaster (Woods, 2005). RE propositions that adverse events can be managed through anticipation and resilience, RE is also cited as the reason why some organisations can bounce back after unexpected adverse events (Wildavsky, 1988). The difference with RE is that its focus is not on the negative and also that it attempts to be proactive in that it anticipates and does not wait for things to go wrong. This study will be based on the RE theory.

This study aims to conduct an assessment of the potential for resilient performance based on employee perceptions, of an organisation in the aviation industry where the requirement to have safety management systems is regulated because the industry mainly deals with the safety of life. A large amount of investment is made in the infrastructure required to ensure a safe service provision through the latest technologies, this includes communication, navigation and surveillance infrastructure. Similarly, large investments are made to ensure adequate training of all operational staff to sharpen skills and ensure a safe service.

Problem statement

Historic safety management approaches are backward-looking and their main focus is on errors whereas RE helps organisations to develop processes that are resilient to enable organisations to function even in adverse conditions and beyond. (Dekker et al., 2008)

The safety critical organisation currently utilises the historical safety management approaches (safety-I) such as investigating incidents to identify what went wrong in the hopes of preventing re-occurrence. This approach has not proven to be very effective in the improvement of safety mainly because it is reactive and measures the absence of safety and it is also not successful in preparing organisations for future mishaps (Dekker et al., 2008). RE, however, explores a different way of thinking about safety. This research will look into how RE can help set up the safety critical organisation for the future by assessing the potential for resilient performance and through this, also identify areas of improvement to make recommendations on how the organisation can improve its safety management processes. This will be done through the use of the Risk Assessment Grid (RAG) in the aviation context using the four abilities to measure resilient performance to establish whether the elements of resilience exist or not. As per the challenge identified by (Hollnagel, 2015), the RAG will have to be adapted to the organisational context and reality to ensure applicability to be able to draw meaningful insights.

The exploration of the new approach to safety management (resilience engineering) and whether this new approach will be better at managing safety by being proactive and not only analysing things that go wrong.
The study will also examine what value can be gained by using the safety-II approach through an assessment of the four abilities that enable resilient performance.

Research objectives

The research objective is to investigate the presence or absence of indicators of resilient performance of a safety-critical organisation in the aviation industry. To conduct the assessment of resilient performance using the four abilities as defined in the Resilience Analysis Grid (RAG) methodology (Hollnagel, 2015) also known as the four potentials of resilience (Hollnagel, 2018).

The study hopes to respond to the following research questions:

- To what extent does the safety-critical organisation monitor its environment to enable it to identify possible threats?
- Does the safety-critical organisation possess the capability to respond to disturbances and is it able to adjust itself and react accordingly?
- Does the safety-critical organisation use its experiences to learn lessons both from negative and positive outcomes?
- Does the organisation have the capability to predict disruptions it may face in the future?

The null hypothesis is the following:

- The company under study does not exhibit the elements of resilience as described by the four RE constructs and therefore does not have the potential for resilient performance.

The alternative hypothesis is the following:

- The company under study does exhibit the four elements of resilience as described by the four constructs of resilience engineering and therefore has the potential for resilient performance.

Definition of terms

Accident	An occurrence associated with the operation of an aircraft which takes place between the time a person boards the aircraft with the intention of flight until such time as all such persons have disembarked in which: • A person is fatally or seriously injured • The aircraft sustains damage • The aircraft is still missing or completely inaccessible (ICAO)
Hazard	Any existing or potential condition that can lead to injury, illness, or death to people, damage to or loss of a system, equipment, or property, or damage to the environment. (Howell, 2020)

Incident	An occurrence other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operation. (ICAO)
Just Culture	It is defined as an atmosphere of trust where people are encouraged or even rewarded for providing safety-related information but also where the line between acceptable and unacceptable behaviours are clearly defined. (skybrary.aero, n.d.)
Resilient performance	Resilient performance definition: “The emergent property or attributes that some systems have which allows them to withstand, respond and/or adapt to a vast range of disruptive events by preserving and even enhancing critical functionality” (Owen, 2017)
Safety management systems	It is a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures. (ICAO)
Safety culture	It is the way safety is perceived, valued, prioritised in the organisation. It reflects the real commitment to safety at all levels in the organisation. (Safety Culture, 2019)

Limitations

The limitations of the study are that the data gathered is dependent on the respondents' knowledge of the subject under exploration and therefore may be limited by this shortcoming. However, the research instrument has been simplified enough to enable logical application and understanding by the respondents. The other limitation is that the researcher has no control of how many respondents will opt to participate in the study and this may have implications for the validity.

Assumptions

The main assumptions of the study are the following:

A good number of respondents will participate in the study to enable sufficient data to work with as this will allow the drawing of valid conclusions. It is assumed that the

respondents will be truthful in responding to the research questions. The respondents' basic knowledge of the subject is another assumption and that they will have a fair understanding of the aims of the study. It is assumed that the respondents will not be biased in their approach to responding to the questions posed by the research instrument. It is assumed that such a study has not been performed in the South African context as research could not be located that supports this in the context of the particular industry of focus.

Delimitations

RE has been studied widely and has even come up with several frameworks to measure the potential for resilient performance in high-risk organisations. The challenge seems to be the adaptation of the RAG to different contexts for the most part. The challenge has been overcome somewhat and this is shown through the body of work where the RAG has been successfully used to measure the potential for resilient performance. What remains is the work that follows an assessment in trying to develop strategies to enhance the four constructs of the RAG into meaningful work that can be implementable practically.

The focus of this study will be on the use of the RAG exclusively and no other methods to measure resilience will be explored.

The study will be conducted over three weeks to collect data and the focus of the study and the data collection will only be on the operational personnel because they are the primary contributors to the safety performance of the organisation. The other employees outside of the operational areas will not form part of the study.

This study does not cover the other areas of the organisation under study and only focuses on the operational area only as this is one area where the application of safety management is entrenched and it is also an area that stands to benefit most out of this exercise.

This study is limited to the measurement of resilient performance in a particular organisation and does not include the development of improvement strategies after the measurement outcomes have been identified.

Literature review

Safety has traditionally been defined as the absence of adverse effects such as incidents and accidents; therefore, the assumption was that the higher the number of incidents, the lower the safety and vice versa. (Hollnagel, 2015) The International Civil Aviation Organisation (ICAO) defines safety as “the state in which the risk of harm to persons or of property damage is reduced to and maintained at or below an acceptable level through a continuous process of hazard identification and risk management”.

Safety-critical organisations

Reiman & Oedewald, (2009)” define a safety critical organisation as “any organisation that has to deal with or control such hazards that can cause significant harm to the environment, public, or personnel”. These organisations are burdened with risk management, having safety as their primary responsibility.

Reliability in these organisations is key, additionally, they are required to anticipate operational risks caused by either technology, organisational structures or procedures and to be able to respond to these.

Safety critical organisations are usually highly regulated and have the following characterisitics:

- They have complex technologies,
- They have complex systems,
- They have standard operating procedures,
- They have decision-making routines and communication patterns.

The work is often very highly specialised requiring specialised skills that take a long time to acquire and are usually not easy to replace. The operation involves different parties and different technical fields and usually there is a play-off between safety and efficiency. (Reiman & Oedewald, 2009)

Safety management

Safety I

The historical safety management approach, termed “Safety-I” was based on looking back at what went wrong, analysing occurrences, identifying causes and contributory factors and making recommendations to prevent re-occurrence, with the main focus being the errors that caused the adverse events (Dekker et al., 2008). It has become clear that retrospective analysis of accidents and incidents is limited in its ability to improve safety in complex environments because past performance is not necessarily a good predictor of future performance. This approach to safety is also narrow in its view because its focus is only on finding out why things go wrong when it should also be looking at why things go right as they do for the majority of the time (Hollnagel et al., 2015).

The evolution of what is now known as Safety I concepts, whose main focus was bringing down the number of incidents and accidents, has progressed to one where there is an understanding that for safety management to be enhanced, it has to involve an element of learning from both adverse events and successes (Klockner, 2020).

Most applications of the old safety practices focused on eliminating accidents or incidents and this approach ties in with the definition of safety being defined by the absence of negative outcomes i.e. high level of safety equals low incidents. The strategies usually applied to achieve the above are linked to rules and regulations, procedures etc. and the assumption is that if people follow the laid-out rules, then nothing should go wrong (Besnard & Hollnagel, 2014).

	Safety-I	Safety-II
Definition of safety	That as few things as possible go wrong.	That as many things as possible go right.
Safety management principle	Reactive, respond when something happens or is categorised as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
View of the human factor in safety management	Humans are predominantly seen as a liability or hazard.	Humans are seen as a resource necessary for system flexibility and resilience.
Accident investigation	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify the causes.	Things basically happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually go right as a basis for explaining how things occasionally go wrong.
Risk assessment	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	To understand the conditions where performance variability can become difficult or impossible to monitor and control.

FIGURE 1: Safety I vs Safety II

The figure above compares Safety I and Safety II approaches and highlights the differences between the approaches to show what organisations can gain in adopting either of the approaches.

Complex systems

The old safety paradigm known as Safety-I would maintain its relevance only if there was no complexity involved. Industries today function in very complex socio-technical systems with varying interactions between humans, machines, procedures and the like. (Patriarca, 2018) This therefore means that the simplistic view of safety-I is no longer good enough when reviewing safety systems, a more robust safety management framework is required.

Safety Management II/Resilience Engineering

Safety II/Resilience Engineering

The management of safety has progressed over the years and now requires the move towards managing variability in complex environments because paper-based safety management systems are not enough anymore. (Borys et al., 2019) The era of resilience is referred to as the third era in safety management and it is where more sophisticated ways are needed to deal with the constantly changing environment (Klockner & Meredith, 2020)

Pillay and Morel, (2020 p2) in a recent paper, gave the following description of resilience after many proposed definitions: “RE is a perspective for organisational safety management which enables organisation members to actively anticipate, respond, monitor and learn; by adapting to operate at the boundary of safe operations through narrowing the gap between work as imagined and work as performed; and manifested in an organisation’s culture, cognition and behaviours”.

RE helps the organisation’s ability for the creation of flexible processes which are also robust. It helps with the use of resources proactively to deal with disruptions and disturbances and supports the adaptations required to ensure survival in complex environments. (Dekker et al., 2008)

Resilience in the flight crew environment has to do with recognising its own system shortfalls and coming up with ways to mitigate problems faced in high-pressured operational environments (Dekker et al., 2006). Similar parallels can be drawn for the Air Traffic Management (ATM) environment.

Adjekun and Tous (2020) in their paper conducted an assessment of perceptions on the linkages between management factors and resilient safety culture, to test causality between management factors and resilient safety culture. The focus was on the principles, policies, procedures and practices and this links partially to this study as the areas that will be looked at in terms of the RAG that will touch on some of these elements but not all.

A study by Owen (2017) explored the idea of taking resilience from theory to practice and recognising the importance of human factors however the realisation was that the exercise is not as simple as it looked.

According to Adjekun & Tous (2020), resilient performance is an important aspect of a safety-critical organisation as it will set the organisation up for future mishaps and enhance its ability to recover and be able to continue operations after major disturbances. This ability for resilient performance is important in safety-critical organisations because it takes safety a step further in that it helps to ensure that even though things will go wrong, they do not get out of hand and the organisation can recover and continue operations. The approach taken by this author is to check whether there is a link between management factors and resilient safety culture. This approach touches on some elements that form part of the RAG and therefore this study will include some elements of procedures and practices which are aligned to the focus of this study.

Measuring resilience

A methodology developed by (Hollnagel, 2015), known as the resilience analysis grid (RAG) assesses resilience by reviewing the four abilities; namely, the ability to monitor, the ability to respond, the ability to anticipate and the ability to learn. The methodology seems usable however the proviso from the author was that it needs to be adapted to an organisational context and reality for it to give meaningful results. See Figure 2 below showing the RAG.

The research objective is to assess the resilient performance of the organisation's safety system. To conduct the assessment of resilient performance using the four abilities as defined in the Resilience Analysis Grid (RAG) methodology (Hollnagel, 2015) also known as the four potentials of resilience (Hollnagel, 2018):

- "The Potential to Respond Knowing what to do or being able to respond to the irregular and regular. Responding to changes, opportunities and disturbances by activating prepared actions or by adjusting current actions to suit the new conditions and changes to the environment in which
  it operates.

- The Potential to Monitor Knowing what to look for or being able to monitor that which is or could seriously affect the organisation's performance in the immediate future either positively (Safety II) or negatively (Safety I). Monitoring must cover the organisation's own performance as well as what happens in the environment in which it operates.
- The Potential to Learn Knowing what has happened, being able to learn from all experiences and to learn the right lessons from the expected conditions and unexpected conditions by understanding both what goes right, as well as the right (Safety II) lessons from unexpected conditions and what goes wrong (Safety I).
- The Potential to Anticipate Determining or predicting what to expect or being able to anticipate conditions/environment further into the future, such as possible disruptions, unusual demands or constraints, new opportunities, or changing operating conditions."

The testing of the existence of the four abilities will give insight into the organisation's safety system's ability to succeed under varying conditions. Adopting these capacities enables flexibility in the operational environment (Mizzi & McCarthy, 2023) which is essential in air traffic management as it is a dynamic environment which requires one to adapt as the situation changes and to do this with speed.

Work by Duchek (2020) has highlighted organisational resilience as a model that represents a proactive action to unexpected events instead of a reactive response and the idea is to be anticipatory, to be able to manage through a crisis, to adapt and change through learning.
The steps to anticipate, monitor, respond and learn provide an opportunity to continually assess, self-reflect and make appropriate decisions.
The study is aimed at establishing the organisation's potential for resilient performance using the constructs as defined by the RAG. This will be done by engaging employee perceptions on the subject under study through a quantitative research methodology. An analysis will be conducted on the data collected to establish whether aspects of resilience can be identified in the organisation. Based on the results of the analysis, recommendations will be made on areas identified for improvement.

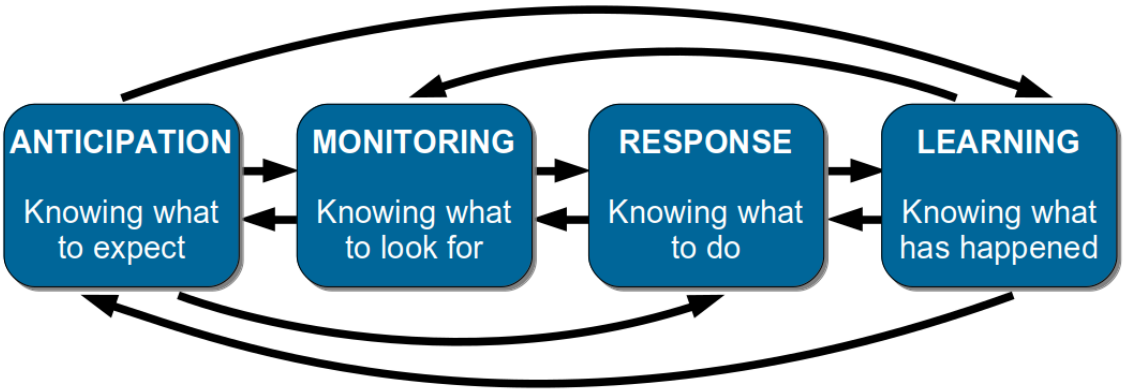


FIGURE 2: Resilience analysis grid

Further studies by Klockner and Meredith (2020) have shown that the RAG can be successfully used to measure the potential for resilient performance at a point in time and subsequently use this information to develop strategies to further enhance the four potentials to enable better management of safety. This study uses the successful application of the RAG as a basis to measure resilient performance in the organisation chosen.

The perspective adopted in this study is that RE appears to be an enabler of safety management and therefore is important to be adopted by organisations to better manage safety. The aviation industry needs such an intervention because history has shown that adverse events cannot be entirely prevented and what becomes important is the ability to deal with adverse events and to be able to bounce back after such events. RE gives organisations the ability to set them up for future successes.

Analytical framework

Theoretical framework

The research problem is to assess the potential for resilient performance in a particular organisation. This is because the world of safety has progressed from the historic safety I approach which is backward-looking and does not really help the

organisation learn from positive outcomes because its focus is only on the negative outcomes.

RE on the other hand focuses on learning from the positive outcomes and states that there is more to learn from the positives because the percentage of the positives, (that is when things go right) far outweighs the percentage of things that go wrong. RE is advantageous because it also helps the organisation deal with unexpected disturbances and gives the ability to function even after such disturbances.

The four constructs that anchor the RE theory as described in paragraph 3.2 above.

These constructs contribute to the resilience of a system and therefore it makes sense for one to conduct an assessment of the four constructs to get sense of the potential for resilient performance with the assumption that the tool will help to identify areas of strengths and areas for development which will then form part of the recommendations.

The majority of work done in resilience points to the fact that the RAG is the appropriate tool to be used to measure resilient performance however the proviso is that the RAG would need to be adjusted to ensure relevance based on which industry or organisation it will be applied in.

Conceptual framework

The theory of RE plus the associated abilities or potentials form the basis of this investigation. The dependent variable is the resilient performance whose independent variables are the four abilities/potentials because for the resilience to be present depends on the presence of the four abilities. The presence or absence of resilience is dependent on whether the four abilities are visible and can be measured. This supports the notion that there may be a relationship between resilient performance and the four abilities as defined by the RAG.

Research design

A quantitative research design was used for this study and involved the gathering of data through an anonymous online survey to obtain employee perceptions on the potential for resilient performance. The quantitative methodology was chosen

because of the theory basis of the study which is already defined and the study aims to assess the applicability of the theory in a particular industry using already established survey questions by amending them to apply to the industry chosen. The survey instrument was developed by Klockner and Meredith (2020) looking at the four potentials of resilience and consisted of 28 items which assess through a 5-point likert scale with 1 being strongly disagree and 5 being strongly agree. The survey questions were reviewed by two Human Factors Specialists with more than 15 years' experience in safety management systems and minor amendments were made based on the review and suggested enhancements.

The survey method was selected because the operations are spread over 22 sites across the country with personnel working shifts and therefore not always available at the workplace. The survey questionnaire covers the four constructs of RE and will therefore help to answer the aim of the study which is to measure the potential for resilient performance, the data obtained from the survey will help determine the existence of the four abilities which is an indicator of resilient performance.

Survey administration and data collection

Approval for the research was obtained from the organisation in which the survey was administered and after approval from the University was obtained. The probability sampling method was used to send the anonymous online survey through e-mails and WhatsApp to a section of the workforce consisting of selected operational personnel. The distribution was through e-mail and WhatsApp groups because these operational teams have established groups for communication purposes. This helped to ensure ease of access to the data collection tool because most of the operational personnel do not have work laptops and therefore accessed the tool through their cell phones. The introductory page of the survey highlighted the purpose of the research and also contained the contact details of the researcher and supervisor and also solicited consent for participation. The survey was open for 14 days and was extended for a few more days to allow more respondents to participate as the response rate was low. There were reminders sent to the participants, periodically to encourage participation.

Population and sample

The study used the probability sampling method known as systematic sampling because the target is a portion of the workforce population and each member of the population has a chance of being selected. The probability sampling method has advantages because it allows for inferences to be made about the general population. The sampling frame includes the whole population however the selection will be made by choosing individuals at regular intervals from a numbered list of the population. The study targeted an average of between 5% and 30% of the population which equates to a minimum of 30 and a maximum of 200 respondents

The sampling interval was calculated as follows:

Total number of operational staff divided by the target number= 598/200 =2.99 rounded off to 3 therefore every third person from the list was selected for participation.

The n to gain meaningful insights equals to 30 or more participants although many factors can affect this number. The target of a maximum 30% response rate was informed by a similar study by (Adjekum & Tous, 2020) which had a population of 1695 and a sample was 516 which translated to 30%.

The Research instrument

The research instrument to be used is adopted from work conducted by (Klockner & Meredith, 2020) which has developed questions relevant to the transport industry requiring minor modifications to make them applicable to the safety critical organisation.

Ability to respond	Fully disagree	Disagree	Neutral	Agree	Fully agree
My organisation has procedures in place to to identify and maintain our capacity to work whenever unexpected events occur					
Operational employees discuss skills with each other to know who has relevant specialised skills and knowledge within the our unit					
Our organisation enables workers to discuss alternative ways of carrying out tasks safely					
Operational employees have access to a variety of resources whenever unexpected events occur					
Our organisation shares information in a timely manner and communicates to those in a position to influence					
Ability to monitor					
The safety performance indicators used are consistent with the organisation					
The organisation's safety performance indicators are revised regularly and properly					
Our organisation uses lead indicators					
Our organisation uses lagging indicators					
The leading indicators used are valid					
The period covered by lagging indicators is appropriate					
The safety performance measurement type (quantitative or qualitative) and frequency are appropriate					
The delay between the measurement and analysis of results is acceptable					
Ability to learn					
Our organisation has clearly established what should be reported					
Submitted safety reports being investigated sufficiently					
There good responses/feedback on submitted safety reports and these responses are in an acceptable manner					
Operational employees are encouraged and given the time to write reports					
The organisation learns lessons from things that go right					
The organisation learns lessons from things that go wrong					
The organisation enables operational employees to meet to learn from each other					
Ability to anticipate					
The organisation has systems in place to look into the future at potential safety and organisational related weaknesses and threats					
The systems or people who make these forecasts have sufficient expertise, capability and resources to make accurate and relevant forecasts					
The time scale and frequency of these forecasts are acceptable					
The criteria used to determine the scope and depth of the forecasted analysis is suitable					
There are systems in place to ensure it is easy, straightforward and welcoming for staff to raise any issue related to potential or anticipated safety and organisational related weaknesses and threats					
The organisation has systems in place to ensure that forecast information is communicated to relevant parts of the organization					
The organisation has systems in place to develop and maintain staff skills and competencies to adequately anticipate future safety and organisation weaknesses and threats					
There are systems in place (where appropriate) to ensure control measures are developed and implemented to address issues raised in forecast analysis					
Operational employees are adequately consulted in the development and implementation process of control measures					

FIGURE 3: Research instrument for data collection (Klockner and Meredith, 2020)

Results

Data analysis strategies and interpretation and quality assurance

After the deadline set, the data was extracted from the Qualtrics system onto a spreadsheet and the data was prepared to be ready for analysis. The incomplete responses were eliminated from the data sets and this was followed by cleaning up the data and estimating those that were missing one or two answers. The data was then coded to ensure that analysis can be done on IPSS.

- Descriptive statistics were used to determine what patterns exist in the data such as averages, standard deviation, means and correlations.
- The data was tested for reliability using the Cronbach alpha which depends on the size of the sample and determines the consistency of data collection. The data would also be analysed to check for validity using factor analysis to check whether the data is valid to proceed with the next step of the process. The questionnaire has a Likert scale for responding to the questions and this will enable factor analysis to be conducted to narrow down variables into a smaller number and to explore underlying dimensions that could explain

whether there are relationships between variables, further supported by the sample size which must be greater than 50 ideally.

- Hypothesis testing conducted using inferential statistic tests such a chi test to check whether predictions made at the beginning of the study are actually true or not.
- A correlation analysis was also be conducted to determine whether there is positive, negative or no correlation between variables.
- The last step would be the interpretation of the results and discussion

Survey demographics

The operational personnel population is approximately half of the total employee population (N-1180), there were 49 responses against a target of 200 after the survey period of 14 days which is appropriate for an internal survey. The response rates can be affected by several factors such as morale depending on the timing of the survey. In this case, the organisation in question is in the middle of an organisational re-design process and this brings with it uncertainties and anxiety, meaning that employees may not be willing to engage. Out of the 49 respondents, only 43 of the responses were usable. The rest had to be eliminated as they had too much information missing. The amount of respondents is within the 5% to 30% rate recorded in other studies (ref). The responses in terms of the different variables were different as expected.
The ages of the participants range from 25-64. The response rate was calculated as follows:
Response rate =Number of responses/Number of invites=49/200=24.5%
The percentage split is displayed in the table below:

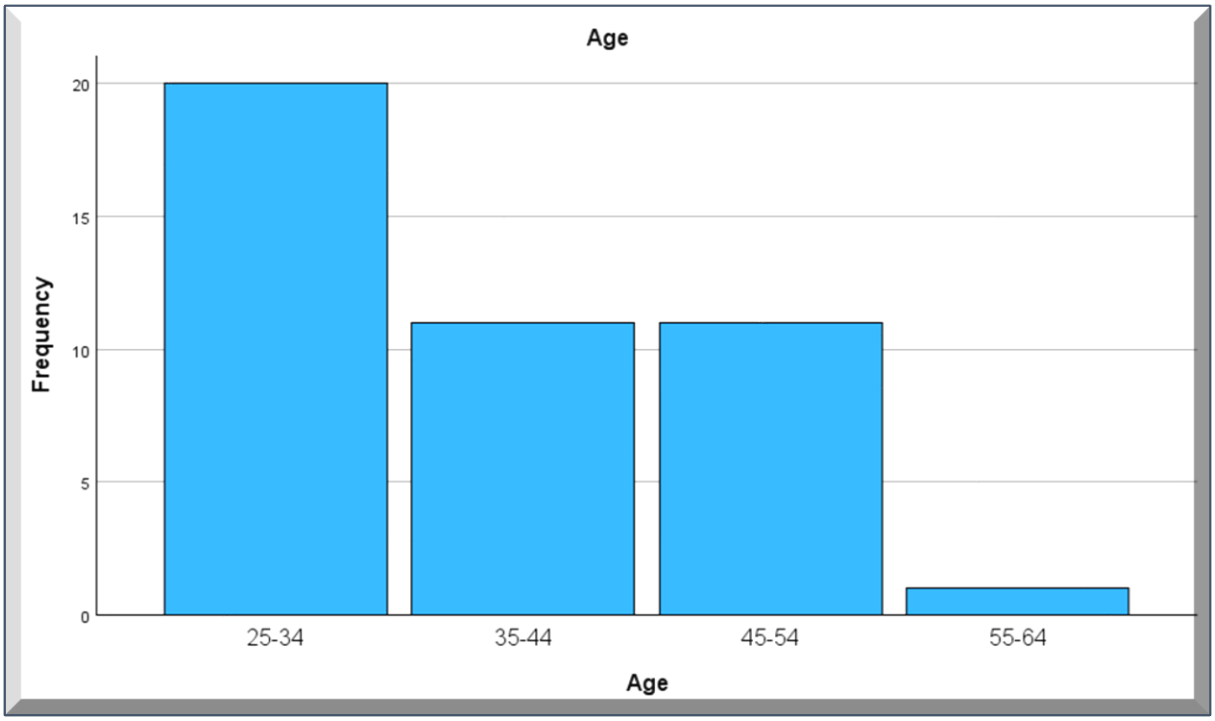


FIGURE 4: Age profile of respondents

The bulk of the participants are aged between 25 and 54 with one responded above 55 and none below 25.

Functional groups of respondents

The percentage split in terms of functional groups is indicated in the following table:

TABLE 1: Functional group profile of respondents

Functional groupings					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AIMO	2	4,7%	4,7%	4,7
	ATCO1	13	30,2%	30,2%	34,9
	ATCO2	7	16,3%	16,3%	51,2
	ATCO3	15	34,9%	34,9%	86,0
	ATSO	5	11,6%	11,6%	97,7
	Other	1	2,3%	2,3%	100,0
	Total	43	100,0%	100,0%	

The highest rate of participation is from the ATCO3 functional groupings followed by the ATCO1 then ATCO2 and ATSO and AIMO respectively and this covers the full spectrum of operational personnel. The overall work experience levels generally

increases from ATSO to ATCO3 level who are the most senior however the same does not apply to AIMO as this role follows a different path.

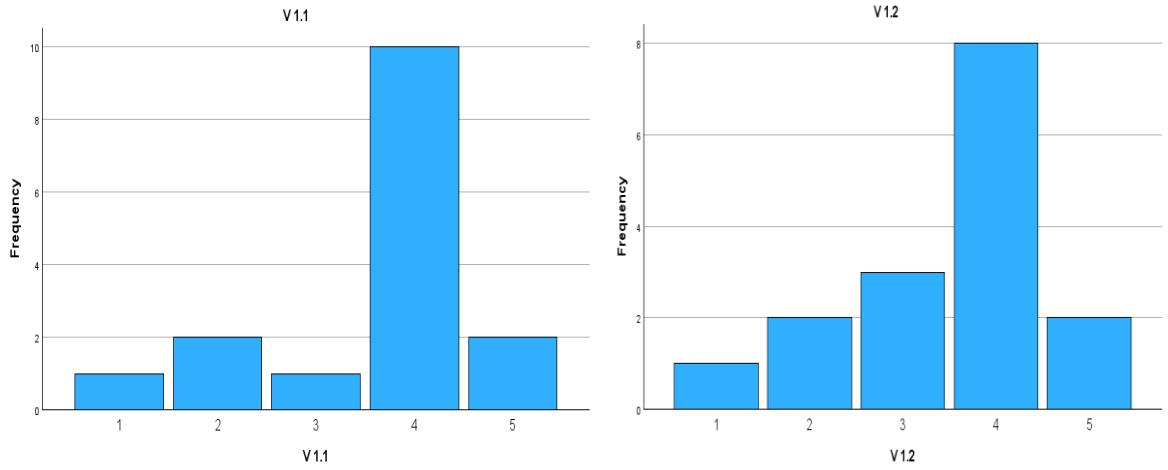
TABLE 2: Location of respondents

Location					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	11	25,6	25,6	25,6
	2	3	7,0	7,0	32,6
	3	6	14,0	14,0	46,5
	4	5	11,6	11,6	58,1
	5	11	25,6	25,6	83,7
	6	3	7,0	7,0	90,7
	7	1	2,3	2,3	93,0
	9	3	7,0	7,0	100,0
	Total	43	100,0	100,0	

The organisation's business units are spread out throughout the country and the participation is representative of eight of the nine provinces of the country. The majority of respondents are based in Gauteng (represented by 1) and the Western Cape (represented by 5), third place is the Kwa-Zulu Natal Region (represented by 3) and then the rest of the provinces, with the lowest participation rate from the Northern Cape province. The only province not represented is the North West with zero participation.

Descriptive statistics

The data was analysed using descriptive statistics to summarise the observations, to examine what patterns exist to give as much information as possible regarding the data (Mishra et. al, 2019). The analysis tested measures of frequency, measures of central tendency and measures of dispersion. Skewness and kurtosis was also tested to check for normality of the data.



FIGURES 5 & 6: Frequency data for Q1 and Q2 for Variable 1 (ATCO3 functional grouping)

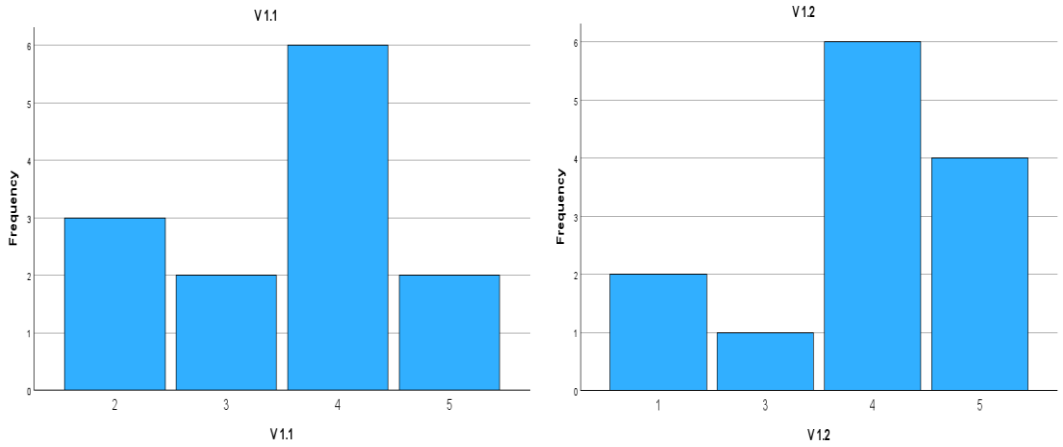
The two tables above are comparing the responses of the ATCO3 functional grouping for question 1 and 2 of the variable 1 (Ability to respond) the result is in favour shown by the number of responses that fall under somewhat agree. The results are confirming that the organisation has implemented procedures to maintain the workers capacity to function during unexpected events. This coupled to the second questions which confirms that employees discuss skills amongst themselves and know who has specialist skills and knowledge.

TABLE 3: Descriptive statistics for Q1 and Q2 for Variable 1 (ATCO3 functional grouping)

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
V 1.1	16	1	5	3,62	1,088
V 1.2	16	1	5	3,50	1,095
Valid N (listwise)	16				

The table above also supports the data in the above graphs which shows a leaning towards agreement for Q1 and Q2 of variable supporting the fact that the said elements are visible in this organisation. Similar results were observed in general for the first variable except for the last three questions of the variable which exhibited means varying between 2.51 and 3.21, suggesting that the three are areas of improvement for the organisation and they refer to the following:

- Enabling workers to discuss alternative ways of working when faced with unexpected events,
- Enabling availability of a variety of resources for unexpected events, and
- The organisation sharing information timeously to ensure that it gets to the right people timeously.(Refer to Table 5)



FIGURES 7 & 8: Frequencies for Q1 and Q2 for Variable 1 (ATCO1 functional group)

The data above has taken question 1 and 2 data for variable 1 and the results show a similar trend to the one seen for ATCO1 functional grouping in terms of the outcome which is in favour as the majority of responses fall under somewhat agree and strongly agree, also confirming the existence of these elements in this organisation.

TABLE 4: Descriptive statistics for Q1 and Q2 for Variable 1 (ATCO1 functional grouping)

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
V 1.1	13	2	5	3,54	1,050
V 1.2	13	1	5	3,77	1,363
Valid N (listwise)	13				

The table above shows the descriptive data (ATCO1 functional grouping) to support the figure 7 & 8 data in terms of results leaning towards agreement for question 1 and 2 of variable 1 with the means of the questions having values above 3.5.

Variable 1: Ability to respond

TABLE 5: Descriptive statistics for Variable 1

Descriptive Statistics										
	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V 1.1	43	1	5	3,67	1,017	1,034	-,857	,361	,083	,709
V 1.2	43	1	5	3,70	1,166	1,359	-1,073	,361	,627	,709
V 1.3	43	1	5	3,21	1,245	1,550	-,650	,361	-,943	,709
V 1.4	43	1	5	3,19	1,314	1,726	-,294	,361	-1,063	,709
V 1.5	43	1	5	2,51	1,183	1,399	,514	,361	-,516	,709
Valid N (listwise)	43									

The means for variable 1 vary from 2,51 which is the lowest to 3.70, the standard deviation for all the questions in the variable is around 1 indicating that the data is clustered around the mean. The standard deviation for the data is approximately 1 which is low indicating normality as it is within the accepted norms (Mishra et. al, 2019). The skewness of the data varies between -1 and 1 and this indicates that the data is somewhat normal. In general the skewness and kurtosis are relatively close to zero and therefore the data can be considered to have normality.

Variable 2: Ability to monitor

TABLE 6: Descriptive statistics for Variable 2

Descriptive Statistics										
	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V 2.1	43	1	5	3,56	1,181	1,395	-,782	,361	,011	,709
V 2.2	43	1	5	3,60	1,116	1,245	-,653	,361	-,258	,709
V 2.3	43	1	5	3,07	1,370	1,876	-,190	,361	-1,181	,709
V 2.4	43	1	5	4,02	,886	,785	-1,123	,361	2,111	,709
V 2.5	43	1	5	3,51	1,279	1,637	-,707	,361	-,455	,709
V 2.6	43	1	5	3,28	1,161	1,349	-,388	,361	-,502	,709
V 2.7	43	1	5	3,49	1,142	1,303	-,574	,361	-,267	,709
V 2.8	43	1	5	2,77	1,324	1,754	-,001	,361	-1,371	,709
Valid N (listwise)	43									

The means for the data vary from 2.77 as the lowest to 4.02 which is the highest indicating different outcomes in terms of the questions posed. The standard deviation approximately one, indicating that most of the data is clustered around the mean indicating a normal distribution. The skewness of the data is between -1 and +1 indicating normality of distribution. The kurtosis is generally between -1 and +1 with one value outside of those values and less than 2 indicating that the data is somewhat normal however variable 2.4 has a kurtosis greater than 2 indicating that the data is more peaked than normal. This method is less reliable for N<300 and for sample size of N<50, the z-test can be used to address this problem and the value must be +-1.96: Skewness value/standard error=0.707/0.361=1.96 (Mishra et. al., 2019). For this variable question 1, 2,4 and 5 are areas of strength as the means vary between 3.51 and 4.02. These questions are about the safety performance indicators that are used by the organisation being adequate and being reviewed

regularly. The third one is about the use of lagging indicators to monitor safety performance. Questions 3,6, 7 and 8 have means which are below 3.5 indicating an area of development. These questions relate to the use of leading indicators to monitor safety performance and the validity of these leading indicators. The last two have to do with the appropriateness of the safety performance measures and the adequacy of the period between measurement and analysis.

Variable 3: Ability to learn

The means for the data vary from 2.47 the lowest to 4.07 which is the highest indicating different outcomes in terms of the questions posed. The standard deviation is approximately one, indicating that most of the data is clustered around the mean. The skewness of the data is mostly between -1 and +1 indicating that there is some form of normality in the data. The kurtosis is mostly negative and less than -2 indicating that the data is flatter than normal however variable 2.4 has a kurtosis greater than -2 indicating that the data is somewhat normal. Question 1 of this variable is the only one showing agreement (somewhat agree) and has to do with the organisation having well-defined processes on what should be reported by employees. The areas of improvement have to do with these reports filed not being investigated sufficiently and the employees feel that they do not receive good feedback on reports that are filed. Employees feel that they are not encouraged and not given time to file reports. The other identified area of improvement is that the organisation does not learn from things that go right, from things that go wrong and it does not enable employees to learn from each other.

TABLE 7: Descriptive statistics for Variable 3

Descriptive Statistics										
	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V 3.1	43	1	5	4,07	1,203	1,447	-1,430	,361	1,219	,709
V 3.2	43	1	5	3,21	1,372	1,884	-,223	,361	-1,219	,709
V 3.3	43	1	5	3,05	1,308	1,712	-,090	,361	-1,197	,709
V 3.4	43	1	5	3,16	1,379	1,901	-,192	,361	-1,332	,709
V 3.5	43	1	5	3,21	1,125	1,265	-,224	,361	-,691	,709
V 3.6	43	1	5	3,26	1,347	1,814	-,309	,361	-1,058	,709
V 3.7	43	1	5	2,47	1,369	1,874	,427	,361	-1,269	,709
Valid N (listwise)	43									

Variable 4: Ability to anticipate

The means for the data vary from 2.14 as the lowest to 3.16 which is the highest indicating different outcomes in terms of the questions posed but mostly showing that this would be area of development for the organisation as most responses are 3 and below (3 neutral and below 3=disagree). The standard deviation approximately one, indicating that most of the data is clustered around the mean indicating normal distribution. The skewness of the data is mostly between -1 and +1 which is considered excellent, indicative of normality in the data. The kurtosis is mostly negative but between -1 and +1 indicating that the data is somewhat normal.

TABLE 8: Descriptive statistics for Variable 4

Descriptive Statistics										
	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V 4.1	43	1	5	2,79	1,226	1,503	-,067	,361	-1,230	,709
V 4.2	43	1	5	2,60	1,198	1,435	,307	,361	-,735	,709
V 4.3	43	1	5	3,00	1,134	1,286	-,103	,361	-,535	,709
V 4.4	43	1	5	2,91	1,065	1,134	-,303	,361	-,320	,709
V 4.5	43	1	5	3,16	1,413	1,997	-,302	,361	-1,257	,709
V 4.6	43	1	5	2,84	1,271	1,616	,101	,361	-1,169	,709
V 4.7	43	1	5	2,70	1,282	1,645	,176	,361	-1,229	,709
V 4.8	43	1	5	3,14	1,226	1,504	-,360	,361	-,756	,709
V 4.9	43	1	5	2,14	1,207	1,456	1,084	,361	,351	,709
Valid N (listwise)	43									

The means for this whole study area are below 3.5 and indicate that improvements are required for this whole variable. The variable is about the organisation having the ability to forecast, the skills and competencies to enable this forecasting, the frequency of forecasting and the adequacy of the scope and depth of the forecast. The area also highlights whether employees are free to raise potential safety issues, whether these forecasts are communicated and if it has ways to address the issues raised during forecasts. It highlights whether the organisation has the required processes to maintain staff skills and competencies and whether these employees are consulted when mitigations are formulated.

Reliability and validity

A reliability test was conducted to measure inter-item consistency and the results are indicated in the table below:. The Cronbach alpha values range from 0.652 to 0.899 indicating that the inter-item consistency and stability is acceptable as all the values are above 0.6 and confirms the construct reliability. This also confirms that the items in the set for the variable data used, are positively correlated to a certain extent.

TABLE 9: Reliability test results

Variable	Number of items	Cronbach's alpha
Ability to respond	5	0.652
Ability to monitor	8	0.758
Ability to learn	7	0.840
Ability to anticipate	9	0.899

The inter-item correlation results vary because some questions with values between 0.20 and 0.50 indicates that the items are assessing the same content and there are those with values below 0.20 indicating no correlation. Variable 2.1 and V2.4 indicate a negative correlation.

TABLE 10: Inter-item correlation matrix for Variable 2-Ability to monitor

Inter-Item Correlation Matrix							
	V 2.1	V 2.2	V 2.3	V 2.4	V 2.5	V 2.6	V 2.7
V 2.1	1,000	,316	,373	-,149	,547	,196	,393
V 2.2	,316	1,000	,564	,299	,412	,124	,436
V 2.3	,373	,564	1,000	,214	,577	,287	,297
V 2.4	-,149	,299	,214	1,000	,199	,179	,106
V 2.5	,547	,412	,577	,199	1,000	,334	,363
V 2.6	,196	,124	,287	,179	,334	1,000	,416
V 2.7	,393	,436	,297	,106	,363	,416	1,000

Factor analysis

The Kaiser Meyer-Olkin measure of sampling adequacy is 0.791 and therefore greater than 0.60 therefore we can continue with factor analysis. Bartlett's test of

sphericity is significant (p<0.05) at 0.001 and therefore this indicates that exploratory factor analysis can be conducted. The Chi-square is significant and tests whether the covariance matrix derived from the model represents the population covariance (Alavi et. al., 2020), the chi-square significance means that we can reject the null hypothesis.

TABLE 11: KMO and Bartlet's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,619
Bartlett's Test of Sphericity	Approx. Chi-Square	824,492
	df	406
	Sig.	<.001

The results below show that the factors with Eigenvalues greater than 1, and these are the factors that explain the total variability in the data, these are factors 1 to 7 as shown on the scree plot below. The remaining factors account for a very small portion and are likely unimportant.

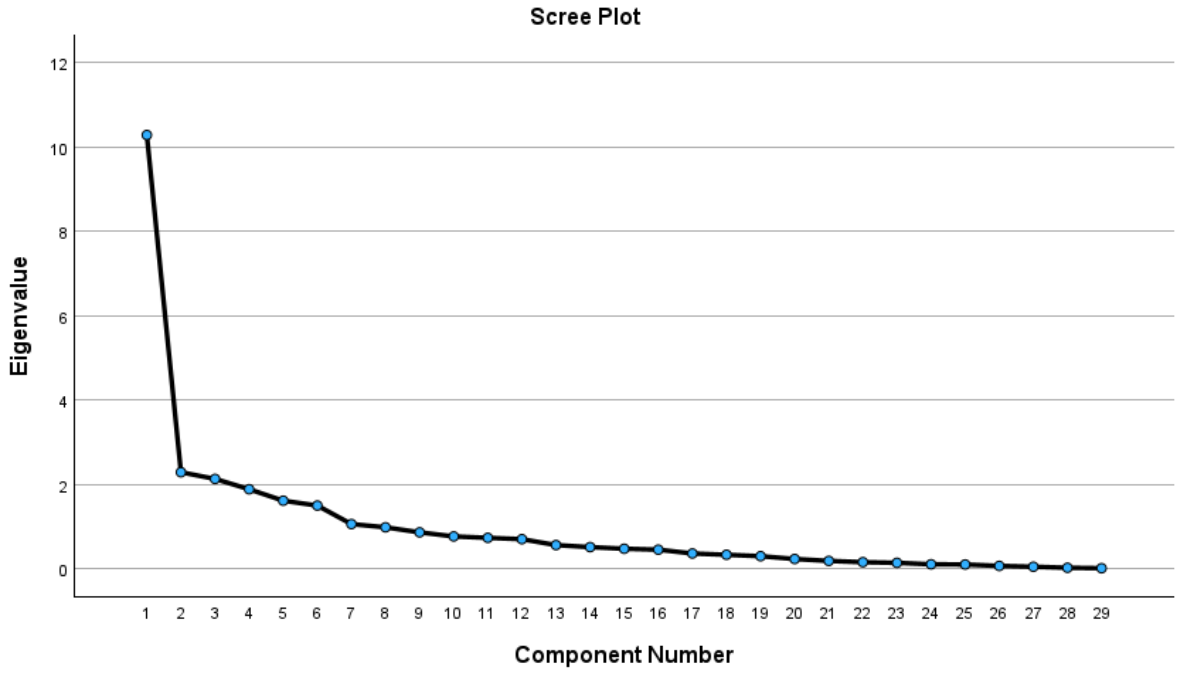


FIGURE 9: Scree Plot

Discussion and recommendations

The results of the study have helped to highlight some areas of strength for performance and also areas of development. The first variable (ability to respond) which is the ability to respond has areas of improvement which require further development to ensure that employees are equipped and able to respond to disturbances through implementing the below recommendations:

- Finding ways of enabling workers to discuss alternative ways of working when faced with unexpected events,
- Ensuring access to a variety of resources for unexpected events, and
- Ensuring that mechanisms are in place for sharing information timeously to ensure that it gets to the right people at the right time as this is critical to enable the ability to respond. There's a quote often used in these circles "an informed worker is a happy worker".

The identified areas of strength for variable two (ability to monitor) relate to the use of lagging indicators, the organisation having safety performance indicators that are relevant to this particular organisation and that these are regularly reviewed. The employees confirm that this is firmly in place and visible. The areas of development have to do with the use of leading indicators to monitor safety performance and the validity of these leading indicators. The period covered by lagging indicators has also been cited as an area of improvement and it would be interesting to know what would be considered adequate. The inadequacy of the safety performance measurement and type has been highlighted and also that the time between measurement and analysis was not adequate.

To answer the questions posed by variable three (ability to learn), the employees have confirmed that the organisation has clearly defined what should be reported however several areas need improvement and the recommendation are the following:

- That reported occurrences should be investigated sufficiently,
- There is a need for good feedback and responses to be given to reporters of occurrences to complete the communication feedback loop,
- Employees must be encouraged and given time to report,

- The organisation must learn from things that go wrong as well as those that go right, and
- The organisation must enable employees to meet to learn from each other.

The ability to anticipate is indicated as an area of improvement in its entirety as shown by the results above that the forecasting capability requires some work. The areas of improvement need to address the capability to forecast future potential safety weaknesses, ensuring that the forecasters are adequately skilled for the role and that the frequency of these forecasts is adequate. The organisation needs to enable workers to raise issues which they deem as potential safety weaknesses and the said employees must be consulted when mitigations are developed. The organisation should ensure that there are adequate processes to develop and maintain staff skills.

The research objective has been answered comprehensively by the study which has also helped to highlight areas of improvement.

In terms of whether the research questions have been answered adequately, the response would be a yes because the results have clearly shown that as much as there are elements of resilient performance visible, there is still a lot of work to be done to ensure that resilient performance is implemented and fully embedded in the organisation. The recommendations will be presented to the organisation for consideration, and if there is agreement a plan can then be drawn up of how the areas of improvement can be implemented. This can then be followed up by a similar assessment in a few years to measure whether progress has been made.

Conclusion

Safety-critical organisations are faced with a multitude of risks and need all the help to manage these, the RAG is one such tool that can be used as in this study it has been shown to give good insights which can help organisations. Resilience is an area that requires further enhancement because there is more to be learnt from things going right than from incidents that often have negative connotations. Organisational learning and timeous sharing of lessons learnt is imperative in safety-

critical organisations and the insights gained from this study can help facilitate this in the areas already highlighted.

The study's results have identified the areas of development, which can assist safety-critical organisations to develop focussed and specific interventions to address these. The environment within which this organisation exists is very dynamic and such a measure would require to be done periodically to ensure continuous improvement and for the organisation to stay ahead of the curve.

This kind of assessment or measure would be a good place to start in establishing a baseline from which to make further improvements.

The area that would be proposed for further study would be to explore the continued development of the RAG to further refine areas of focus and maybe to dig a bit deeper in some of the areas, in terms of the specific questions asked, depending on organisational challenges; to ensure that organisations do not fall into the trap of practical drift to enable organisations to respond adequately to identified challenges.

Additionally, further studies can explore whether the RAG in its current form can be used to conduct an assessment in areas of the organisation other than operations or would a different RAG need to be developed to assess other areas of the organisation that also contribute to safety and safety performance, albeit indirectly. This is because safety is a collective effort and any improvements, no matter how small, in all areas of the organisation can have a positive impact on the overall safety and safety performance.

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APPENDIX

Component matrix

Component Matrix[a]							
	Component						
	1	2	3	4	5	6	7
V 4.1	,804						
V 4.4	,764			-,381			
V 4.7	,717						
V 4.2	,714						
V 4.6	,695				-,440		
V 4.3	,690			-,510			
V 3.6	,688				,356		
V 3.1	,678						-,318
V 4.5	,672	,331				,310	
V 2.2	,667		-,360				
V 4.8	,637	-,367					
V 3.7	,637		,349				
V 2.7	,615					-,574	
V 2.3	,608	,431		,301			

V 3.4	,596						
V 1.4	,568				-,540	-,318	
V 1.2	,562						,485
V 4.9	,557	-,443					
V 1.5	,518	,340					-,455
V 2.5	,516	,386			,448		
V 1.1	,477		,464				,343
V 3.5	,461		-,433				
V 3.3	,555	-,612					
V 3.2	,585	-,606					
V 1.3			,659			,453	
V 2.4			-,554	,447			
V 2.1	,427		,467		,466		
V 2.6	,371		,347	,548			
V 2.8	,579					,601	

Extraction Method: Principal Component Analysis.