Improving the quality of quantifiable environmental information on gold mines

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Abstract

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As part of their corporate responsibility, gold mines report their environmental impact in a sustainability report. The most commonly used sustainability-reporting framework is the Global Reporting Initiative (GRI). The GRI framework recommends the use of external assurance to increase the credibility of the sustainability report.

However, this recommendation does not address all the issues concerning credibility, with the report users still questioning the quality of information found in these reports. Furthermore, current assurance practices and outcomes are not well defined. For example, audit sampling is not completely accurate.

The challenges within the auditing process are assumed to form part of normal sampling distribution and the possibility of bias sample selection exists. Similarly, researchers argue that the assurance statement is a “rational myth”. This is possible since the assurance statement may be used as a tool to reduce information asymmetries and enhance reliability. The after-effect of this is poor data quality is increased cost and poor decision making.

A need exists to improve the credibility of reported information by developing a verification procedure. The credibility of information is improved by improving the accuracy of reported data. To address this need, this study combines current audit practices with the ISO Plan-Do-Check-Act (PDCA) cycle.

The methodology used has been adapted from the continuous improvement method (PDCA cycle). This method will look at the reporting process, information collection process, verification procedure, documentation and error management. The reporting process shortlists the most important Key Performance Indicators (KPI) and identifies all documentation within the various reporting chains.

The information collection process uses a web-based data management platform and an information collection timeline. Data is verified with a logic procedure that incorporates the two main forms of verification namely, proof verification and double-entry verification. The final step is to document both the KPI’s and the identified errors.

The methodology described above was implemented on a gold mine. After implementation, the methodology was successfully verified through literature and the assurance statement. The objectives were validated by reducing the quantifiable impact of errors, in some instances, tenfold. The margin of error was reduced from 22.2 % to 4.9%.

This study avoided the incorrect allocation of R 138 million worth of resources. Thus, the study was successful in improving the quality of environmental reported data and offered further insights into the benefits of assurance practices. These include improved budgeting for environmental resources and critical anomaly detection within the organisation.

Acknowledgements

First and foremost I would like to thank Allah by quoting the English transliteration of the opening for the Quran:

In the name of Allah, the entirely merciful, the especially merciful.

All praise is due to Allah, lord of the worlds.

The entirely merciful, the especially merciful,

Sovereign of the day of recompense.

It is you who we worship and you who we ask for help.

Guide us to the straight path.

The path of those upon who you have bestowed favour, not of those who have evoked your anger or of those who are astray.

To my parents Mohammed and Zelda Ebrahim. I will never find the words to express my gratitude and love I have for you. My sister and brother your guidance in this life has continuously given me light and been a source of my strength.

My cousin Reyana Nacerodien, Kate Mathews and Elsie Fourie; thanks for being my proof-readers. Reyana, thanks for always being willing to help me with my academics. May Allah please bless you in this and the next life.

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Abbreviations

ANN	Artificial Neural Networks
DMAIC	Define, measure, analyse, improve, control
EnMS	Energy management system
EHSQ	Environmental, Health, Safety and Quality
FY	Fiscal year
GIS	Geographical Information System
GHG	Greenhouse gas
GRI	Global reporting initiative
KPI	Key performance indicator
MAR	Mandatory audit firm rotation
MICAVS	Mobile Information Collection and Verification System
OP	Operation
PDCA	Plan, do, check, act
PNG	Papua New Guinea
PV	Partially verified
RA	Reading aloud
RSA	Republic of South Africa
SDV	Source data verification
SERA	Social and environmental reporting assurance
TBL	Triple bottom line
TOC	Theory of constraints
V	Verified

Nomenclature

List of symbols

Symbols	Description	Units
E	Electrical energy	(kWh)
$\dot{m}$	Mass flow rate	(kg/s)
V	Volume	(m^3)
x	Reported data set	(t, l, m^3, kWh)
y	Amount of reported field	(no unit)
z	Percentage reduction	(no unit)
KPI	Key performance indicator	(t, l, m^3, kWh)
PE	Percentage error	(no unit)
ER	Error rate	(no unit)

1 Introduction

1.1 Preamble

Due to the environmental impact of their activities, gold mines are required to report on them. Transparency in this regard promotes scrutiny from various stakeholders while also opening the door for positive change to occur within the organisation.

Investors and stakeholders use the information in these reports to inspect whether environmental liabilities have been addressed or transgressed, during the reporting period. The primary source for this communication is the organisation‘s sustainability report. The most widely used sustainability reporting framework is the Global Reporting Initiative (GRI) [1].

The GRI reporting framework recommends the use of external assurance for sustainability reports [1]. The motive for external assurance is to improve the credibility of reporting. While assurance practices have multiple benefits for an organisation, the benefit being highlighted in this study is the strengthening of the reporting structure.

The focus on this benefit is due to report publishers and report users questioning the quality of information in reports, and the actual present practices of assurance being considered a rational myth [2], [3]. Thus, a need arises to develop a verification procedure that improves the quality of information.

1.2 Background on corporate sustainability reporting

1.2.1 Introduction to gold mining responsibility

Environmental concerns, and an understanding of the connection between the business world and the natural environment, have become an integral part of business decision-making. This has resulted in more attention being given to this aspect of reporting, by a wider range of stakeholders. In this regard, the management strategy has been adapted to communicate how the business is responding to environmental changes. This is done by communicating the sustainable performance of the company, which is a significant way to acknowledge the impact on natural systems.

Sustainability is defined as the ability of a society to meet the needs of the present without compromising the ability of future generations to meet their own needs. Beyond operational sustainability, organisations are forced to address environmental sustainability, given the focus on organisations as active role players in the environment. [4], [5], [6]

The United States Environmental Protection Agency recognised in 1987 that “… the release of mining waste can result in profound, generally irreversible destruction of the ecosystem" [7]. Gold mining practices that cause these adverse effects include effluent discharge, run-off from slimes dams, run-off from rock dumps, radioactivity and cyanide processing [7]. The overall environmental impact of a specific gold mining company will be the focal point of this report. Companies in developing countries, like South Africa, reduce costs and harness capital by often disregarding regulations and not exhausting expenditure on costly environmental considerations [8].

The King IV Report addresses issues of corporate governance. King IV states that organisations should take responsibility for the environmental consequences of their activities and outputs, as those affect society as a whole, due to the organisation being an integral part of society [9]. A claim can be made that organisations such as gold mining companies, have a responsibility to make positive changes to the world's environmental, social and economic issues [4]. Through the communication of sustainability performance, many positive changes can be recognised. This report sets out to offer a benchmark for such sustainability performance in South Africa.

1.2.2 Corporate responsibility

The historical reasoning behind corporate environmental reporting, differs from company to company. The main drivers for organisations generally include their duty to the environment, public relations, gaining a competitive advantage, shareholder pressure and legal compliance. [10]

Investors use environmental reporting to inspect whether the businesses' environmental liabilities have been addressed. If not correctly managed, this could lead to heavy losses in dividends and low returns on their investments. Both non-profit organisations and pressure groups, use the contents within the reports to highlight ill-intentions and encourage a greater environmental corporate responsibility. [10]

There is however, also resistance to environmental reporting, due to the insight that can be gained by other parties [10]. For example, environmental information provides an insight into what technological advancements are used, consequently sharing what may be a mechanism for competitive advantage.

In any reporting, all aspects of the organisation should be considered before incurring costs to generate the information and produce the report. In spite of the cost, the produced body of work should be viewed as an asset to the organisation due to its many benefits. Some of the benefits of corporate environmental reporting include: [10]

- Improved organisational reputation;
- Enhanced transparency, accountability and responsible governance;
- Enhancement between management and stakeholder communication;

- Contribution to the wider education of the public;
- Improved risk management;
- Identification of potential opportunities for the reduction of resources used and operating cost;
- Improved customer confidence and exposure; and
- Improved competitive advantage.

These corporate benefits lead to a sustainable organisation. The concept of sustainable development of an organisation, is identified through corporate responsibility [11]. Therefore, an organisation can communicate its corporate responsibility through a sustainability report.

1.2.3 Sustainability reporting

Sustainable reporting enables an organisation to recognise its impact on natural systems [4]. This specific report documents the impact over a particular period. The content of the report includes information regarding the organisation’s interactions with its social and ecological environments [1]. Furthermore, the management of environmental data has the ability to govern change towards a more sustainable global economy [2].

The most critical aspects of sustainability reporting are accountability, and transparency of the activities of an organisation [1]. The report must provide the specific efforts being addressed in a particular field of responsibility; how these overall efforts influence the sustainable development or the organisation; and how the negative effects are planned to be resolved.

A similarity can be drawn between a sustainability report and traditional financial statements. Traditional financial reporting involves financial unit measurements, whereas sustainability reporting generally focuses on non-financial measurements as performance indicators. These indicators take into account the environment, as well as the social and economic dimensions of sustainability. [1]

The GRI is the most widely used sustainability reporting framework [1]. It has pioneered the world’s sustainability reporting and is continuously being improved. The framework sets out standards that organisations can use to measure the three key areas in sustainability reporting namely, people, planet and profit [1].

These three key areas of focus are based on the Triple bottom line (TBL) concept. This concept, proposed by John Elkington, is used to broaden the focus on the financial bottom line, by businesses, to include social and environmental success and wellbeing. The TBL’s consideration of business outcomes in the areas of planet, people and profit, enhances the communication of the company’s performance to stakeholders, by establishing principles by which an organisation should operate to draw focus on the effects of their actions. [12]

Companies that decide to follow the reporting principles deduced from the GRI guidelines, have to address significant decisions in their reporting, such as the scope and voluntary actions done by the company and also their future plans as a business [1].

The GRI categorises the environmental indicators into 12 indicator groups: [13]

(1) Materials

(2) Energy

(3) Water

(4) Biodiversity

(5) Emissions

(6) Effluents and Waste

(7) Products and Services

(8) Compliance

(9) Transport

(10) Supplier Environmental Assessment

(11) Environmental Grievance Mechanisms

(12) The inal Overall Category.

A company selects the appropriate indicators based on what they would like to report. Due to the significant number of GRI reports being produced, and most of those reports not being checked by either a third party or GRI, there are some concerns regarding the credibility of these reports. To address these concerns, organisations seek assurance for the reported values. Additionally the GRI recommends the use of external assurance for sustainability reports. [1], [4]

1.3 Assurance practices

The term assurance refers to the verification of non-financial information. The crucial elements of assurance are independence; an auditable subject; examining documentation; and gathering evidence. [14]

The outcome of assurance is an opinion published within an assurance report or statement. The opinion expresses the truth about the disclosed values, thereby increasing the credibility of the report. [14]

The assurance opinion provided by an assurance report is directly linked to the level of assurance. This defines the level of work behind the assurance opinion. Assurors and auditors cannot be entirely sure about aspects and details within the report. This is due to the constraints of time, effort, cost, benefit and the nature of the subject matter. Assurors estimate the degree of risk behind each reported value. This is based on the quality of the system as well as the evidence and scope of the work. The difference in degrees of risk is expressed in two levels of assurance: reasonable and limited assurance. [15]

By its nature, limited assurance reflects a narrower scope of work than reasonable assurance. The assurance level concept is valuable, and already used by most assuror providers. [15]

Researchers have commented on the assurance statement's validity, characterising its present practices as a "rational myth", disputing that it demonstrates only artificial legitimacy. This artificial legitimacy stems from the low transparency and overall quality of the assurance process. Yet, the quality of the process should be communicated via the level of assurance. [3]

The reason for this finding is the vulnerability of these practices, given their proposed premise and control applied. These typically stem from organisations' upper management and assurance providers. The motive behind this is to gain commercial reputation in the industry. [16]

Therefore, the issue with present auditing practices is not the final assured values, but rather the communication of the process itself. This is due to the assurance statement being compiled in a format that possibly alters the perception of the credibility.

This can be observed with the level of assurance where the volume and depth of information being audited, is not communicated in the level of assurance. An example of this is when little volume and depth are covered during an audit, yet no findings occurred, and a reasonable level of assurance was issued. Thus, the findings of the audit can be misleading to any reader of the assurance statement.

The process of verifying reported information benefits the company both internally and externally. The internal benefit is demonstrated by an improvement in reporting structure, which leads to reduced risk and added value in the organisation, resulting in better engagement on higher levels within the organisation. The external benefit relates to the perception of the organisation, which increases trust and credibility. This promotes mutual communication and understanding to stakeholders. [2]

In Table 1 below, each of the above-mentioned internal and external benefits is listed. The benefit is further described with a publication of its benefit.

Table 1: Publication of benefits with Assurance (adapted from [2]**)**

Benefits	Publication of benefit
Increased recognition, trust and credibility	Assured reports bring about a greater sense of importance and confidence in the reported figures.
Reduced risk and increased value	Less risk of issuing a restatement because the disclosed figures have been verified. This additionally increases the value of information.
Improved board and Chief executive officer level engagement	More credible and trustworthy data is likely to be used for internal decision-making.
Strengthened internal reporting and management systems	Reporting systems and their influence play a crucial role in managing the impact and sustainable performance of an organisation. Therefore, outcomes that are more viable can be reached with assurances.
Improved stakeholder communication	Some organisations make use of reporting processes as an ongoing dialogue with their stakeholders, thus ensuring correct and stable communication.

In conclusion, the GRI recommends external assurance to improve the credibility and quality of the report. The published statement made by assurance providers has been criticised for not increasing the credibility. Yet, there are multiple benefits in the assurance process. The specific benefit that increases the credibility and quality of the report, is the strengthening of internal reporting structures within the organisation.

1.4 Quality reporting

The quality of the information being reported continues to be a significant issue for both reporters and report users [2]. This issue has been addressed in the GRI reporting framework, under the reporting principles [13].

The principles are broken up into two groups namely, defining report content and quality. The principle for defining report content, describes the process for identifying what content the report should cover when considering the organisation's activities, effects, expectations and interest of its stakeholders. The principle for defining report quality, ensures the quality of information in the sustainability report and its presentation. [13]

With assurance statements being questioned, the report quality principles are being challenged. The principles for report quality are given in the table below.

Table 2: GRI principles for reporting (adapted from [13])

Principles	Description
Balance	Both positive and negative aspects of organisational performance must be given in the report.
Comparability	The reporting, selection and compiling must be done consistently. The report must also be presented in a way that performance changes can be identified easily.
Accuracy	The information in the report must be accurate enough for stakeholders to determine the performance of the organisation.
Timeliness	To ensure there is enough time for stakeholders to make decisions, the report must be periodically published.
Clarity	The disclosed information should be easily available and clearly communicated to ensure the stakeholders understand the company and its outcomes.
Reliability	All processes involved in preparing the report should be well planned and able to undergo an examination at any time. Additionally, these processes must establish quality and materiality of disclosed information.

Based on the table above, it can be inferred that the specific principle being challenged is the principle of accuracy. This is because the assurance statement may be used as a tool to reduce information asymmetries, and enhance reliability [3]. The aftereffect of this is poor data quality which could result in increased costs and poor decision-making [17].

Thus, the data itself must represent the true state of the organisation without the need for a statement of validity. Yet an argument can be made that the true value cannot always be measured [18]. An example of this is made in audit sampling, where more samples are taken, the closer the measured value represents the true state.

In order to obtain a sufficiently accurate value, accuracy itself must be defined. Accuracy refers to the deviation of a measurement from its true numerical value [19].

These deviations are referred to as errors. There are generally two categories for errors: systematic and random errors. Systematic errors occur constantly in one direction from the true value. Random errors are a result of human, or accidental actions. [20] Systematic errors occur due to defects in the instruments or improper measuring techniques. Random errors are broken up into accidental and human error. Accidental errors occur due to changes in the experimental conditions, often beyond the control of the experimenter. Human error involves miscalculation, incorrect reading of instruments and personal bias with assumptions which affect results. [20]

By eliminating both systematic and human errors, a higher level of accuracy can be achieved. This fulfils the principle of accuracy and leads to beneficial outcomes for all parties.

1.5 Need for the study

From the research investigated in this study, it was seen that gold mines in South Africa must be held accountable for their actions that result in environmental damage [21]. To address this accountability, mines issue a sustainability report. The most critical aspect of sustainability reporting is transparent information, allowing for a company to be held accountable for poor environmental performance [1].

Accountability and transparency are highlighted by the quality of information reported. Reporters and report users, question the quality of the information being reported [2]. Additionally, assurance statements are being critiqued by researchers as a “rational myth” [3]. Therefore, the quality of information and representation of credibility, is being questioned.

If the quality of information is questioned, the quality reporting principles of the GRI framework are not adhered to. The specific principle being negatively affected is accuracy. Accuracy can be improved by the elimination or reduction of errors. The process of external assurance can reduce or eliminate errors by strengthening internal reporting systems [2]. Yet, within companies, employees are questioning whether external assurance is necessary [22].

Thus, the accuracy of information must be determined, and an assurance procedure must be developed that can improve on accuracy.

1.6 Objectives of the study

The primary objective of this study is to develop and implement a verification procedure that improves the accuracy of reported information. The success of this study will be determined by the degree of which the objectives are met, empirically and from literature.

Detailed descriptions of the literature objectives are given below:

1. Investigate existing methods that determine the accuracy of reported information.
2. Investigate existing processes that improve internal systems within companies.
3. Investigate and recommended practices for error management.

Detailed descriptions of the empirical objectives are given below:

1. Determine the accuracy of environmental reported data.
2. Develop a process that improves the accuracy of environmental reported data.
3. Implement and determine the impact of the developed methodology.

Each objective must be met to ensure the study is effective.

1.7 Overview of document

Chapter 1 provides the background needed to define the need and objectives of the study.

Chapter 2 focuses on evaluating relevant literature. Data quality was explored in terms of its representation, verification and measurement. Present practices in the GRI framework, auditing and error management are discussed. After multiple continuous improvement methods were analysed, a comparison was made to find the best-suited method for the core structure of the methodology. The PDCA cycle was identified as the most suited method for the continuous improvement of the reporting structure.

Chapter 3 made use of all the research done in Chapter 2 to develop a verification methodology. The methodology was adapted from the PDCA cycle. The four steps of the adapted methodology are: the reporting process investigation, information collection system development, verification procedure, and documentation and error management. These steps were used to identify, prevent and continuously reduce errors.

Chapter 4 implemented the methodology developed in Chapter 3 on a gold mine. The results of the methodology being implemented were discussed and further analysed.

Chapter 5 presents a summary of the study. The results and insights gained are discussed. The limitations were defined and recommendations for future research are made.

1.8 Conclusion

Improving the accuracy of environmental reported data is the main objective of the study. The motive is to satisfy stakeholders' interests, so they recognise positive efforts towards the environment. The GRI sustainability-reporting framework will be used to report the organisational information.

The information being reported and the method of providing credibility through a statement, is being questioned. Due to this scrutiny, the principle of accuracy founded by the GRI is not being adhered to.

Further investigation demonstrated that the accuracy of the reported information can be improved. This is as a result of multiple forms of errors occurring in the reporting process. Eliminating or reducing these errors results in a higher level of accuracy, which satisfies the principle of accuracy and increased credibility of disclosed information.

2 Literature study

2.1 Introduction

Chapter 1 defines the primary objective of the study, which is to develop a verification procedure that improves the accuracy of information being reported. In order to do so, certain topics within literature must be researched.

The specific topics needed to be researched are the measurement of data quality; improvement processes; and error management. The measurement of data quality can be explored by investigating the measurement of errors. The improvement processes being researched must contain aspects of verification within them. Error management must therefore be considered on the basis that it can continually be implemented.

The measurement of data quality consists of three parts:

1. the handling and representation of data, which is a critical aspect in terms of measurement;
2. the identification of an error through verification methods; and
3. the actual measurement of the discrepancy itself.

The improvement process highlighted in literature is broken up into two fields. The present field used to verify organisational practices is auditing. Auditing simplification and evidence must be further investigated. Continuous improvement methods, the second field, contain aspects of verification within them.

Error management contains two aspects that need to be explored, the first being preventative measures, that can be taken to prevent errors from occurring, and the second being corrective measures, that can be taken after the error has occurred.

2.2 Data quality

The significance behind data quality originates from poor data being used to generate business intelligence. This leads to 81% of businesses encountering issues that affect their bottom line. The bottom line is influenced by inaccurate data, resulting in an average of 17% of revenue being wasted. All the root causes of poor data in businesses are given in Figure 1 below. [23]

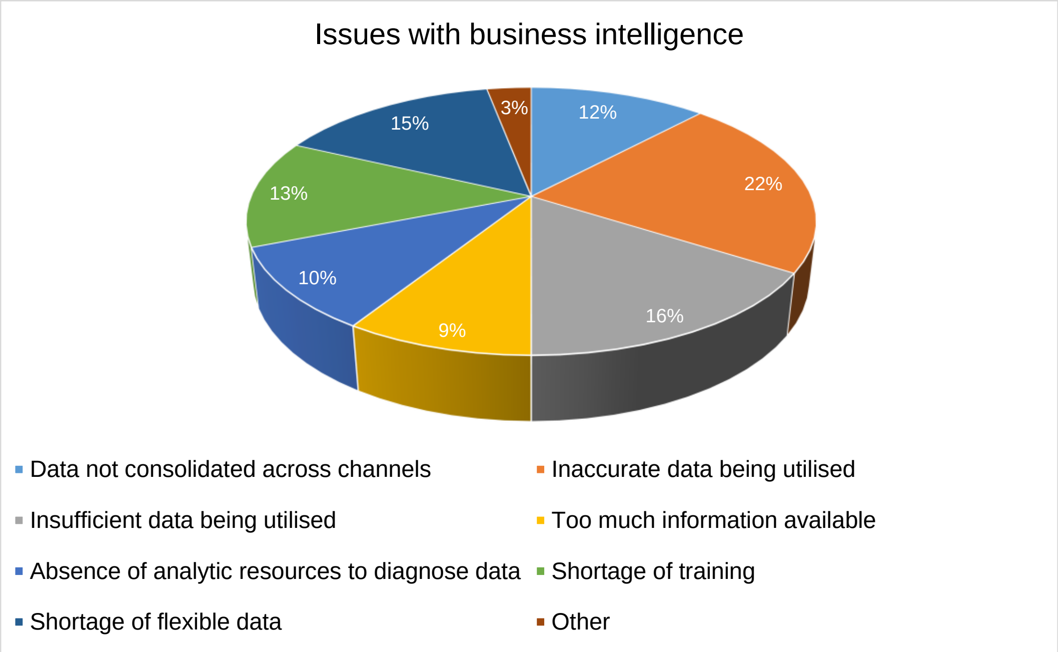

Figure 1: Issues with business intelligence (adapted from [23])

As demonstrated in Figure 1, the biggest contributor to these issues is inaccurate data. These inaccuracies can lead to critical problems for organisations.

Therefore, the key topics needing focus to address data quality are broken up into three sequential topics. The first is the actual representation of data, followed by the identification of errors and the quantifiable impact of the error.

2.2.1 Data handling

Data is at the heart of the system, beginning at the input and maintained through the storage of the information. Data alone has no meaning without interpretation. The storage of this data and its interpretation is vital. This is evident once a powerful and efficient storage mechanism is used to physically represent such data. [24]

The storage mechanism in question may organise information in multiple ways. A mathematical or logical model that specifies the organisation of data, is referred to as a data structure. Efficiency is a requirement for a data model. [24]

Data models are chosen based on two aspects. The first aspect dictates that the structure must be rich enough to mirror the actual relationships of data in the real world. The second is the simplicity and effectiveness of the processing of this information. [24]

There are two main categories for data structures: the primitive data structure and the non-primitive data structure. One of the best non-primitive data structures is the tree form. This data structure represents a hierarchical relationship between data elements. The tree data structure is demonstrated in Figure 2 below. [25]

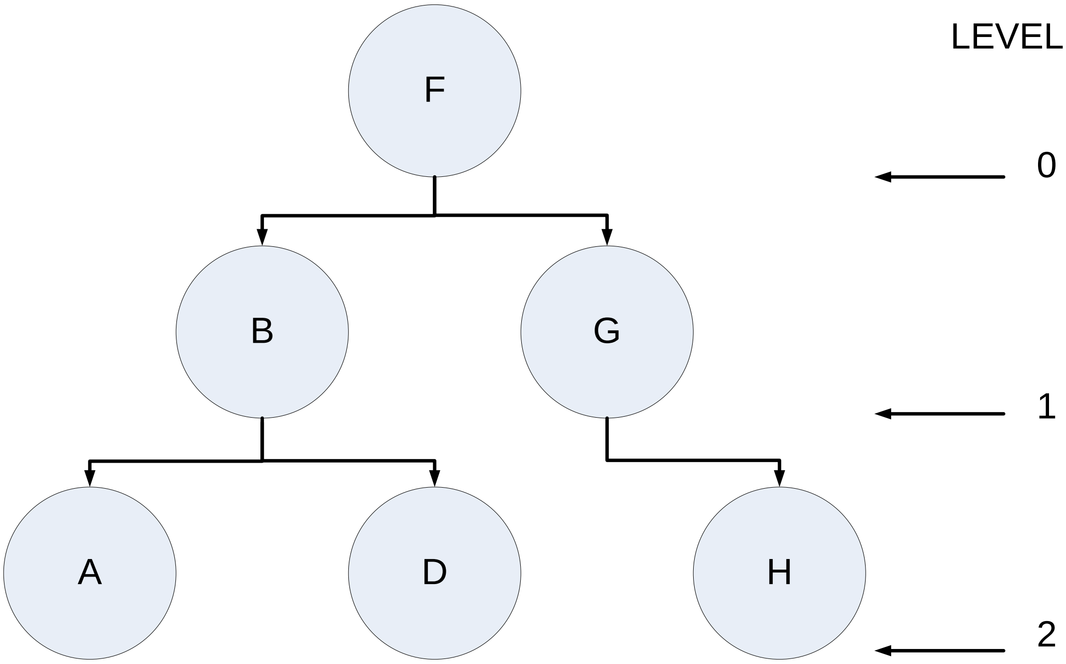

Figure 2: Standard tree data structure (adapted from [25]**)**

A tree data structure is categorised by the vertices leaving or exiting. The total number of exiting vertices are referred to as outdegrees. The total number of inflowing vertices are referred to as indegrees. The categories for each type of node are given in Table 3 below based on these defining characteristics. [25]

Table 3: Categories of tree data structure nodes (adapted from [25]**)**

Type of node	Description	Graphical example
Root node	The node that has zero indegrees.	F
Leaf node	The node that has zero outdegrees.	A, D, H
Branch node	All other nodes which do not fall into root and leaf node category.	B, G

There are additional relationship features that must be considered in the tree data structure. The predecessor of a node is known as a parent, while the successor of a parent node is known as a child. Siblings are nodes that share the same parents.

2.2.2 Verification

In order to recognise these issues, an error identification technique must be used. Error identification is obtained through error checking or verification methods.

Error checking in the computational fluids field is defined as an assessment of the model's accuracy through a comparison of known sources [26]. The assessment of accuracy is possible through many different methods depending on the model being verified.

In the information and communication field, two main methods of verification are highlighted. The two methods of verification are proofreading and double-entry verification. Proofreading consists of a comparison between inputs of information against the source of the data. Double entry of data involves two parties independently processing source data and comparing the two outputs. The comparison in both of these methods identifies errors. [27]

In clinical trials, the practice of proofreading is referred to as source data verification (SDV) and is done from either case reports or electronic records. The reason for SDV being considered the superior method is due to it identifying both minor and major errors. Minor errors may seem unimportant, but consistent minor errors add up and could lead to poor data quality. [28]

Another verification method is the reading aloud (RA) method. The method is a graphical comparison that is comprised of two steps: error detection and error correction. The error detection is done by reading aloud the entries while looking at the source data. The error correction step involves discrepancies that are checked and data entry errors corrected. [29]

This study will make use of both double-entry and proofreading verification, based on auditors' insights. Additionally, the RA method will be suggested with the use of error prevention.

2.2.3 Error

Errors are quantified by two principle methods: absolute error and relative error. Relative error is the ratio of the absolute error and the real size. The equations for absolute and relative error are written as: [30]

$$Absolute\ error = |Estimated\ value - Real\ value| \tag{1}$$

$$Relative\ error = \frac{|Estimated\ value - Real\ value|}{Real\ value} \times 100\% \tag{2}$$

In equations (1) and (2) the estimated and real values are the dependant variables. The estimated value is the value that has the opportunity of having an error in it. The real value is the value free from error.

The relative error will be used for insights into the size of errors due to it being a more intuitive measurement of error. The absolute error will be employed to identify errors and determine the implications of an error. [30]

Errors are subject to the bullwhip effect; this effect intensifies the issues in the quality of data [31]. The bullwhip effect is a phenomenon that occurs when variability increases as the orders move upstream in the supply chain [32]. Thus, due to this phenomenon, percentage errors have high variances in measurement.

An additional form of error measurement is the rate at which errors occur. The error rate is calculated by dividing the combined number of incorrect events by the total number of events. The equation that represents error rates is given below in equation (3). [33]

$$Error\ rate = \left|\frac{Number\ of\ erred\ fields}{Number\ of\ the\ total\ fields}\right| \times 100\% \tag{3}$$

Published literature discussing error rates show a dependency on the extraction of information and a high variation of error rates (0 to 71%) [34]. Similarly, many case studies of commercial banks reported wide ranges of error rates (0.5 to 30 %) [35].

Within literature, there were unreliable results regarding “acceptable” error rates. Although limited literature exists, a standard was set in a clinically reviewed study. This demonstrated that the gold standard within the electronic data set is a 5% error rate. In addition, a 10% error rate can be considered to be too large to draw a valid result. [28]

The range of known error rates will be used to corroborate the verification procedures outcomes. Furthermore, based on these recorded ranges, a prediction can be made. The newly developed verification procedure will be considered successful if an error rate of 5% is met.

2.3 Auditing firm practices

Presently auditing firms undergo assurance procedures for environmental information. As mentioned previously, assurance refers to verification of the provided information. The purpose of this action is to bring about more value to the information being disclosed [2].

This is demonstrated by market value having a positive relationship with auditing [36]. The firms’ value can also be strengthened by third party assurance for environmental audits [37]. Yet, non-financial auditing is a new assurance service for the auditing profession [38]. With new practices emerging, multiple opinions are born. These opinions give insight into the perception of social and environmental reporting assurance (SERA).

Literature found on these developed opinions was based on interviews within organisations. The opinions on SERA were divided, yet even those in favour were reluctant to make use of auditors. The reluctance seems to stem from the negative perceptions that auditors benefit excessively from companies, due to companies needing to verify their information in all areas. [22]

This is not the only issue when considering the ethical nature of the auditing profession. The issue began with the collapse of financial institutions endured by investors and taxpayers. This was due to these institutions receiving clean audit opinions shortly before reporting enormous losses. Consequently, mandatory audit firm rotation (MAR) and more regulations were employed to address this issue. [39]

MAR could also reduce auditors' rent because of assumed cost differences between auditors. Gigler and Penna show that switching cost can reduce auditors rent and MAR enforces the switching of auditors. [39]

The reviewed study alternatively addressed the issues of excessive benefits to auditors and ethics, by means of providing the company with their own developed verification procedure. Hence, the dependency on the auditors is reduced.

Additionally, the procedure will be developed according to auditors' understanding of adequate evidence, thereby addressing the other issue of incorrect opinions being developed.

During the assurance process, certain constraints are identified. The amount of testing needing to be done by the auditor is limited by cost and time. The auditing profession addresses this issue by employing audit sampling. This involves an audit procedure to less than 100% of items within a class of transaction, yet all of the samples had an opportunity to be chosen. [40]

2.3.1 Audit sampling

There are two groups of audit sampling methods: statistical and non-statistical sampling. Statistical sampling makes use of two features: 1) The random choice of sample items; 2) The use of the probability theory to evaluate the sample outcomes which includes the measurement of sampling risk. The non-statistical method is any method that does not make use of any of these features. [41]

The biggest advantage for statistical sampling is the feature of grounding the accuracy to probability characteristics, whereas the non-statistical sampling makes use of subjectivity when selecting samples. [41]

Both of these methods have their flaws. Statistical sampling depends on statistical techniques that count on assumed normal sampling distribution. This leads to the actual sampling risk being larger than the nominal assumed risk. Non-statistical sampling could be inadvertently biased with the sampling solution. All these flaws are addressed by selecting a larger sample size to reduce the auditing sample risk to an acceptable level. [42], [43], [44]

As a response to these flaws, the study will investigate each item behind the reported value removing all risk in the process. Yet, time and cost were the initial problem, and the study attempts to resolve this by implementing a sequential continuous procedure. This is possible by simultaneously running an audit procedure periodically when information is being generated, thereby dividing the amount of testing needed into smaller chunks and reducing time and cost.

2.3.2 Source document

When investigating each of these samples, the evidence provided for each of them is critical. The evidence or source of information for the samples is a source document [45]. Source documents are considered the “gold standard” from which data is obtained in clinical trials [34].

Yet, there are varying definitions of source documents across fields. Thus, the study investigated different literature definitions to formulate a new understanding of the term. The variance in the definition of a source document is given in the following Figure 3.

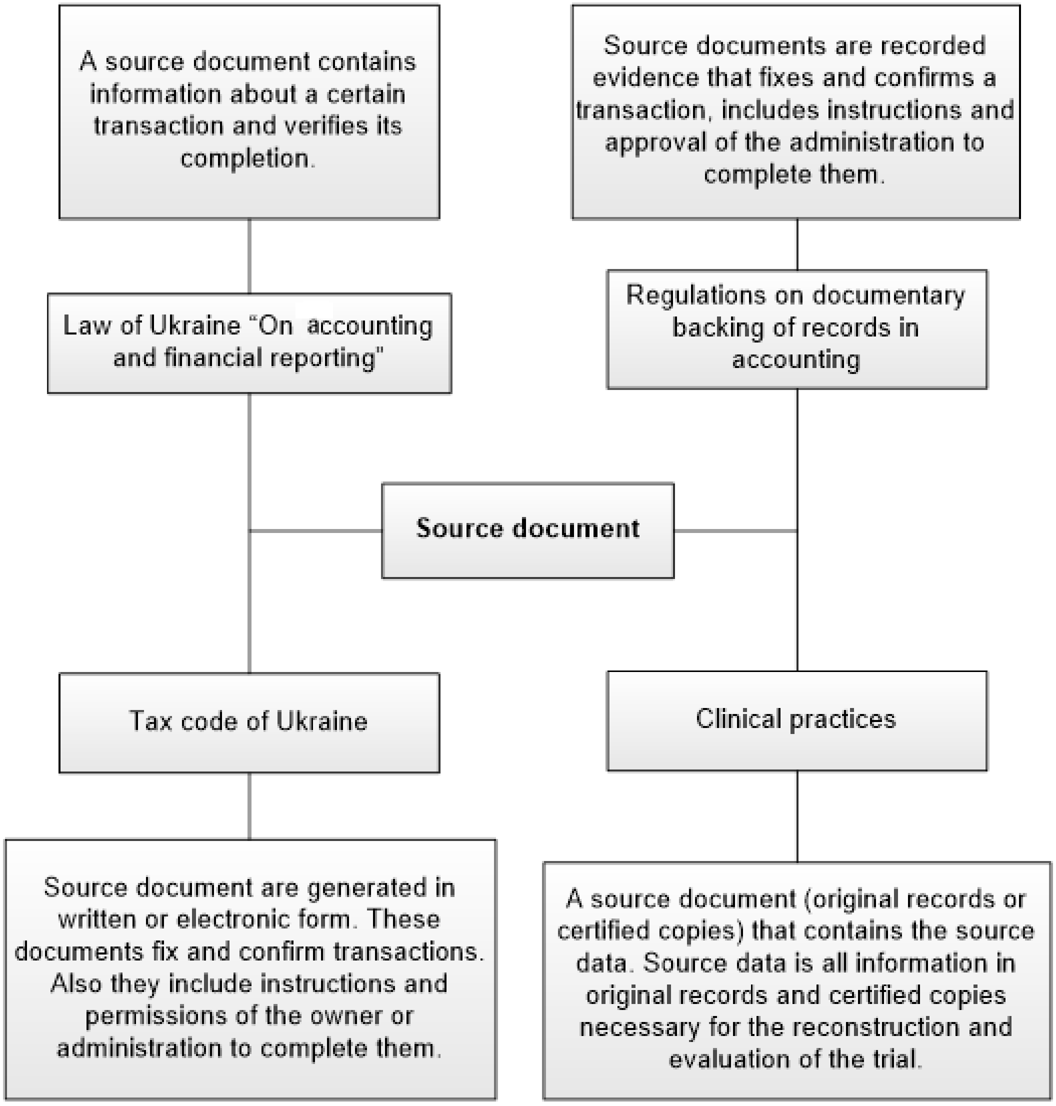

Figure 3: Definitions of a source document (adapted from [45] **and** [46]**)**

Although these definitions are mostly similar, certain characteristics can be derived from these definitions. The specific characteristics identified are listed below:

- Information of the transaction must be documented on the source document;
- The source document can be a written document or in electronic form;
- The source document must contain the source data, which is the original records or certified copy; and

- The competition or instruction to complete the transaction must be documented on the source document.

The study will make use of these derived characteristics to identify source documents. By using these multiple views of what a source is, a more efficient audit procedure will be used in this study.

2.3.3 Advanced technologies in auditing

The future of auditing involves automation and forecasting. The two topics that will be investigated for automation is block chain and mobile applications. Forecasting will be investigated by looking at neural network.

Block chain

Block chain was the most important innovation in recent years. It provides a secure infrastructure for unfamiliar parties by establishing a decentralized public ledger without a central authority. Figure 4 demonstrates how the block is broadcasted and recorded in the public ledger. [47]

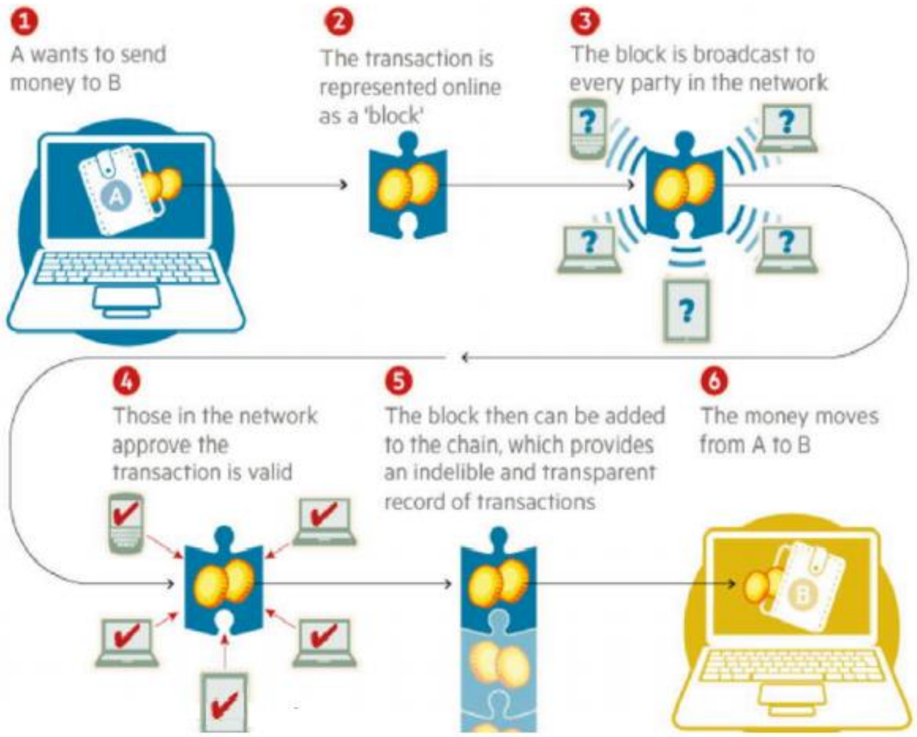

Figure 4: How block chain works (taken from [48]**)**

Figure 4 demonstrates how a transaction is broadcasted to every party in the network using block chain. Using this technology, the network can consist of multiple measuring instruments that effectively communicates the readings to all required devices. The automation technique proposed eliminates human error and therefore improves quality.

Additionally, in Figure 4, the block chain technology provides indelible and transparent record of transactions. The indelible nature of block chain ensures the first recording of information cannot be altered. The transparency of the transactions enables information to be easily verifiable.

This technology reduces cost, increases transaction settlement speed, improves auditability of transactions, reduces risk of fraud and improves the effectiveness in monitoring. Additionally block chain provides transparency among business practises, data, productivity and sustainability of the economy. [47]

The advantages of block chain in terms of this study is its ability to provide a communication platform for devices, eliminates human error, protects against fraud and presents easily verifiable information. Yet, the internet of things infrastructure is needed for this type of innovation **[48]**.

MICAVS

The second form of automation is making use of mobile applications. A new opportunity for data collection exists by making use of handheld computing devices [49]. A mobile application named Mobile Information Collection and Verification System (MICAVS) was developed and implemented in the mining industry to capture and verify environmental source documentation. [50]

MICAVS was used on a monthly basis for water readings [50]. Photos were taken of the meter reading and uploaded to a web-based system. The interface showing the reading and image on the web-based system is given in Figure 5.

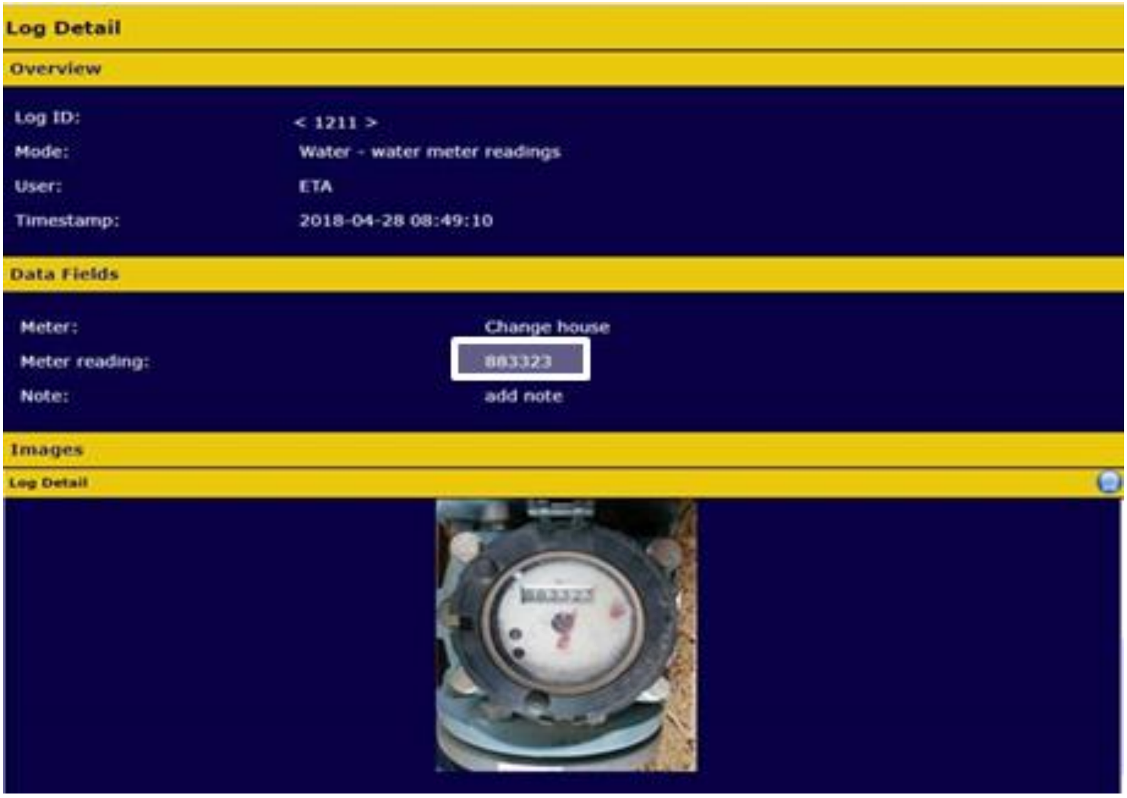

Figure 5: MICAVS on web-based system (taken from [50]**)**

A timestamp and location are attached to the photos of the readings. This system provides evidence and verification of the readings, which is important for auditing [50].The interface for MICAVS on the mobile devices is represented in Figure 6 below.

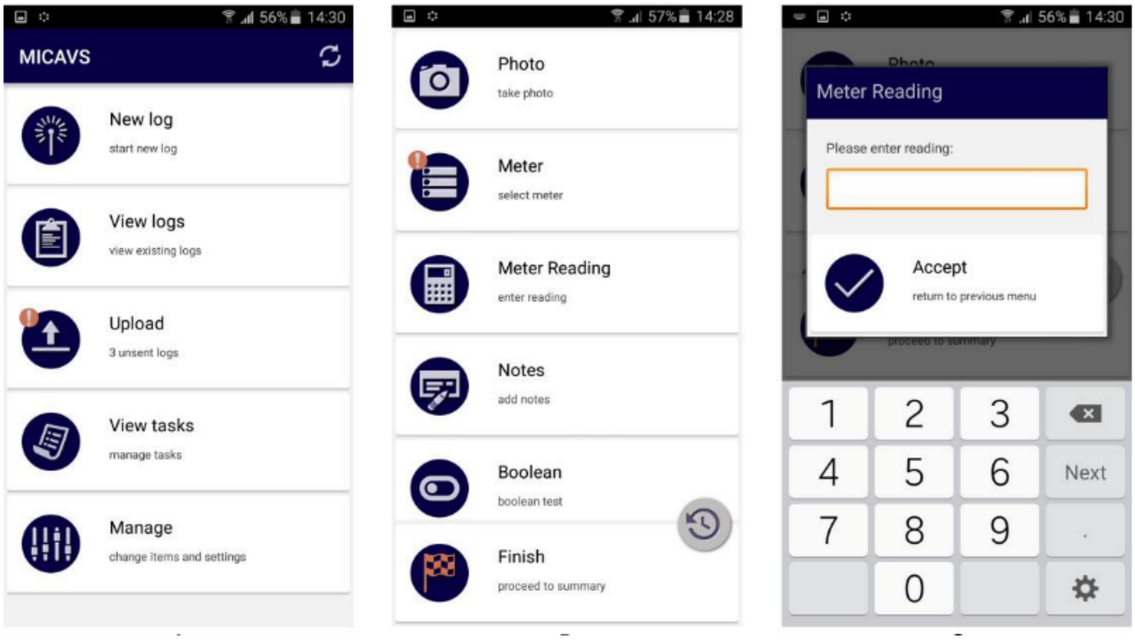

Figure 6: Mobile device interface (taken from [49]**)**

Neural network

A possible innovation in the auditing field can be artificial intelligence. Artificial intelligence tools such as Artificial Neural Networks (ANN) are mathematical models which try to stimulate the structure and function of biological neural networks. [51]

The neural network is made up of neurons. A neuron has a simple mathematical function within it. It also has multiple inputs with a single or multiple outputs. An example of these neurons being connected into a neural network is given in Figure 7. [51]

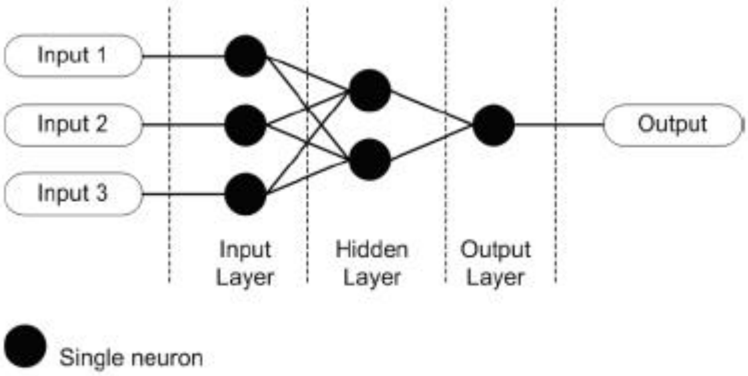

Figure 7: An example of a simple neural network (taken from [51]**)**

The ANN tool has been utilised in the auditing field to predict future revenues and expenses of an organisation. The model was trained and tested with monthly values from the past to the most recent period. The ANN system has to be continuously updated and refreshed with new data to refine it further. [52]

Therefore, the ANN can be used as a tool to predict the environmental indicators, but the system must be continuously updated with assured values. Thus, the values must be continuously assured to develop an appropriate ANN system. The ANN technology can be used in combination with this study's outcomes to forecast future KPI's of an organisation. However, this falls outside the scope of the document.

2.4 GRI principles

Due to the process of verification being extremely time and effort consuming, only the most valid KPIs should be verified. In order to select the most appropriate KPIs, the GRI reporting content principles will be used. A brief explanation on each of these principles is given in Table 4. [13]

Table 4: Principles for defining report content (adapted from [13])

Principles of report content	Explanation
Stakeholder inclusiveness	The expectations and interest of the stakeholders.
Sustainability context	The communication of the organisation's performance, which addresses the widespread context of sustainability.
Materiality	Materiality is a gauge of importance to deduce what aspects should be reported.
Completeness	The report must address all material features and their boundaries must be clearly defined. This is to ensure that the performance is clearly represented over the reporting period.

Each of these principles' explanations will be further investigated. In doing so, the study offers insight into how these principles have a relationship with the mining industry.

2.4.1 Stakeholder inclusiveness

Stakeholders in the corporate world are defined as groups or individuals that affect, or are affected by the organisational objectives [53]. Stakeholder inclusiveness refers to these groups' expectations and interests [13].

The interest of groups such as researchers and sponsors can be represented in publications [54]. Therefore, it can be assumed stakeholders' interest can be viewed in publications.

2.4.2 Sustainability context

The essence of sustainability is captured in the TBL. As mentioned in the previous section, it takes into account all three dimensions of impact an organisation has. The three spheres of sustainability represent graphically the interrelationship between each dimension. The spheres are given below in Figure 8.

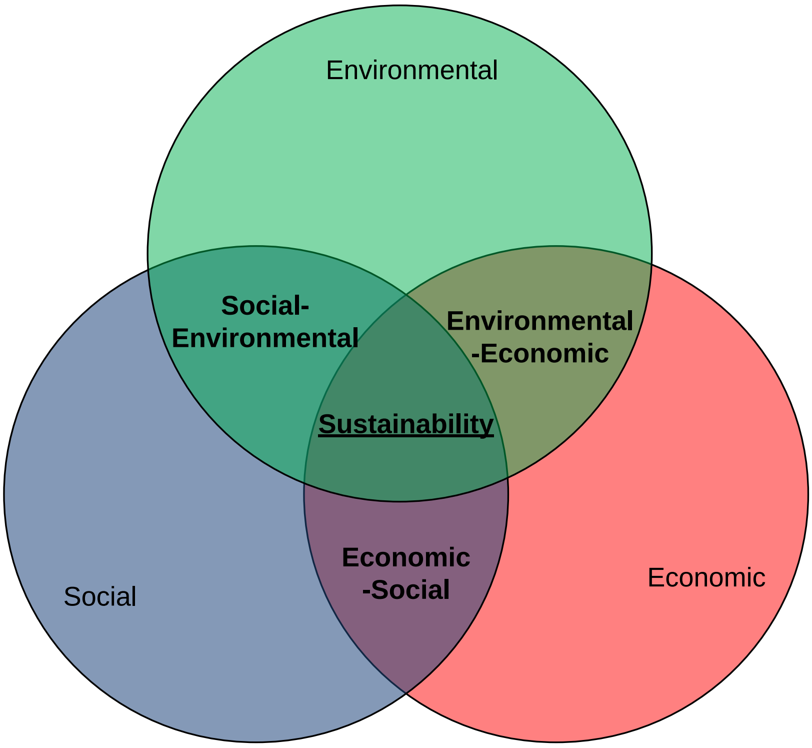

Figure 8: The three spheres of sustainability (adapted from [11]**)**

Each sphere signifies that dimension of sustainability. A brief explanation will be given of each dimension. The environmental sphere of sustainability embodies natural resource use, environmental management and pollution prevention. The economic sphere embodies profit, cost saving, economic growth, research and development. The social sphere symbolises standards of living, education, community and equal opportunity. [11]

As demonstrated in Figure 8, once all three spheres overlap, true sustainability can be achieved. Weaker forms of sustainability are possible also by overlapping two spheres. The economic-social overlap shows business ethics, fair trade and worker rights being implemented. The environmental-economic overlap indicates energy-efficiency and incentives for using natural resources. The social environmental overlap specifies environmental justice, and natural resource stewardship locally or globally. [11]

Therefore, the sustainability context can be estimated based on the three spheres of sustainability.

2.4.3 Materiality

Materiality can be broken up into two main aspects. Firstly, the reflection of an organisation's economic, social and environmental impacts, and secondly the effect it has on stakeholders' decisions and assessments. These two aspects can be used to measure materiality. [13]

These two aspects were combined to develop an approach to estimate the materiality. This widely used approach is referred to as the materiality matrix. The materiality matrix is demonstrated in Figure 9 below. [55]

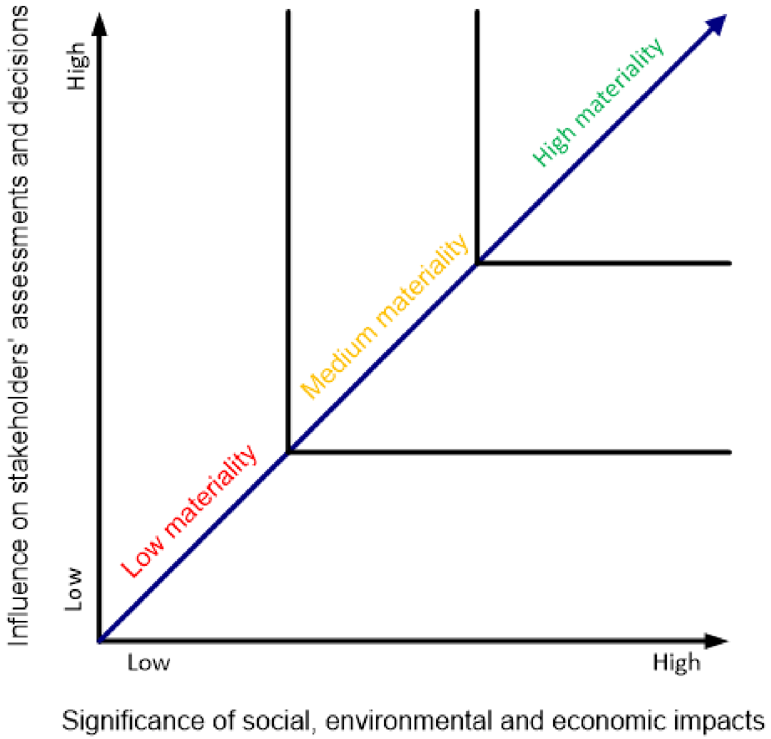

Figure 9: Materiality matrix (adapted from [55]**)**

The two aspects are represented by the two axes in Figure 5 as labelled, and indicated by the black arrow-headed lines. The linear blue line represents the increase in materiality. The matrix has been broken up into three sections of strengths indicated in the figure. Thus, an estimate in materiality can be made.

2.4.4 Completeness

The completeness principle consists of reporting boundary, scope and time. The report must meet the test of completeness in all three of these dimensions. Reporting boundaries demonstrate what bodies are included and excluded. The scope suggests the features or issues being reported. The timeframe of reporting information offers further context. [56]

2.5 Error handling

There are two approaches to error handling: error management and error prevention [57]. Error management focuses on reducing negative consequence and increasing positive consequence [58].Error prevention consist of avoiding negative error consequence by avoiding negative error consequence [58]. Both of these approaches are needed because error prevention deals with the before and error management deals with the after an error occurs [59].

Error management is the way personnel cope with, view and learn from the errors that occur. The perception of errors suggests the strain employees feel from committing these errors. They should review their own errors because these errors can affect not only the project, goals and rewards, but also their employment. [60]

Error management theory suggests three key concepts identified. The concepts are: (a) errors will happen; (b) errors have positive and negative effects and (c) attempts must be made to increase the positive effects of errors, such as the learnings derived from them. [60]

The common error management practises are listed below with a brief explanation: [61]

1. Error analysis, also referred to as error pattern analysis, is the study of errors and the reasoning behind the origin of the error [62].

2. Communication error in error management is when the gap between intention and perception are lessened to improve transfer of information [63].

3. Knowledge error sharing, knowledge error sharing is when an individual's knowledge about errors turns into group organizations knowledge [64].

4. Error assistance, the presence of trained assistance which reduces the error rate [65].

5. Co-ordinating errors, refer to the action of error management being done as a unit among individuals, groups and departments [66].

The most important practice is the communication of error, as it allows for the development of shared knowledge [61]. Thus due to its importance, reporting of errors will be the focus of error management.

There are two main error prevention strategies employed in training which are scaffolding and training wheels. Scaffolding is a term used when instrumental learning support is utilised in the early stages of developing a skill or concept. Training wheels is a strategy which uses lockouts or worked examples. A lockout is much like a performance constraint, were actions that are not relevant are left out. [67]

Error communication was further investigated due to it being the most important error management practice. The form of error communication being investigated will be error reporting, as this can be implemented in the study. Error reporting lessens the gap by informing people of their previous mistakes.

Error prevention will also be further investigated for both strategies. The environmental targeting method will be the scaffolding strategy- further investigated. The restricted response method will the training wheels strategy- further investigated.

2.5.1 Restricted responses

One of the simplest methods developed from the positive effects of errors is restricting responses. Restricting responses reduces errors by limiting the options to only valid answers. This is done by ensuring only a finite number of responses is possible. [68]

Numerical data entries can be constrained to be within a valid numeric range. An example of this can be found on Microsoft's Excel software package, which allows the user to specify only the use of whole numbers in entries. This prevents data from being entered out of the valid range needed. [68]

2.5.2 Environmental targets

A method of implementing preventative measures is the setting of targets. Gold mining companies set and achieve targets for the use of natural resources. These targets are set with the purpose of developing, implementing and improving systems for constant improvement in the organisation. [69]

The gold mine's targets were based on operational level improvements that support a five-year plan in development [70]. The percentage targets estimated are given in Table 5 below.

Table 5: Percentage targets (adapted from [70])

Targets FY14 - FY 18	Baseline	FY 18 target %	Per year target %
Reduce water use for primary activity	FY 13	4.5	0.9
Reduce electricity consumption	FY 08	5	1
Reduce total carbon emissions	FY 08	3	0.6

These percentage targets can be used as a limiting factor for restricting responses for the KPI's specified. Furthermore, for any other KPI's not specified, an average of 0.83 can be used as derived from the calculation of the average of the per year target values.

2.5.3 Error reporting

Learning can be initiated with error reporting. This requires an investigation into the reason behind each error, and makes it possible for them to be corrected and prevented in future. The main reason for this reporting is to reduce errors and reduce the negative consequences on customers, employees and the organisation. [71]

Within the medical field, there are multiple types of error reporting systems. The reporting can be voluntary, anonymous, confidential, active, spontaneous, mandatory or passive. The other important aspect of reporting in this field is to inform the patient that the error occurred. [72]

There are practical error reporting programs being used in the medical field. These reporting systems can be used internally or externally. In addition, six best practice categories were identified to affect the quality and frequency of the reports. [73]

Table 6: Six best practices for error reporting (adapted from [73])

Categories	Brief description
Trustworthy	The people who receive the report and act on it must develop trust in the reporters and program.
Confidential	The recipient of the report must keep the identity of reporters and employees involved and the location of events confidential.
Clear and easy	The recipient of the report must take care over the format and length of the report. If too long, the necessary information will be suffocated. If too short, not all the necessary information will be communicated.
Rewarding	Acknowledgments of anyone contributing to the positive effects on the reporting process.
Credible and useful	There are things that obstruct improvement other than perceived inactions or not using the information provided. Thus, the communication of feedback and outcomes of the reporting system are critical.
Reinforces the imperative to report	New staff should be taught about the reporting process. The importance of the reporting process and benefits must be constantly communicated to all people involved.

This study makes use of mandatory reporting with best practices to ensure a successful error reporting system.

2.6 Continuous improvement methods

Presently, there are several types of continuous improvement methods in use such as lean thinking, PDCA (Plan-Do-Check-Act), Six Sigma and the theory of constraints (TOC). Each of these will be briefly discussed based on their origins, methodology and main characteristics. Using this information, a literature comparison will be done to investigate the most suited method that the study can implement.

2.6.1 Lean thinking

The term lean thinking was termed by Womack. The Japanese established this philosophy in the mid-50s. The early application of lean thinking was concentrated on manufacturing, resulting in an adopted term, “lean manufacturing”. This approach was used systematically to identify and eliminate waste by continuous improvement. [74], [75]

The first step in lean thinking is the identification of value added and non-value added processes. In order to identify these processes, a qualitative analysis tool referred to as the value stream mapping is used. This mapping provides insights into current state and possible future state of the system. Thus, future mapping of processes is used to implement lean improvement strategies. [76]

These lean improvements focus on identifying value added and non-value added activates. Then, the non-value added activities are eliminated in all areas and tasks in the system. The elimination of waste is the main target of lean thinking. The seven main forms of waste identified are listed below: [76]

1. Overproduction
2. Defects
3. Unnecessary inventory
4. Inappropriate processing
5. Excessive transport
6. Waiting
7. Unnecessary motion

There are three key principles which encompass the lean manufacturing methodology. They are: improving the flow of information and material within the organisation; focus on customer wants or needs; and the dedication of the organisation. [75]

2.6.2 Plan-Do-Check-Act cycle

The Japanese developed the PDCA method as a systematic, continuous problem solving approach. This approach emphasised the constant interaction among sales, design, production and research, to assure product quality and customer satisfaction. This tool is now widely used and highly recommended in the manufacturing industry. The approach is demonstrated in Figure 10 below. [77]

Figure 10: PDCA cycle (taken from [78]**)**

Figure 10 demonstrates the four phases of the cycle. Each phase has specific characteristics. The planning phase consists of identifying and making decisions to accomplish the targets. The doing phase consists of implementing tasks associated with the previous phase. The checking phase compares the results of the doing phase with the requirements needed to achieve the wanted targets. The last phase consists of the lessons and unsolved issues obtained from the previous phases. [79]

The PDCA cycles empowers two types of corrective action. The temporary action consists of practically fixing the problem. The preventative corrective action involves inspecting and reducing the root cause. Thus, it attempts to achieve sustainable improvement in processes. [80]

2.6.3 Six Sigma

Bill Smith at Motorola first formulated the Six Sigma method when a target of 99.99966% defective free products was established. This approach is more project management driven because it sets out to improve organisations' products and/or services and processes, by removing defects. The Six Sigma uses an adapted structured pattern of the PDCA cycle illustrated in Figure 11. [81]

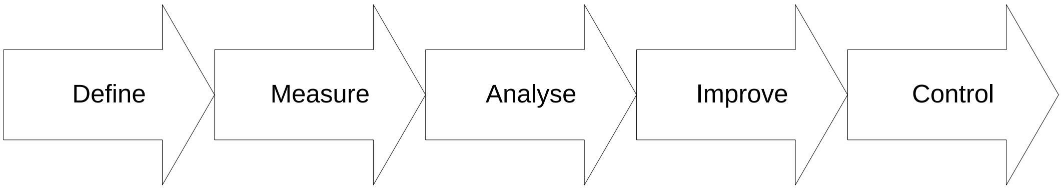

Figure 11: Six Sigma DMAIC steps (adapted from [81]**)**

Figure 11 demonstrates the production improvement used by Six Sigma known as DMAIC. The first step defines the customer, their requirements and the processes that affect them. The measuring step recognises the key measurements needed and implements a plan to collect this critical information. The analysis step collects the information to determine the cause of processes not performing as desired. The improvement step determines the possible solution by making use of these possibilities for positive improvements in process performance. The last step, control, deals with the development, documentation and implementation of a plan that ensures a desirable level of performance improvement. [82]

The Six Sigma philosophy for eliminating defects is done through fundamental process knowledge. The elimination of defects is done by making use of six standards between the mean and nearest specification limit. [82]

2.6.4 Theory of constraint

Eliyahu M. Goldratt in 1984 developed a philosophy of system management named the Theory of Constraint (TOC). The principle of TOC is to establish constraints on performance limits on any system. Most companies have only a few critical constraints. Goldratt states the TOC uses a five-step process given in Figure 12 that continuously improves systems. [83]

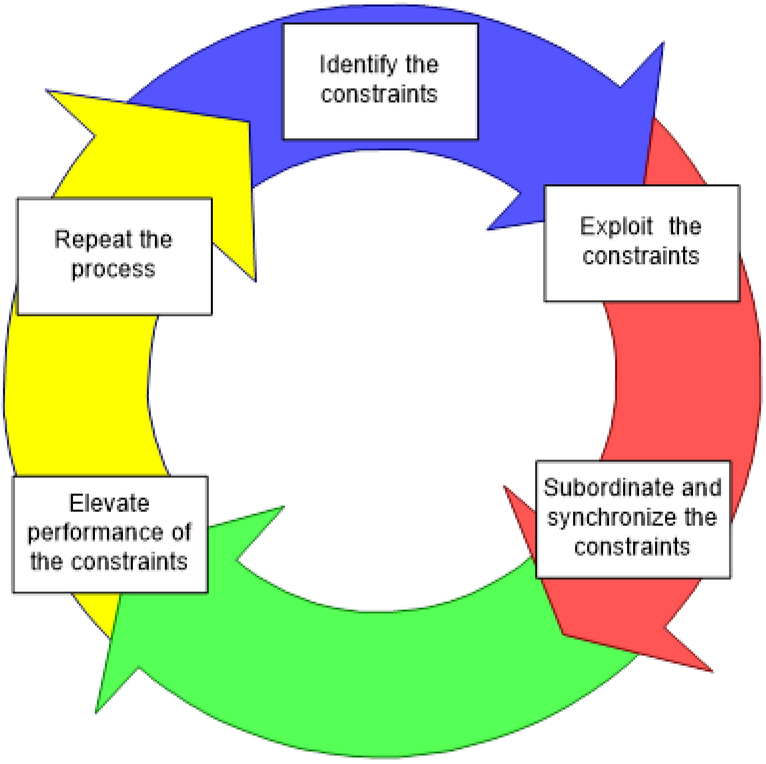

Figure 12: TOC cycle (adapting from [83]**)**

Figure 12 illustrates the five-step process of the TOC methodology. The first step identifies the limiting factor that contributes to the rate at which the goals of the process were achieved. Following that, quick improvements can be made with the resources that are on hand. The next step deals with revising all processes to ensure each supports the needs of the constraints. The final step considers constraints that still exist and attempts to eliminate them. Capital investments can be used to eliminate some constraints. The final step considers the continuous improvement cycle, by repeating the process to the next constraint after the previous one has been resolved. [83]

The theory views organisations as chains, in which the entire system's performance is dependent on the weakest link in its chain. The methodology focuses on detecting the constraints (weakest link) and strengthening it until it is no longer the weakest link in the system. Through continuous improvement of the weakest links in the system, the system is continuously reaching its most optimal performance. [84]

2.6.5 Comparison

In order to compare each of the continuous improvement methods, a brief summary with criticism will be used. This comparison is demonstrated in Table 7 below.

Table 7: Continuous improvement method comparison

Continuous improvement methods	**Lean thinking** [74], [75], [76]	**PDCA cycle** [77], [78], [79], [80]	**Six Sigma** [81], [82]	**TOC** [83], [84]
Focus	Maximising both value and speed in processes.	Continuous improvement.	Aim to achieve perfection in performance to have defect-free outputs.	Control constraints in processes.
Step methodology	• Identification of value added processes • Mapping of the value stream • Improving the flow of processes • Pull work through the organisation's processes • Seek faultlessness	• Plan • Do • Check • Act	• Define • Measure • Analyse • Improve • Control	• Identify • Exploit • Subordinate • Elevate • Repeat
Main improvement strategy	Adding value in all processes of the organisation.	Two forms of corrective action being implemented.	Using the fundamental process knowledge to eliminate defects.	Improving the weakest link in the organisation constantly.

In Table 7, a comparison was drawn between the focus of each continuous improvement method. The lean thinking and TOC are utilised for these processes. Six Sigma is used to reduce defects in production. Therefore, due to PDCA being focused on continuously improving any system, it will be the most suitable candidate.

The step methodologies were also compared with each other. The insight that was drawn from the comparison was that the lean thinking and TOC were more applicable to process development and control. In addition, the Six Sigma is more specialised in product development. The PDCA cycle has a more universal methodology that can be implemented in any scenario. In addition, the cycle includes a verification step which is a requirement for the study.

The improvement strategy for each method was given in Table 7. The lean thinking focuses on adding value in process not correcting the actual process. Six Sigma's focus is on eliminating defects which only surface at the end of the process. TOC improves only the weakest link in the system, which is not an efficient method for continuous improvement. The PDCA cycle has two forms of corrective actions, which double the probability of correction in an efficient manner.

When comparing each of these methods the PDCA cycle was selected as the best-suited methodology. The PDCA method will be adapted to suit the need for the study.

2.7 Developed systems

Platforms for centralising information will be investigated. These systems will provide easy and efficient data capturing and limit human errors. A number of computerised environmental management systems exist in the market [50], [85]. These systems primarily focus on improving the quality of information and ensuring that company standards are followed. Systems relevant to this study were investigated and the highlights are presented below.

2.7.1 Enerit Ltd

Enerit developed the world's first comprehensive Energy management system (EnMS). This system assisted users to achieve best practices in energy management in energy-intensive industries. Once the system is well established, implemented and maintained, the ISO 50001 certification can be applied for. Additionally, web-based platforms can be used for accessibility. [85]

The uniqueness of this product is that it collates the EnMS information such as the policies, data, audits, ideas, processes and other valuable information, into one central location. In doing so, a wide range of energy-related information can be processed, resulting in energy savings. These savings are possible with no cost or a low cost to a company. The web-based interface utilised is given in Figure 13. [85]

Figure 13: Interface for Enerit (taken from [85])

The positives of this product in terms of the study is the ease to access all relevant information yet, this product is specific to energy-related information. This might be a problem for utilising this product in the study as it focused on energy indicators.

2.7.2 IsoMetrix

IsoMetrix was originally a simple access database which helped companies with their environmental management systems. Through multiple iterations, the product has grown and developed governance, risk, and compliance (GRC) management. The heavy industries using this software includes extractives, utilities, transportation, logistics, manufacturing and construction [1].

IsoMetrix traces and records all activities. Thus, the organisation has a system of record and audit trails. This huge advantage provides the ability to defend the organisation by delivering evidence of compliance and control through complete traceability. The access and security of this system are moderated and all users see the same dashboard. [50]

[1] GRC 2020 https://grc2020.com/product/isometrix

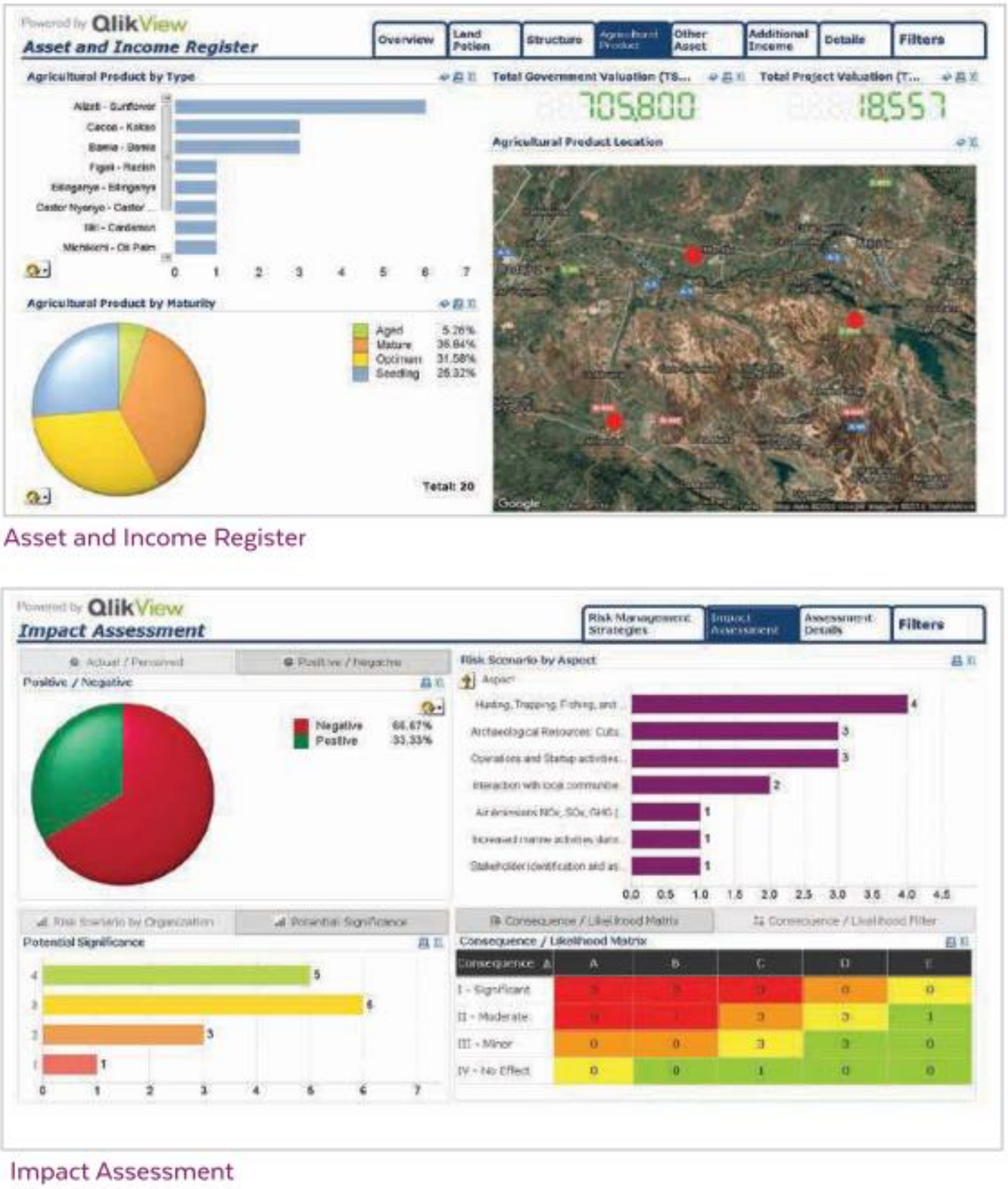

Figure 14: Interface for IsoMetrix [2]

The IsoMetrix offering has advantages over other products yet, the moderate security will be an issue for the study as different users should have different privileges. The system cannot store source documentation which limits its assurance capabilities.

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[2]IsoMetrix Good Busniess. https://www.isometrix.com/wp-content/uploads/2018/07/IsoMetrix-Social-Sustainability-2017_Digital.pdf

2.7.3 Online environmental system

The online environmental system was developed for traceability and availability in real time. The system was implemented in the gold mining industry and centralises relevant data and processes. High-security measures were implemented since it is highly confidential information. [50]

The system has a document manager and a database. Data is stored from the user and relevant documents are also captured. All environmental indicators are stored on the system such as energy, water, fuel used, explosives, and many other environmental indicators. Error prevention techniques are employed on the system. The system display is simple, and has added mobile application features. [50]

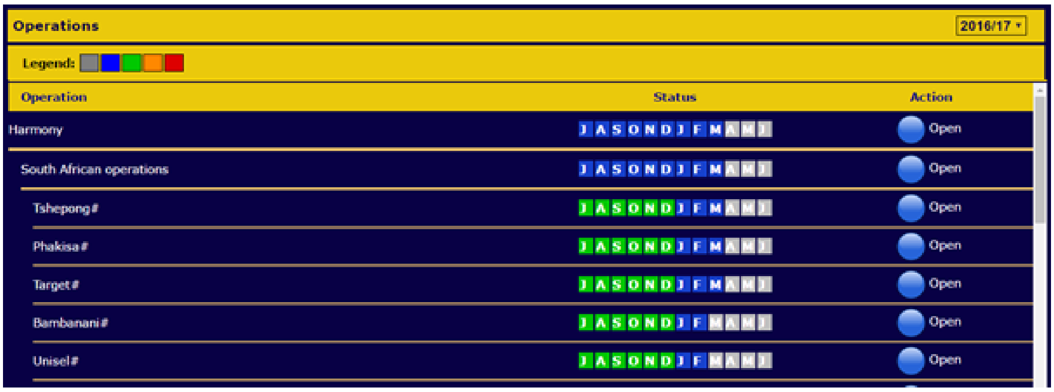

Figure 15: Interface for the Online environmental system (taken from [50])

The real-time system captures data and documents efficiently and is designed specifically for mining environmental reporting.

2.7.4 Intelex

Intelex is a Canada-based provider for Environmental, Health, Safety and Quality (EHSQ) Management across a wide range of industries worldwide. The software is suited for all sizes of organisations. The platform is a mobile solution and provides integrated tool EHSQ professionals. [3]

The enterprise software offered by Intelex has a wider functionality than cloud-based software. Also, the software and servers are owned by the customer making it more secure. Intelex offers a fully customizable product with no restrictions on queries and reports. The upfront cost is lower since the software is rented rather

[3] Intelex. https://www.intelex.com/resources/insight-report/implementing-new-ehs-software-value-buy-and-engagement

than purchased. An example of the Intelex interface for the web-based platform is given in Figure 16. [3]

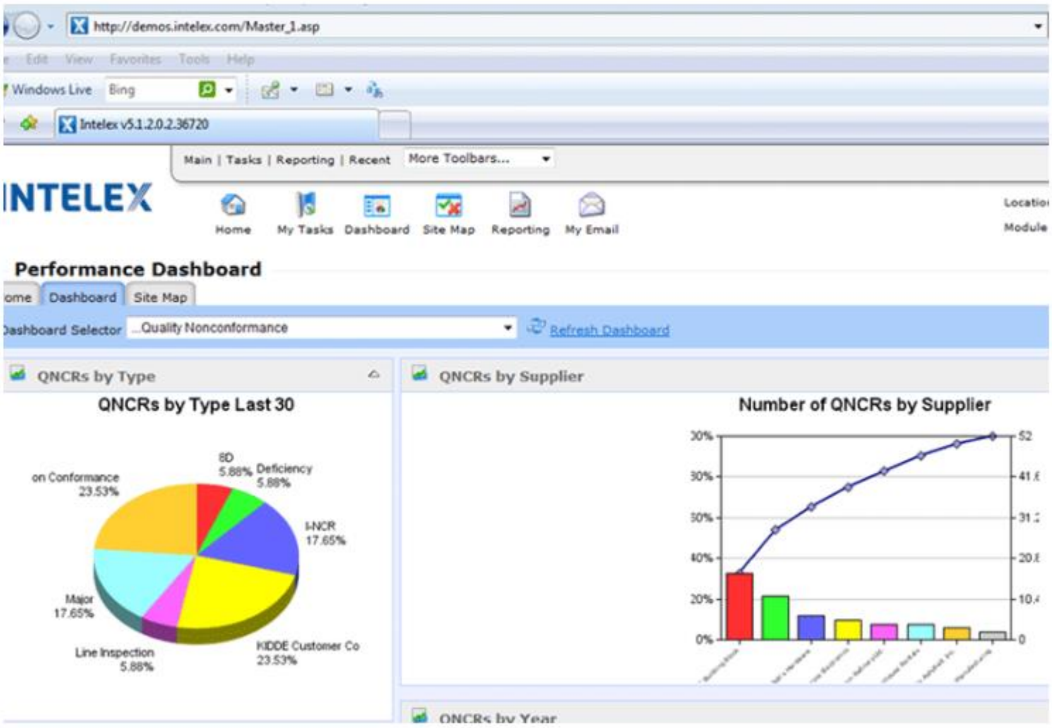

Figure 16: Interface for Intelex [4]

Intelex's best attributes are its cybersecurity and its low cost, yet a lot of customisation of the product will be required for this study.

2.7.5 Enviro Data

Geotech's Enviro software brings affordable, yet powerful environmental management software. Enviro Data stores and displays quality data such as field and laboratory data for water and soil.[5]

The system is a web-based application to address the needs of a specific business. The product is easily customizable and new capabilities are easily added. By linking Enviro Data with Enviro Space, the information of Enviro Data can be represented on a Geographical Information System (GIS) map. [5]

[4] ClockShark Blog. https://www.clockshark.com/Blog/intelex-review/

[5] Geotech Computer Systems. https://geotech.com/envirodata

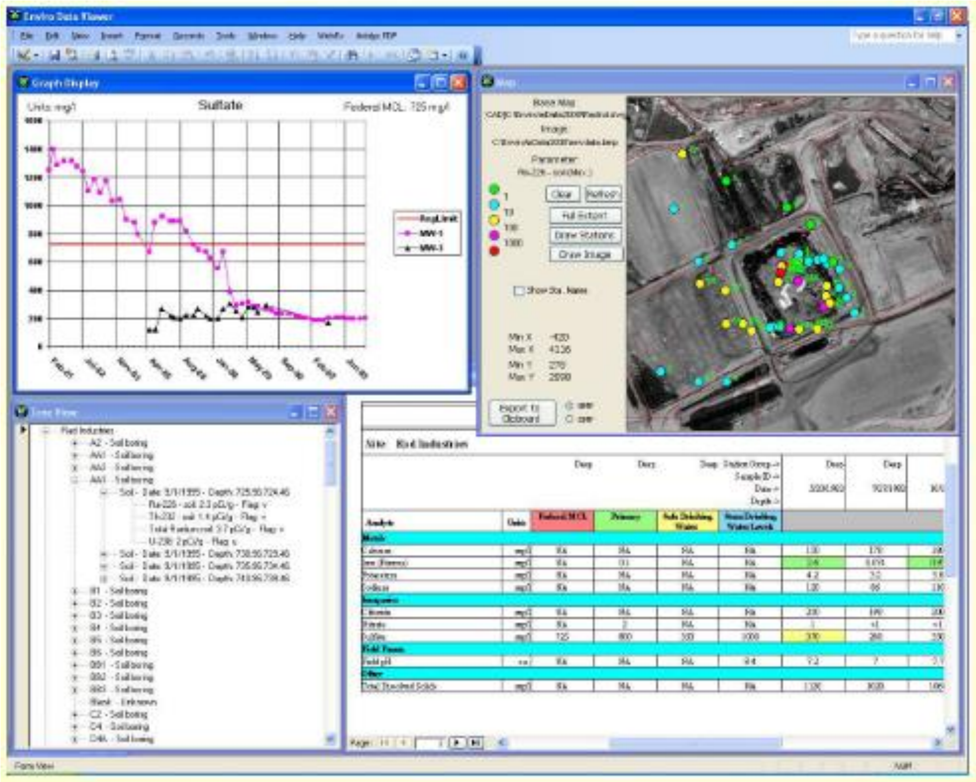

Figure 17: Interface for Enviro Data [5]

The best feature developed for Enviro Data is the extension made onto a GIS map, which could have multiple benefits. Enviro data has been developed for the water and soil industry which is the only limiting factor.

2.7.6 Comparison

Table 8 compares each of the developed systems based on four categories relevant to this study. As seen from the previous section, various systems exist in different focus areas. It this therefore important to consider the type of industry the system is used in.

Gold mining companies are normally configured across far distances and have different management levels, and users with different needs [50]. It is therefore important to consider the accessibility of the system as well the ability to customise the system for different focus areas.

The last element considered was the various environmental performance indicators (KPI) the system can manage. Different companies have different KPI's and therefore systems that can manage KPI's relevant to the mining industry will have a big advantage over other software products.

In Table 8, the first comparison made was the industry the specific system was designed for. The Enviro Data system can be eliminated due to it being developed for only soil and water.

The next comparison is accessibility, which represents the ease for personnel to gain access. All systems compared were easily accessible as they utilise web-based or server platforms that can be accessed across different networks.

Customisability were compared next. IsoMetrix is less customisable for specific users. As discussed above, this poses a security risk. Intelex, Enerit and the Online environmental system give the consumer a fully customisable system to meet their needs.

The last comparison, KPIs, indicates that Enerit only focusses on energy management and has limitations when considering the other KPIs mines need to report on. The remaining feasible systems therefore include Intelex and the Online environmental system. Even though both these systems are relevant to the study, the Online environmental system has a document manager module where source documentation can be liked to specific values. This makes the Online environmental system the best-suited system when considering data validation. This system was also used by the by the mining company discussed in the case study (Chapter 4).

Table 8: Developed systems comparison

Developed systems	**Enerit Ltd**	**Isometrix**	**Online environmental system**	**Intelex**	**Enviro Data**
Industry	Energy Intensive industry	Extrusive industry	Mining industry	Wide range of industries	Water and soil industry
Accessibility	Web-based software	Simple access database	Web-based system	Rented software and servers	Web-based application
Customizability and features	Stores all energy-related data, audits, processes and other valuable information into one place	Traces and records all activities of the solution.	Stores both data and documents, and shows different views for different users.	Fully customizable product with no restrictions on their queries and reports	The product is easily customizable and new capabilities are easily added
Environmental indicators	Energy indicator	There focus is more on governance, risk, and compliance (GRC) management.	All environmental performance indicators for mining	For all Environmental, Health and Safety Indicators.	All Environmental data.

2.8 Conclusion

Each of the literature objectives was met and insight into these topics was conveyed. The measurement of accuracy was determined by quantifying errors in the data. The PDCA continuous method of improvement in combination with auditing practices, was explored to improve systems. Both error management and prevention were investigated. Also, developed systems were explored for environmental data management.

Investigating the quantifying of errors led to the representation and identification of errors. The representation of data needs to convey the relationship between data and its meaning. Hence, the tree structure was found to be a viable system for representation. The identification of errors is done by identifying valid information with verification techniques.

Research was done on multiple continuous improvement methods to investigate the most relevant method. The PDCA cycle was found to have the most suited characteristics for the study and will be adapted as the core methodology of the study. Yet, auditing practice has some basis on verification strategy and data validity. Data validity provides evidence in the form of source documents. Auditing sampling as a verification strategy was investigated.

Auditing sampling was found to have issues and these problems were addressed with further literature. The issues were addressed by investigating each of the reported information. In order to do so, KPIs need to be shortlisted in order to investigate each item of reported information efficiently. Thus the GRI reported content will be further explored to shortlist KPIs.

Error management was broken up into error analysis, communication error, knowledge error sharing, error assistance and co-coordinating error. Error prevention consisted of scaffolding and training wheels. This led to a detailed investigation into restricted responses, environmental targeting and error reporting which are forms of error management and prevention.

Lastly, systems fit for environmental information management were investigated., The systems include: Enerit Ltd, IsoMetrix, Online environmental system, Intelex and Enviro Data. These systems were compared based on four criteria: industry, accessibility, customizability and environmental indicators. The comparison led to Online environmental system being the most suited data management system for this study.

3 Methodology

3.1 Introduction

From Chapter 2 it can be noted that the PDCA methodology is a valid practice to improve the performance of systems over time. Because of this finding, the implementation of this methodology will be used in the development of an assurance procedure.

Each stage of the PDCA approach is used for key factors in the process of assurance. The "Plan" step deals with the investigation of what is being reported and where exactly this information originates. The "Do" step refers to the collecting of information at the first and last points of communication within the organisation. A recommendation was used in combination with this section to increase the likelihood of a reduction in errors. The "Check" section uses the two main forms of verification to ensure the correct values are recorded. Lastly, the "Act" portion focuses on documenting, reporting and error management.

The verification is done by verifying the two critical objectives the methodology seeks to meet. The outcome of the procedure must represent the true state of an organisation, and, with the use of the methodology, the accuracy of the organisation reporting gradually improves.

3.2 Reporting process investigation

The methodology developed in this study aims to improve the accuracy of reporting processes. In order to achieve this, many different methods were combined within a continuous improvement method. The continuous improvement method, PDCA, was used as the core methodology. This sequential procedure will be altered to fit the objectives of the study, and will be periodically implemented. The altered PDCA used is represented in Figure 18.

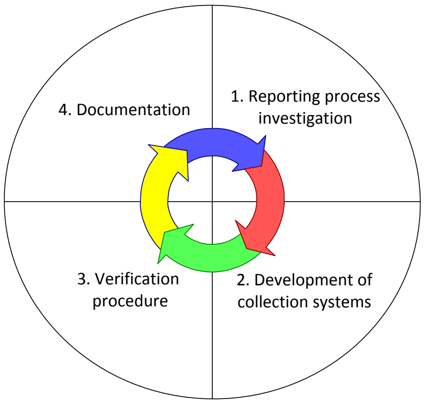

Figure 18: Core PDCA methodology (adapted from [78]**)**

The investigation determines the most important KPIs and then investigates their origins. KPIs are a measure for an organisation to demonstrate how successful they have been. In terms of the environmental reporting, KPIs need to demonstrate their impact on the environment.

The selection of these KPIs for assurance procedures is important for decisions that influence the perception of the sustainability report reader. The selection of KPIs here is based on literature findings about GRI reporting content principles demonstrated in Chapter 2.

First, all the KPIs possible must be identified with the GRIs grouped categories mentioned previously. When identifying each of the KPIs, it is important to consider that the GRI indicator groups were not specifically developed for gold mines. Therefore, a combination of the GRIs recommendation and insight into gold mining was used to derive all the KPIs possible. The listing of all the possible KPIs is given in Appendix A.

The first step in shortlisting the KPIs will be based on the decisions made by upper management of the gold mine. The upper management of the gold mine selects specific KPIs for assurance. These KPIs are given in the assurance report in Appendix B. The KPIs are broken up into separate dependant indicators. An example is scope 1 emissions, which comprise explosives, petrol and diesel. The study will consider the dependant indicators as the KPIs.

The KPIs assured by auditors will be further shortlisted due to the findings found in literature. Audit sampling will not be used, rather, each KPI reported data will be verified in detail. Therefore, further shortlisting of KPIs is required.

In order to further shortlist the KPIs, the principles for defining report content investigated will be used. Each of the KPIs will be cross-evaluated against each principle to determine which KPIs take priority in the verification of the study. The cross evaluation will have a brief discussion of the importance between that KPI and a specific principle.

The first principle being cross-evaluated with the KPIs is stakeholder inclusiveness. Based on literature findings publications can represent the interest of stakeholders. Therefore, publications offer insight into stakeholders’ interests. The cross-evaluation discussion for the principle is given in Table 9.

Table 9: Stakeholder inclusiveness cross evaluation

KPIs	Group and sites	Brief discussion
Total Scope 1 Carbon Emissions (tCO_2e)Note:	Diesel	Stakeholders have great concerns about climate change [86]. Thus,
	Petrol	

KPIs	Group and sites	Brief discussion
Quantities before conversion to (tCO2e)	Explosives	Greenhouse gas reporting is critical to stakeholders.
Total Scope 2 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	RSA (Republic of South Africa)	
	PNG (Papua New Guinea)	
Total Scope 3 Carbon Emissions (tCO_2e)Note: Quantities before conversion to (tCO_2e)	Explosives	
	Cement	
	Timber	
	Cyanide	
	Caustic soda	
	Lime	
	Business travel	
	Air travel	
Volume of mineral waste disposed (tonnes)	Slimes/tailings	Stakeholders have great concerns regarding environmental impacts [86]. Mineral waste is a form of environmental impact. Tailings have irreversible environmental impact and waste rock additionally contains potentially toxic elements [87], [88].
	Waste rock	
Electricity purchased (kWh)	RSA (Republic of South Africa)	The usage of both of these resources needs to be reduced due to their scarcity and need. Measures must be taken to reduce energy usage of the past [89]. Water is becoming a scarce commodity around the world [90].
	PNG (Papua New Guinea)	
Water used for primary activity (kilolitres)	Group	

KPIs	Group and sites	Brief discussion
Land rehabilitation	Group	South Africa legislation requires mining land to be left in an improved state, which is done by land rehabilitation [91].

The principle of sustainability content refers to the future performance of the company and its ability to maintain it. Literature findings explored the three spheres of sustainability as an approach to estimate the company's sustainability. This approach will be used in the cross-evaluation of the KPI with this principle given in Table 10 below.

Table 10: Sustainability content cross evaluation

KPIs	Group and sites	Brief discussion
Total Scope 1 Carbon Emissions (tCO_2e)Note: Quantities before conversion to ($tCO2e$)	Diesel	The Greenhouse gas (GHG) emission KPI can be considered to be within the social-environmental dimension of sustainability.
	Petrol	
	Explosives	
Total Scope 2 Carbon Emissions (tCO_2e)Note: Quantities before conversion to (tCO_2e)	RSA (Republic of South Africa)	
	PNG (Papua New Guinea)	
Total Scope 3 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	Explosives	
	Cement	
	Timber	
	Cyanide	
	Caustic soda	
	Lime	
	Business travel	
	Air travel	
Volume of mineral waste disposed (tonnes)	Slimes/tailings	The mineral waste KPI can be considered to be within the social-environmental dimension of sustainability.
	Waste rock	
Electricity purchased (kWh)	RSA (Republic of South Africa)	Both of these KPIs can be considered truly

KPIs	Group and sites	Brief discussion
	PNG (Papua New Guinea)	Sustainable due to them encompassing all three dimensions of sustainability.
Water used for primary activity (kilolitres)	Group	
Land rehabilitation	Group	Land rehabilitation KPI can be considered to be within the social-environmental dimension of sustainability.

The principle of materiality addresses the environmental impact and its influence on the perception of the stakeholders. These two factors are united in the materiality matrix, and will be considered in the cross-evaluation given in Table 11 below.

Table 11: Materiality cross evaluation

KPIs	Group and sites	Brief discussion
Total Scope 1 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	Diesel	The influence can be considered medium and the significance can be considered high. Thus, the material matrix outcome is medium materiality.
	Petrol	
	Explosives	
Total Scope 2 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	RSA (Republic of South Africa)	
	PNG (Papua New Guinea)	
Total Scope 3 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	Explosives	
	Cement	
	Timber	
	Cyanide	
	Caustic soda	
	Lime	
	Business travel	
	Air travel	

KPIs	Group and sites	Brief discussion
Volume of mineral waste disposed (tonnes)	Slimes/tailings	The influence can be considered high and the significance can be considered high. Thus, the material matrix outcome is high materiality.
	Waste rock	
Electricity purchased (kWh)	RSA (Republic of South Africa)	The influence can be considered high and the significance can be considered high. Thus, the material matrix outcome is high materiality.
	PNG (Papua New Guinea)	
Water used for primary activity (kilolitres)	Group	
Land rehabilitation	Group	The influence can be considered low and the significance can be considered medium. Thus, the material matrix outcome is low materiality.

The principle of completeness deals with the boundaries and material features of the KPIs. More specifically, the three dimensions of boundary, scope and time will be considered in cross-evaluation. This will be considered in the cross-evaluation of the completeness principle represented in Table 12 below.

Table 12: Completeness cross-evaluation of KPIs

KPIs	Group and sites	Brief discussion
Total Scope 1 Carbon Emissions (tCO_2e)Note: Quantities before conversion to (tCO_2e)	Diesel	All three dimensions of boundary, scope and time can be considered.
	Petrol	
	Explosives	
Total Scope 2 Carbon Emissions (tCO_2e)Note:	RSA (Republic of South Africa)	

KPIs	Group and sites	Brief discussion
Quantities before conversion to (tCO_2e)	PNG (Papua New Guinea)	
Total Scope 3 Carbon Emissions (tCO_2e)Note: Quantities before conversion to (tCO_2e)	Explosives	Scope 3 emissions is much more complicated and reporting its entirety is less successful than other scopes [92]. Due to this, scope and time can be considered.
	Cement	
	Timber	
	Cyanide	
	Caustic soda	
	Lime	
	Business travel	
	Air travel	
Volume of mineral waste disposed (tonnes)	Slimes/tailings	All three dimensions of boundary, scope and time can be considered.
	Waste rock	
Electricity purchased (kWh)	RSA (Republic of South Africa)	All three dimensions of boundary, scope and time can be considered.
	PNG (Papua New Guinea)	
Water used for primary activity (kilolitres)	Group	
Land rehabilitation	Group	All three dimensions of boundary, scope and time can be considered.

After each of the discussions has been completed, a final rating matrix can be compiled. The rating matrix will be purely based on the discussions above. The purpose of the matrix is to determine which of the KPIs have more priority over others. By determining the priority for each of them, a suitable selection can be made.

The rating matrix is compiled by listing all the KPIs against each of the defining principles of content, once again setting up a cross-evaluation, but this time, the discussion will be used to give a rating in this matrix. The rating will be between one and three, with the worst being one and best being three. The rating is based on the strength of the relationship between the KPI and the principle.

Once the selection of the KPIs is complete, an investigation into the origins of the KPI can begin. The origins of each KPI can be traced back to a specific value chain. A value chain is a network of processes that describes the flow of material, information and services needed to create goods or services [93]. This study refers to a section of the value chain that deals with the flow of information in the reporting chain.

When considering reporting chains within the organisation, it is essential to investigate the configuration of the gold mine. The configuration refers to the actual physical layout of the organisation. A gold mine has multiple forms of operations.

An operation can have different functions within the mine. An operation can be either a plant, or a shaft or a combination of the two. A shaft's main purpose is to extract the raw materials from the ground. A plant's main purpose is to process the raw material into the final product. The reporting chains between these different forms of operations differ and should be noted during the investigation.

A generic form of a reporting chain is indicated below in Figure 19. A reporting chain consists of a source document, summary and the resulting GRI value. Multiple forms of sources and summaries are possible within a reporting chain. The arrows indicate points of communication. An example of these points of communication are: emails, phone calls, transfer of record, entering data on system and verbal communication.

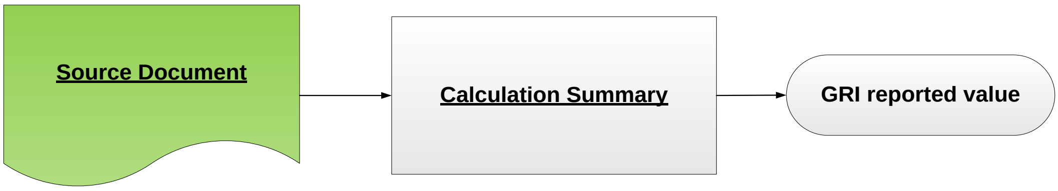

Figure 19: Generic reporting chain

Source documents vary depending on the reported information. Contracts or invoices have been viewed to be the most credible due to them being legal documents. Electronic sources follow due to their minimal possibility of error. All other forms follow, but the credibility of these sources can be further improved by providing signature, date and responsible persons.

Summaries are between the sources and actual reporting of information. Summary documents are mainly used for calculations and recording of values from the source documents. Calculations differ widely from conversions to adding and subtracting different source documents. The subtraction and addition of sources are mainly due to the boundaries of an operation. Recording of values on summaries is done for efficiency and historical purposes, making it possible to easily track usage and make multiple calculations from a range of sources.

3.3 Information collection system development

The first portion of this study highlights what KPIs need to be reported and further investigates the origins of those KPIs. This section deals with the collection of the reported KPIs and the supporting documents, which are the relevant documents in the reporting chain.

Presently, the online environmental system is utilised in the gold mining company. Also in the Section 2.7.6, a comparison was done between the researched developed systems. This demonstrated that the online environmental system was the most suited for the study. Therefore the online environmental system will be utilised for this study.

The system is web based which makes it easily accessible. The users are split in two, being the environmental representative and the environmental management. The access to information is restricted between this split. Additionally, these two groups gain access through their internal organisation network into the web-based system.

Each mine has a dedicated environmental representative. The responsibility of this employee is to collect, capture and verify the data for the specific operation. All records of the mines activities relating to KPI's, must be stored and processed by the representative.

The representative reports to the environmental manager, who is dedicated to a mine or group of them. The main responsibility for the environmental manager is to verify all environmental results and to react to the risks and responsibilities of the mine.

Restriction is controlled by credentials and password security at the homepage of the system. Once logged in, the environmental management can view all information, but the environmental representative can only view information for their specific mine. The homepage referred to is represented in Figure 20.

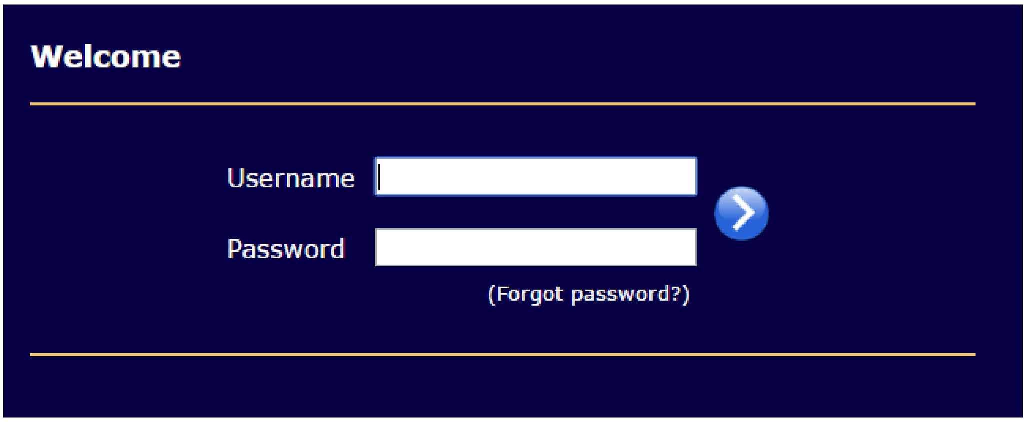

Figure 20: Homepage of environmental system (taken from [50])

After the user has logged in, they can easily navigate within the system through bubble icons. The specific icons being used for the environmental data are the overview and operations icons. An example of the configuration of the following page is given in Figure 21.

Figure 21: Configuration of the environmental system (taken from [50])

The overview icon is the icon where access is restricted to only environmental managers. The operations icon is the main function for the environmental data inputs, and is used mostly by environmental representatives. After the operation icon has been selected, the following page shows the tree structure being utilised by the system for input and storage. The web page is illustrated previously in Figure 15. [50]

The web page represented in Figure 15 makes use of a tree data structure to configure the gold mine's reporting. Tree structured data is used because of proven convenience and effectiveness in storing and retrieving data [94]. An example of a gold mine's configuration is represented in Figure 22 below.

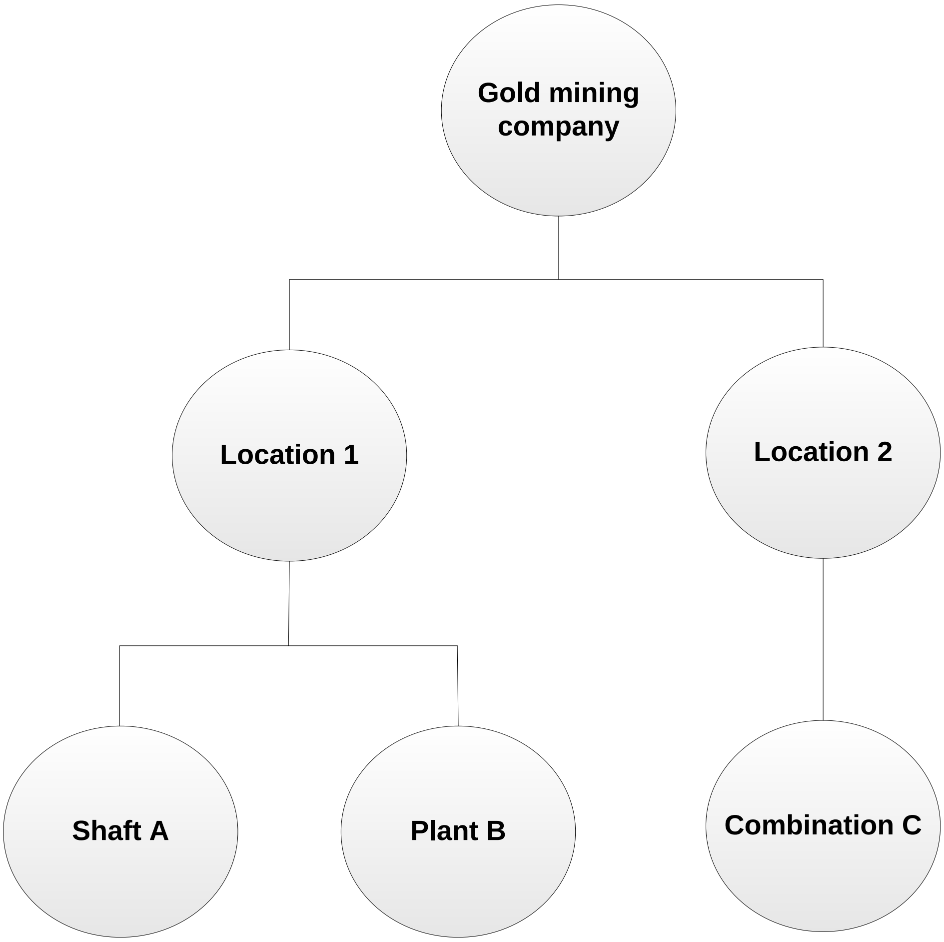

Figure 22: Example of gold mines' business tree structure

In Figure 22, the tree structure demonstrates the gold mine as the root node. The parent nodes are grouped by the location or function of the multiple operations. The leaf nodes represent the operations. Of course, multiple levels can be constructed depending on the company's configuration. The leaf refers to the final node in a link. In Figure 22's example, shaft A, plant B and combination C are the leaf nodes. The leaf nodes store all the information being reported by its corresponding operation.

The KPI's are then stored on the leaf nodes which are linked to another tree structure. The other tree structure is framed differently because it has multiple parent nodes in its structure. The parent nodes in this tree structure are the grouped indicators, and the leaf nodes are the KPIs themselves. The advantage of this structure is the KPIs can be summed up automatically for the complete gold mine. An example KPI tree structure is given in Figure 23 below.

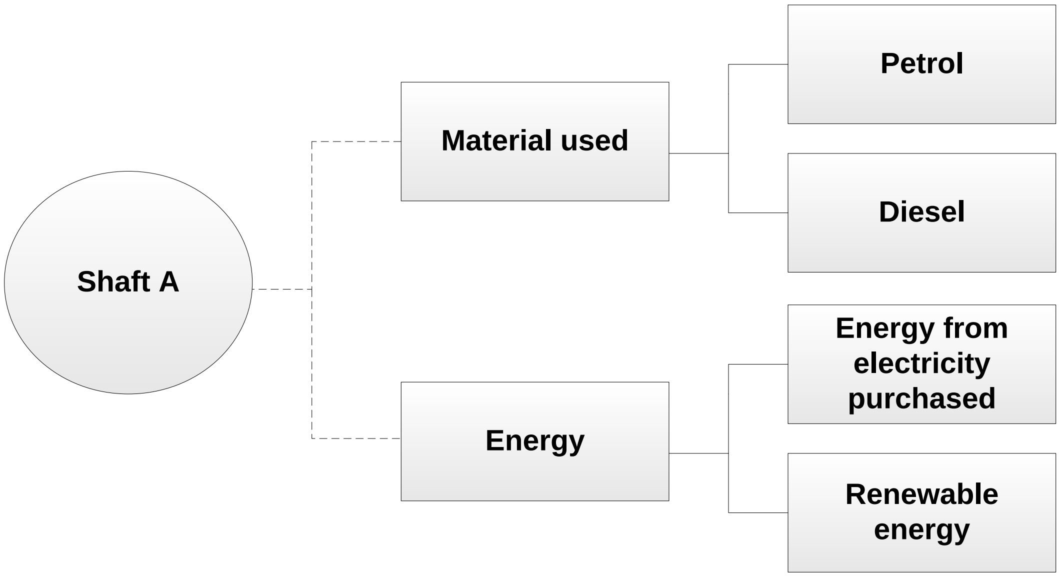

Figure 23: Tree structure link between operation and KPIs

Each of the KPI nodes is linked to three strings. Each month of the financial year has three strings that must be completed. The three strings are the actual value of the KPI, the target value for the KPI and the reason behind the actual value. Both the target and reason strings were added as error prevention strategies.

Targets are set based on the previous year's assured values. The calculation for these targets is used as a management strategy to lessen the use of material per operation. The reduction percentage is one percent from the previous year. The equation used to calculate the target is given in equation (4) below.

$$KPI_{present} = KPI_{last\ year} \times (1 - z_{percentage\ reduction}) \quad (4)$$

An alert is activated when the actual is above the target. This ensures that personnel double check their own work before entering the values. The alert compels the user to provide a reason for the KPI being above its target. The reason is stored and acts as evidence for the user.

The reason can be completed each month but only becomes compulsory when the alert is activated. These features act as an error prevention strategy to ensure the user transfers the correct information.

Once the entries have been saved, a further prevention strategy is used by upper level management. This is done by the presentation of the actual monthly values using cell colours to indicate whether the actual values are above or below target. Red is used to indicate values above their target and green indicates those below their target. Thus, upper management personnel could use this system to pick up abnormalities using the graphics generated by the system. The prevention strategy and the web page configuration for the KPI's, is represented in Figure 24.

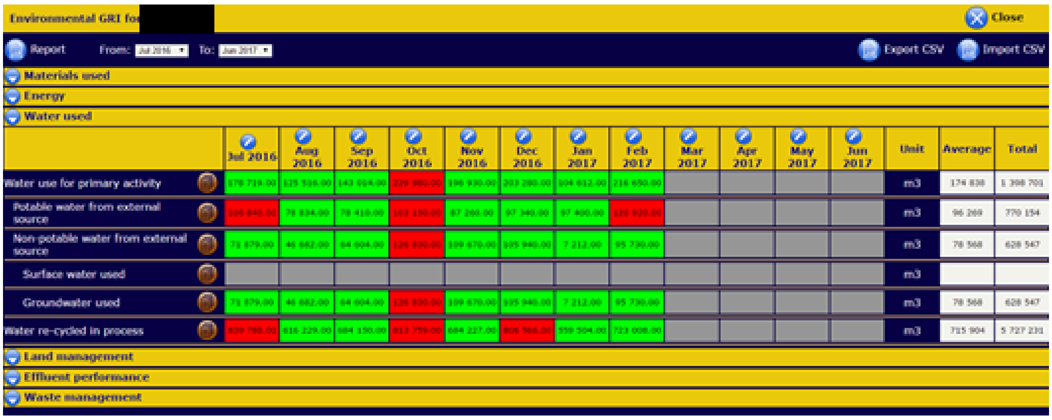

Figure 24: Prevention strategy of system (taken from [50])

Collecting the reporting chains documents is done by using the same KPI and operations tree structure platform. The tree structure links the document manager directly to a specific KPI and operation. This link allows the user to access only documents that relate to the selected operation and KPI on the system. The activation of the document manager is done by clicking an icon next to each KPI name on the display.

Gathering the data and source documents is done according to a standard schedule. The schedule ensures a standard guideline for the environmental representative to follow for each operation. An example of a standard schedule to follow would be where, at the end of each month, all KPI's reported data and supporting documents would be uploaded onto the system. This will be completed for a full financial year.

The environmental representative at each operation is the environmental officer. The representative has the responsibility of reporting all KPIs on the system and submits reporting chain documents. The documents are not always on hand or understood by the environmental representative. Therefore, the reporting chain must be communicated to the representative. This ensures the correct data and documents are collected.

Environmental representatives must follow the standard schedule to ensure appropriate time management of the system. When considering the time management of the system, certain elements must be considered. These elements are: when can supporting documents be collected; when can the final value be reported; what periodic limits can be implemented; and the human factor. All these elements will be addressed in the discussion below.

The collection of supporting documents can begin at the start of the reporting month. This is due to early issuing of invoices and other forms of payment in the reported month. Yet the collection for most of the reporting chain documents will only begin in the preceding month due to the compiling and calculations needing completion before documents can be collected. Once all supporting documents are complete, the KPI final value can be reported.

A limitation on the schedule for submission of the KPI's entered, and the supporting documents must be implemented. The limitation indicates when the verification procedure can begin because all required information is available. If there is missing information once the limit is reached, a more authoritative approach is needed.

To account for human factors, multiple reminders will be implemented. The reminders will be for both the reporting of values on the web-based system and the submission of supporting documents. All of these elements will be considered in the final standard schedule.

3.4 Verification procedure

The two main methods of verification found in the literature will be used – the proofreading verification method and the double-entry verification method. Both of these verification methods are used to eliminate errors in the reporting chain.

Before errors can be eliminated their origin points must be identified. Based on the generic reporting chain, the typical origins for errors are illustrated in Figure 25 below.

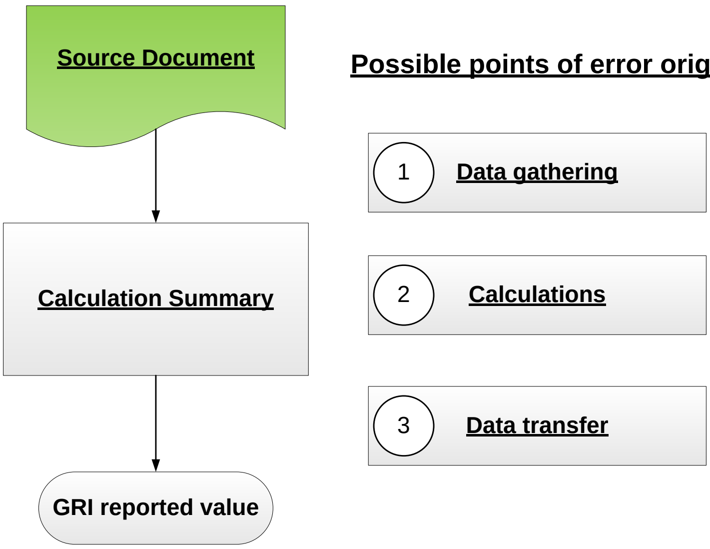

Figure 25: Typical origins of errors

Figure 25 indicates the typical origins of errors in the reporting chain. The study categorises all of the typical errors into three groups, namely, data gathering, calculations and data transfer. Data gathering is specific to errors originating from the transfer of information from a source. Group calculations are errors originating from mistakes in calculations. Data transfer refers to errors originating from data transfer that does not come from sources.

Each of these points can be addressed with verification methods. Proofreading verification will be used to verify the data gathering. Double entry will be used to verify the calculations and data transfer.

An independent reporting chain will be constructed to employ these verification methods. The study refers to the independent reporting chain as the mirrored reporting chain. This reporting chain will receive information directly from source documents. In addition, all transfers and calculations will be done electronically to replicate the original reporting chain. This facilitates the use of both methods of verification and eliminates the potential of errors.

Additional error preventions will be implemented by applying conservation laws within the mirrored reporting chain. The mirrored reporting chain uses the laws to simplify all calculations and source data gathering. In addition, it will ensure the conservation of both matter and energy. The conservation of mass law states that mass cannot be created or destroyed during a process. The conservation of energy law states that energy cannot be created or destroyed. [95]

Based on these laws we can derive the following equations (5) and (6). Equation (7) is derived from equation (6). The first assumption used is that the density of the resource used will remain constant. It is safe to assume this when considering the resource does not change density when being recorded in the reporting chain. Furthermore, the rate of a resource entering and exiting the recording system is assumed to be constant. This assumption is suitable due to the quantity being recorded, not the rate. Equations (5), (6) and (7) are given below.

$$E_{in} = E_{out} \tag{5}$$

$$\dot{m}_{in} = \dot{m}_{out} \tag{6}$$

$$V_{in} = V_{out} \tag{7}$$

The use of the conservation laws within the mirrored reporting chain is indicated in Figure 26, and the combination of original and mirrored reporting chains with the verification methods are demonstrated.

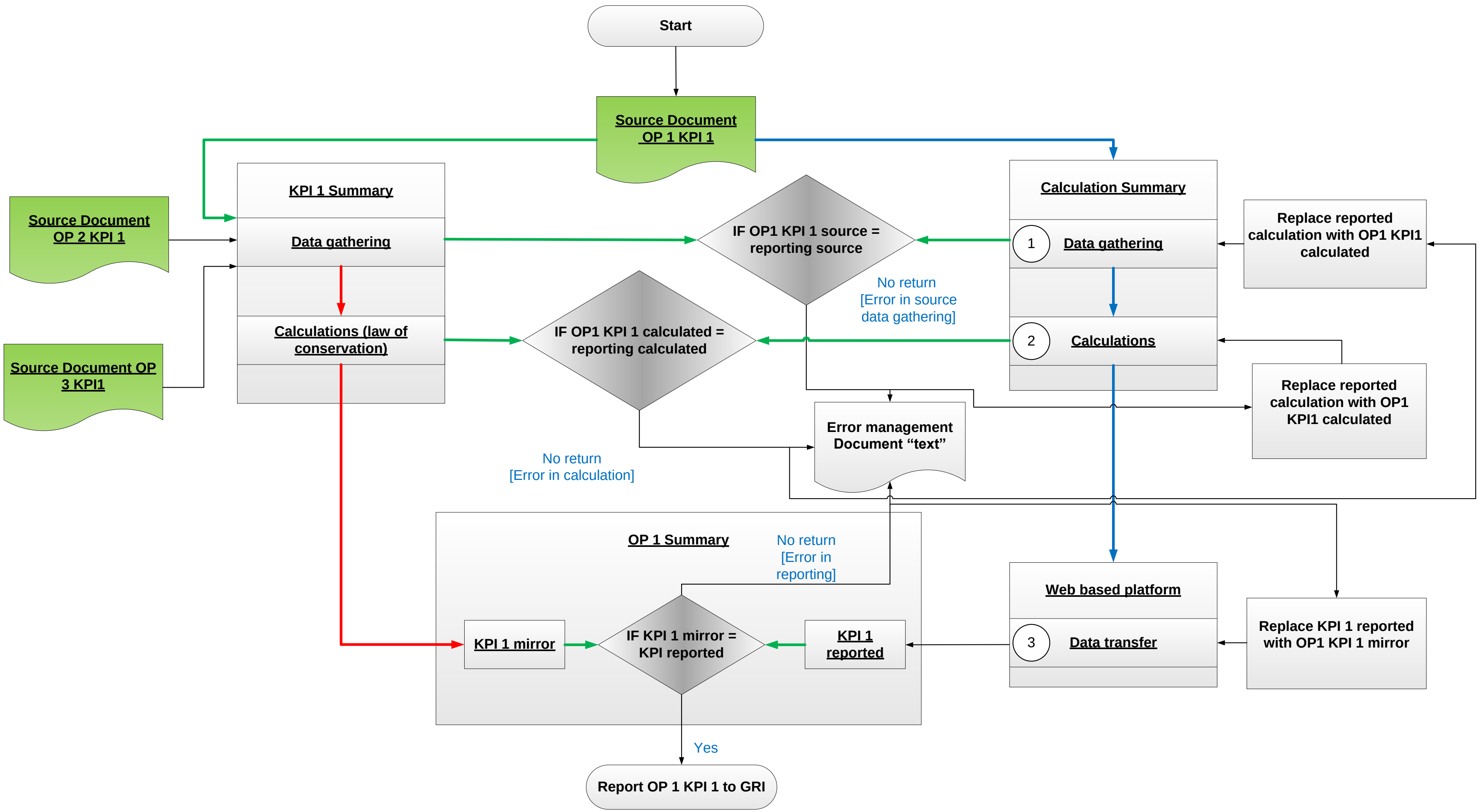

Figure 26: Verification procedure for a generic reporting chain

The verification procedure in Figure 26 demonstrates the use of verification against the origin points of error prevention. This procedure can only begin once all the tasks in the standard procedure are completed. The procedure is demonstrated for one reporting chain's KPI.

The blue arrows indicate the original gold mine's reporting chain. The reporting chain has been altered to graphically display the origin points of error given in Figure 25. In addition, the web-based platform has been added in the chain.

The red arrow indicates the mirrored reporting chain. The mirrored reporting chain was developed to verify and mirror multiple reporting chains. This was done by making KPI summaries which gather and calculate the information from multiple operations, after which each KPI is summarised in operations summaries. This configuration allows multiple verifications to occur simultaneously across all the environmental KPIs.

All forms of verification are indicated with green arrows on Figure 26. The verification procedure will be discussed from the perspective of the mirrored reporting chain. The procedure begins with a source document used in an example reporting chain. The first form of verification is applied by capturing information directly from the source, proof verification, then double-entry verification is applied to the data gathering section by comparing the original reporting chain and the mirrored reporting chain.

The double-entry verification is based on a logic diagram. The logic diagram compares the values gathered from the source documents of the two reporting chains. This comparison allows for minimal deviation based on manual entry, where the personnel might round off numerical data. This deviation is specified using relative error. The relative error must be less than a unit, which allows for rounding off. This is represented in the equation (8) below.

$$\left|x_{reported} - x_{source}\right| > 1 \qquad (8)$$

After the double-entry verification has been completed, the same method will be applied to the calculations section of the summary. This verification method compares the outcomes of the two calculations from the two different reporting chains. The logic diagram for this comparison is the same as the previous one by using equation (8). Both of these verifications were done in the KPI summary.

The information in the mirrored reporting chain is then transferred to the operations summary. Once again, double entry is used to verify the final reported KPI. The comparison is then made against the web-based platform's reported value. Equation (8) is once again used to determine how much deviation is allowed between values.

If the values from the gold mine's reporting chain have gone through each double verification and abide by equation (8) limits, it can be finally reported to the GRI since the accuracy of the value has been confirmed.

If the condition for the final verification is not met, that value will not be reported. Rather, the error management and corrections will be done on that value which will be discussed in the next section. This process will then be repeated until the value is reported.

3.5 Documentation and error management

This section deals with the documentation of the procedure outputs and the error management. The documentation is used to document the improvement of the gold mine's reporting chain. The error management deals with communicating the errors identified and then correcting them accordingly.

The documentation is broken up into three parts: the qualitative, quantitative and discrepancy of data quality. The quantitative involves recording the actual quantities. These are the final KPIs recorded by the web-based platform and the mirrored reporting chain. The documentation of these values occurs in the operation summary mentioned previously. An example is given below in Table 13.

Table 13: Example of output for operation M

Operation M	**Jul-17**		**Units**
GRI category	**Mirrored reporting chain**	**Gold mine reporting chain**	
Energy from electricity purchased	100	100	kWh
Water used for primary activity	100	88	litre
Accumulated tailings in tailings dams	100	100	tonnes
Accumulated waste in rock dumps	100	42	tonnes
Petrol	100	100	litre
Diesel	100	72	litre
Explosives	100	100	tonnes

These values are recorded for reporting purposes and for determining the amount of deviation. The deviation is gauged by determining the percentage error. The percentage error considers the mirrored reported value relative to the original reported value. The percentage error is calculated in equation (9) below.

$$PE = \left|\frac{x_{reported\ value} - x_{calculated\ value}}{x_{calculated\ value}}\right| \times 100\% \qquad (9)$$

The qualitative documentation records the number of errors identified by the verification methodology. This documentation is recorded by the double-entry checking condition indicated in Figure 27. This recording is done periodically and it is only recorded before any corrections are made. By doing so, it demonstrates the number of errors originating from the gold mine's reporting chain. A tracking matrix will be used to record this information. An example of a tracking matrix is given in Table 14 below.

The matrix records the reported GRI condition as a "V" which denotes 'verified'. The not reported condition is recorded as a "PV" which represents 'partially verified'. Colour coding was used for further graphical description. The "V" is represented by a green shaded block and "PV" is represented by a red shaded block. It is important that not only the condition is recorded but also what operation and category that specific recording is taken from.

The discrepancies of the data quality are broken up into two parts. The first is documenting the discrepancies and second is correcting the errors found. Both of these parts are addressed in the verification methodology. In Figure 27, these parts are graphically represented in the developed methodology.

Table 14: Example of recording matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	PV	V	V	V	V	V	V	V	V	V	V	V	V	V
Diesel	PV	V	V	V	V	V	V	V	V	V	V	V	V	V
Explosives	PV	V	V	V	V	V	V						V	V
Energy from electricity purchased	PV	V	V	V	V	V	V	V	V	V	V	V	V	V
Potable water from external source	PV	V	V	V	V	V	V	V	V	V	V	V	V	V

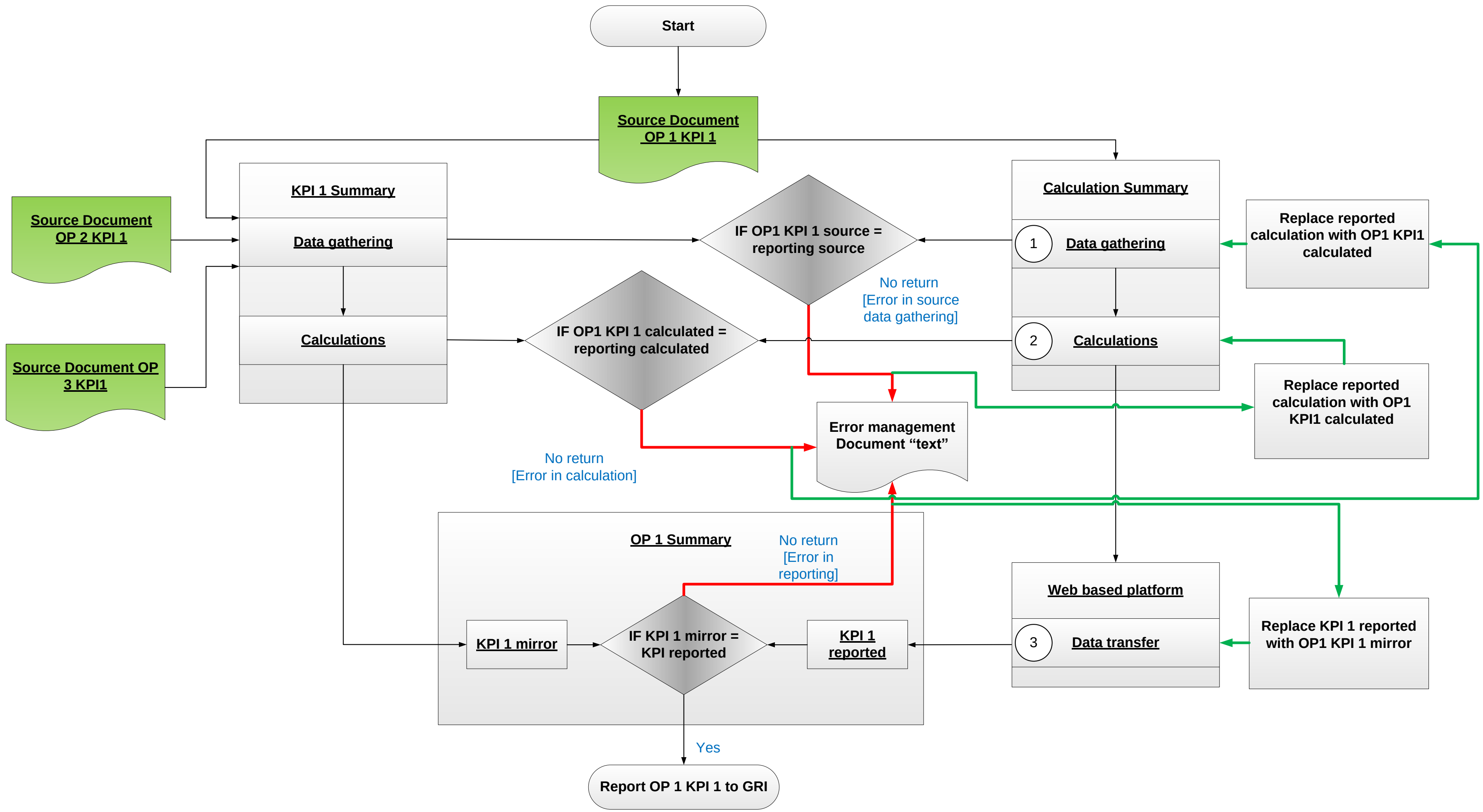

Figure 27: Verification methodology error management

The two different processes for discrepancies are separated in the verification methodology given in Figure 27. The red arrow indicates the transfer of information from the logic diagram to an error management document. This error management document represents the compiling of the discrepancy report. The green arrow represents the parallel path of corrections, which occur after documentation has taken place.

The documentation of discrepancies begins once equation (8) has not been met for any of the logic diagrams. The error management document records the operations' KPI, and the quantitative value of both reporting chains. The location of the error is determined by the specific logic diagram that was not met. All this information is compiled together in a discrepancy report. This report is communicated monthly to all the responsible personnel. The responsible personnel must then further investigate the reasoning for the discrepancies and confirm or reject the source-generated values. An example of a discrepancy report is given in Table 15.

Table 15: Example discrepancies report

Operation	Category	Reported	Source	Unit
A	Energy from electricity purchased	10	100	kWh
	Accumulated waste in rock dumps	40	100	tonne
	Petrol	50	100	litre
B	Energy from electricity purchased	10	100	kWh
	Accumulated waste in rock dumps	40	100	tonne
	Petrol	50	100	litre

After the errors have been documented, the correction of these errors can begin. Each logic diagram has a split in the path represented by a green arrow that goes to its corresponding error origin point. This path then corrects the reporting chain by substituting the mirrored with the original reporting chain. The mirrored value is the more credible value, due to all the error preventions implemented. This is sequentially done from the top down to ensure each problem is addressed in the original reporting chain. The procedure is then repeated constantly until all the errors have been corrected and all the KPIs have been reported to GRI.

3.6 Conclusion

Each stage of the methodology was successful in providing valid information for the study. The reporting process investigation identified all reported environmental performance indicators and gave a generic, simplified form of a reporting chain. A centralised web-based platform was developed for the information collection system for the final recording of environmental reported information. The verification procedure verified the generic reporting chain's output. The documentation and error management deals with the documentation of reported values and communication of errors.

The reporting process shortlisted the KPIs which were most critical, after which each of the critical KPIs reporting chains was further investigated. This highlighted each dependent document in the chain, more specifically, the source document. Each of the outputs of the reporting and their document must be collected in the information collection system. This section deals with building a web-based tree structure platform that suits the KPIs being reported. In addition, preventative measures will be made use of to eradicate errors. The information system also developed a timeline process for the submission of information in the form of a Gantt chart.

The verification process uses the two main forms of verification. This is done by building an independent reporting chain using the source documents of the previous system. The process also added documentation points in the system that are discussed in the documentation and error management section. This section focuses on documenting both the impact of errors and the number of errors. The management of errors makes use of the communication of errors to improve the original reporting chain.

4 Results

4.1 Introduction

In this chapter, the adapted PDCA cycle for accurate environmental data reporting was implemented on a South African gold mine. The reporting chain was investigated to indicate the source documents and the points of communication. All reported information was centralised by operation on a web-based platform, and the source documents identified in the reporting chain were collected. An independent reporting chain was made with the source document equations. Double entry was used to compare the web-based values with source document results. The results are documented and errors communicated to the responsible person.

The validation of the results was done by confirming the reduction of the number of errors and the impact of each error. The impact of each error from the methodology is verified against the assured annual values. The reduction of the number of errors is verified by using literature from organisations' disclosed values.

The validation of the objectives is broken into the number of errors and the impact of these errors. The impact of errors makes use of percentage errors as a comparison between originally reported values and the outcome of the verification procedure. The number of errors is made up of the number of errors identified per month. The identification of errors is recorded in the tracking matrix. Further insights will be derived from these results.

4.2 Implementation

The developed PDCA methodology was implemented on a gold mine, with the specific reporting chain documentation focussed on a single operation referred to in this study as operation M. The financial year of implementation was from July 2016 to June 2017. The total number of operations considered in the procedure was 14 of the 16 units. Two of the business units were not included due to their location and a lack of reporting infrastructure.

4.2.1 Reporting process

The first selection of the KPIs was based on the assured KPIs selected by the gold mine company. The KPIs that were assured are given in Appendix A in the form of an assurance report, after which a further reduction in KPIs was achieved through the understanding of the defining report content principles. The first step of the selection process was a discussion between the authors' different views. The discussion consisted of a cross-evaluation between the content principles and each KPI being assured.

Based on the discussions, a rating matrix was compiled. The matrix sums up the total strength of relationships between the KPI's and the content principles. This rating is purely based on the discussion outlined in the previous section. Therefore, it can be used to prioritise the selection of KPIs. The rating matrix is given below in Table 16.

Table 16: Rating matrix

KPIs	Stakeholder inclusiveness	Sustainability context	Materiality	Completeness	Total
Total Scope 1 Carbon Emissions (tCO2e) Note: Quantities before conversion to (tCO2e)	3	2	2	3	10
Total Scope 2 Carbon Emissions (tCO2e) Note: Quantities before conversion to (tCO2e)	3	2	2	3	10
Total Scope 3 Carbon Emissions (tCO2e) Note: Quantities before conversion to (tCO2e)	3	2	2	2	9
Volume of mineral waste disposed (tonnes)	3	2	3	3	11
Electricity purchased (kWh)	3	3	3	3	12
Water used for primary activity (kilolitre)	3	3	3	3	12
Land rehabilitation (Hectare)	2	2	1	3	8

When considering the rating matrix outcomes, two KPIs can be eliminated from the list to ensure a more efficient procedure. The two indicators that can be eliminated are land rehabilitation and the scope 3 carbon emissions.

Therefore, the final KPIs that were selected are: scope 1 emissions; scope 2 emissions; mineral waste; electricity purchased; and water used for primary activity. When considering the dependant indicators, the final set of selected indicators will be slightly altered. This is due to electricity purchased being a dependant indicator for scope 2. In addition, scope 1 is comprised of three dependant indicators: petrol, diesel and explosives. Also mineral waste is broken up into accumulated tailings in tailings dams and accumulated waste in rock dumps.

The final selected KPIs are given in Table 17 below. In addition, a brief explanation of these KPIs is given with their corresponding International System of Unit.

Table 17: All performance indicators that are reported

Categories	Explanation	SI Symbol
Energy from electricity purchased	Total amount of electricity purchased from the supplier. This excludes the electricity supplied to the third party users.	kWh
Water used for primary activity	Total volume of water that is drawn into the boundaries of the operation from all sources (including surface water, groundwater, rainwater and municipal water supply). This excludes internally recycled water, water discharged to the environment and supply to third party users such as communities and businesses.	m^3
Accumulated tailings in tailings dams	Total amount of slimes produced by the plant and pumped into the slimes dams.	t
Accumulated waste in rock dumps	Amount of waste rock produced and hoisted from the shaft to be added to the waste rock disposal sites.	t
Petrol	Fuel used for machinery and transport at the operation.	l
Diesel	Fuel used for machinery and transport at the operation.	l
Explosives	Materials used to blast rock underground.	t

After the selection of the KPI’s, the investigation into reporting chains began. Due to the sheer number of reporting chains, only one reporting chain is used. All the reporting chains are extremely similar; therefore, it is feasible to only demonstrate one of them and explain the differences between others.

The difference between operations is the amount of the water and electricity accounts. This is due to accounts being separated between areas when the operations are situated on both. Similarly, the number of third parties for both water and electricity differ. Some third party companies have agreements that include the billing for water and electricity. Therefore there will be no issued invoice to the third party.

The number of invoices and accounts may differ and will not be stated in the reporting chains illustrated. All the reporting chains are given in Figure 16 below.

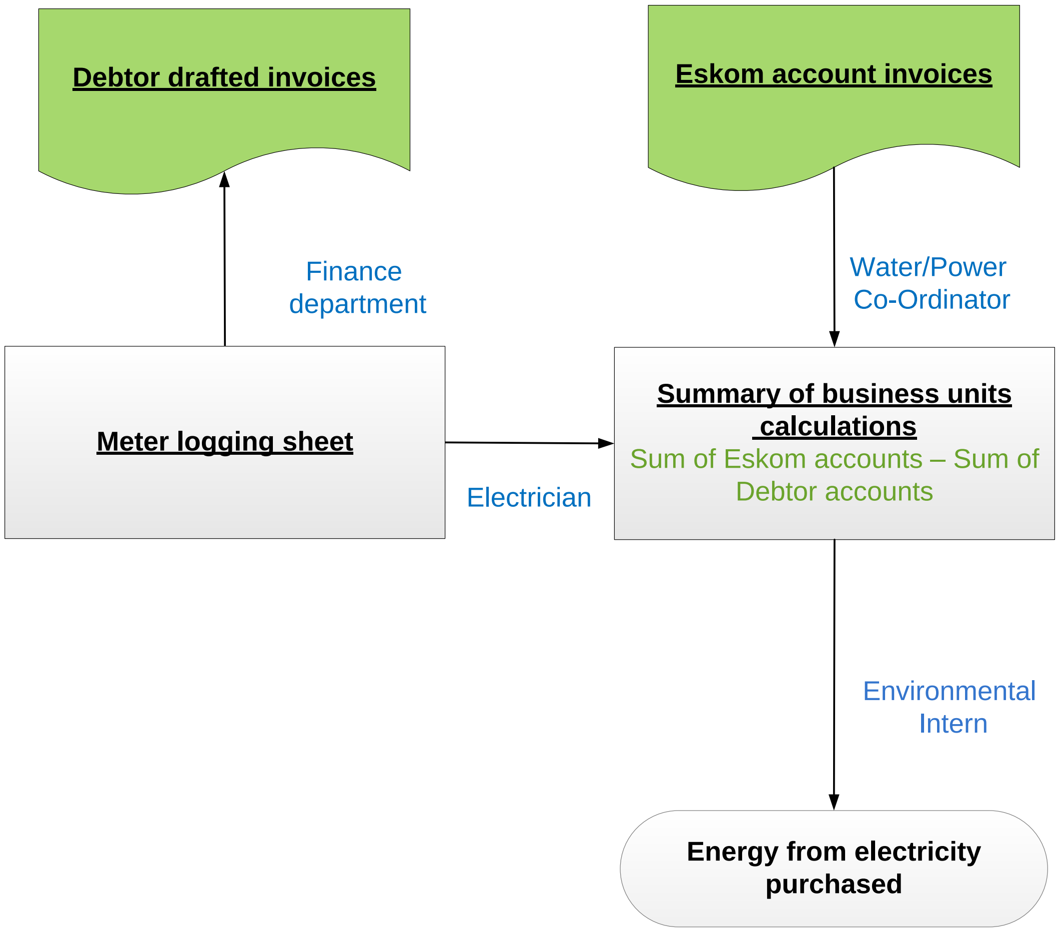

Figure 28: Energy reporting chain

The first of the performance indicators that was investigated was energy from the electricity purchased in Figure 28. The energy reporting chain begins at the electricity provider's invoice. Then the power coordinator documents the energy consumption for that specific month. The electrician begins reading the meters for each third party energy consumer and then simultaneously communicates the consumption to the finance department and power coordinator. Once all the information has been gathered, the water coordinator completes the compiling of the calculation summary. The environmental intern reports the outcome of the final energy consumption. Additionally, another outcome is the compiling of invoices to third party consumers.

The two main source documents considered by the study are the Eskom accounts and invoices drafted by the gold mine. The debtor invoices were selected as a better source due to it being a contract between two entities, although the meter logging sheet is the point of origin. Examples of both the Eskom account and drafted third party invoices are given in Appendix D.

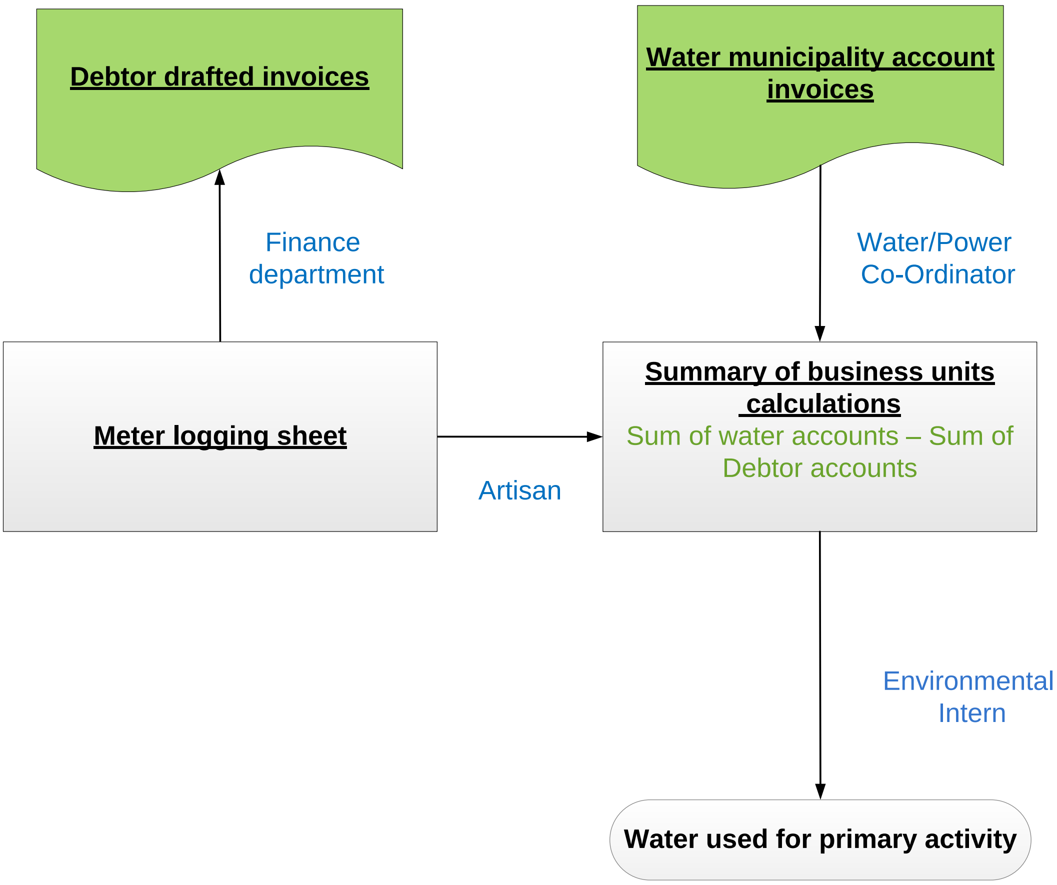

Figure 29: Water reporting chain

The performance indicator being investigated is the water used for the primary activity reporting chain. The reporting chain is given in Figure 29. The reporting chain starts at the water provider's invoice, which was sent to the water coordinator. The coordinator begins compiling a summary document. The artisan collects the data from each third party consumer's meter on a logging sheet. This logging sheet is simultaneously sent to the coordinator and the finance department. The finance department invoices the third party consumers and the water coordinator completes the calculation summary. The two outcomes of the reporting chain are the invoices to third party consumer and the final value that represents the operational water consumption.

The two main source documents considered by the study are the water provider's invoice and invoices drafted by the gold mine. Once again the debtor invoices were selected as a better source due to them being a contract between two entities, although the meter logging sheet is the point of origin. Examples of both invoices are given in Appendix D.

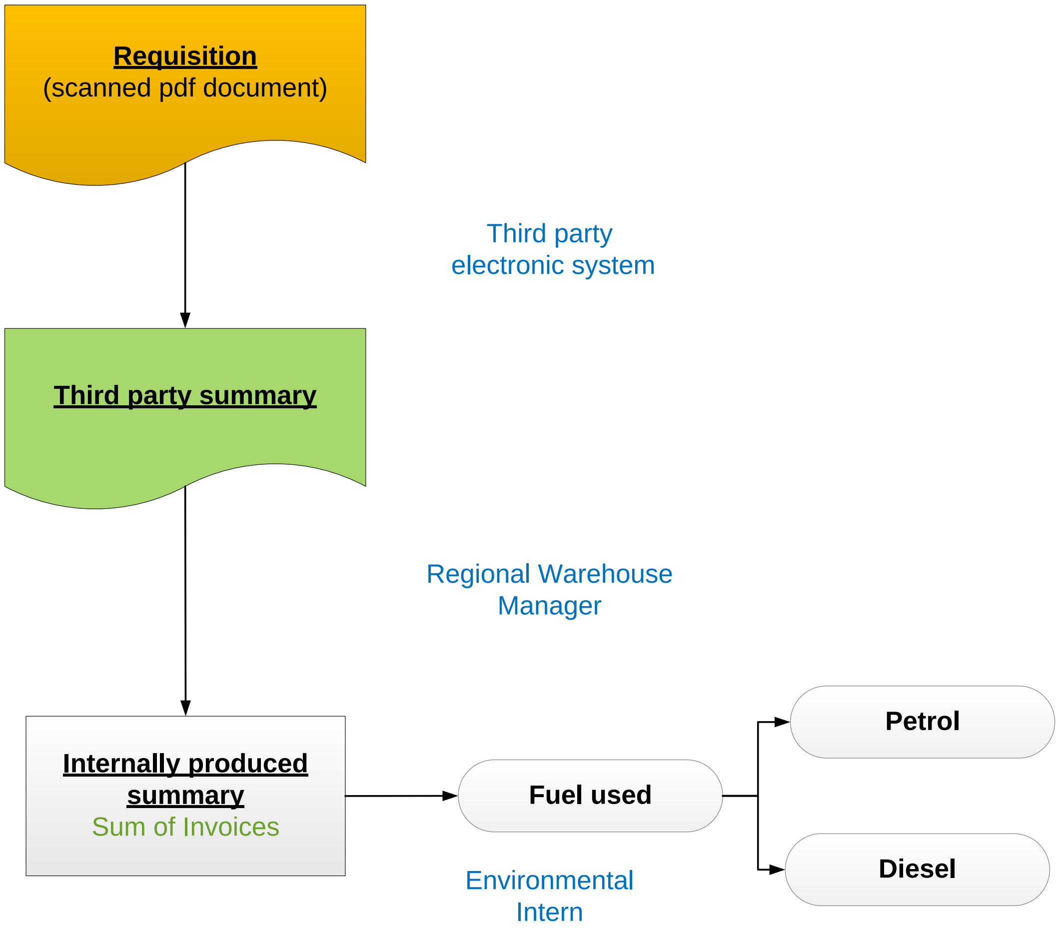

Figure 30: Fuel used reporting chains

Petrol and diesel have the same reporting chain referred to as a fuel used reporting chain. The fuel used reporting chain is given in Figure 30. The reporting chain begins with a requisition that is issued once an order is communicated for fuel. An electronic system then compiles a Microsoft's Excel document each month for each operation. The regional warehouse manager internally produces a higher-level summary summing up all fuel used. The environmental intern then reports the outcome of the fuel consumption.

The true source is the invoice drafted by the third party, yet the third party summary can be a considered better option due to it having much more information, and it being electronically generated makes it reliable. Thus, the study considers it as a valid source. An example of the invoice drafted by the third party company is given in Appendix D.

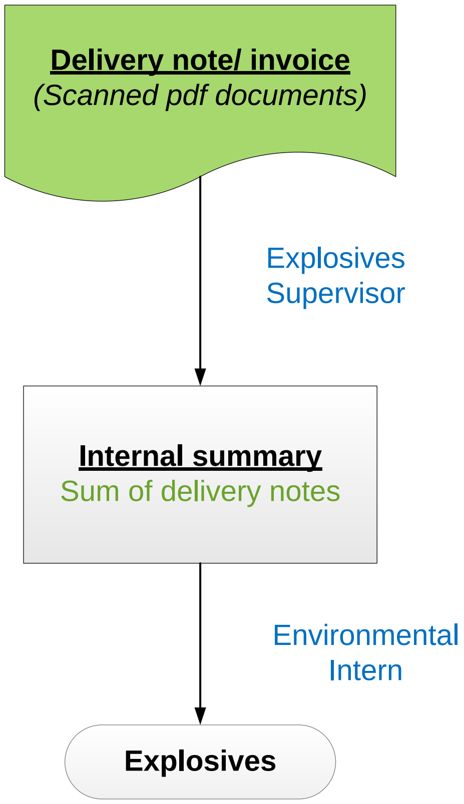

Figure 31: Explosives reporting chain

The explosives reporting chain is given in Figure 31. The reporting chain starts with the delivery note or invoice issued by a third party company. This third party company produces the explosives and sells them to the gold mine. The invoice or delivery note is sent to the explosives supervisor. The supervisor compiles an internal summary of the reporting duration. The total consumption of explosives is calculated in the internal summary. The total is sent to the environmental intern who reports the final consumption of explosives.

The source document in the reporting chain is the delivery note or invoice. The invoice and note are a valid contract between two entities, therefore, can be regarded as a strong form of source documentation. An example of the invoice is given in Appendix D.

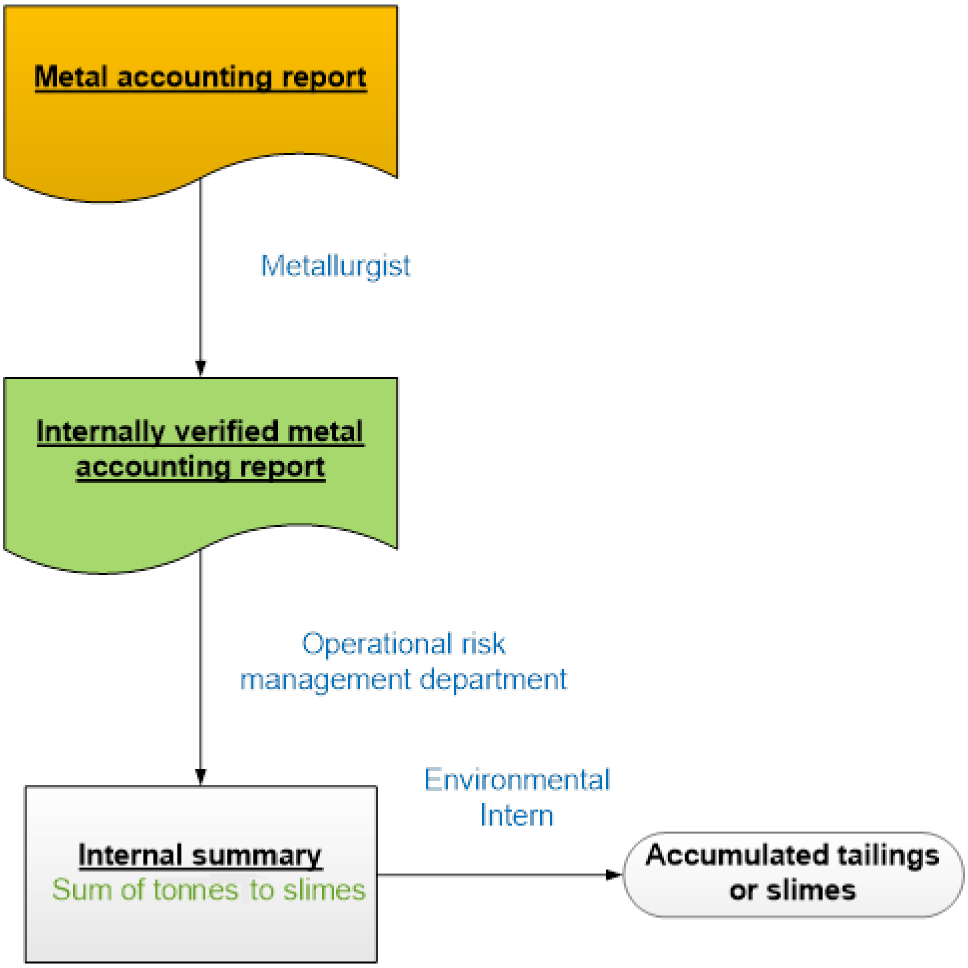

Figure 32: Tailings reporting chains

The tailings reporting chain is given in Figure 32. The metal account is the first generated document in the reporting chain. It is produced by an electronic meter system,that automatically populates an Excel document. This Excel document's information is emailed to the operational risk management department. The operational risk management department validates and consolidates the monthly values and issues an internal metal account. The department sends this information to the environmental intern. The intern then summaries this information in another summary. The outcome of the final summary is the final value for the number of tailings produced by the operation.

The first point of recording is the metal account report that should be considered the source document. Yet the internally verified metal account is considered to be the source for this study. This is due to values being consolidated from the metal account report if instrumental defects are detected.

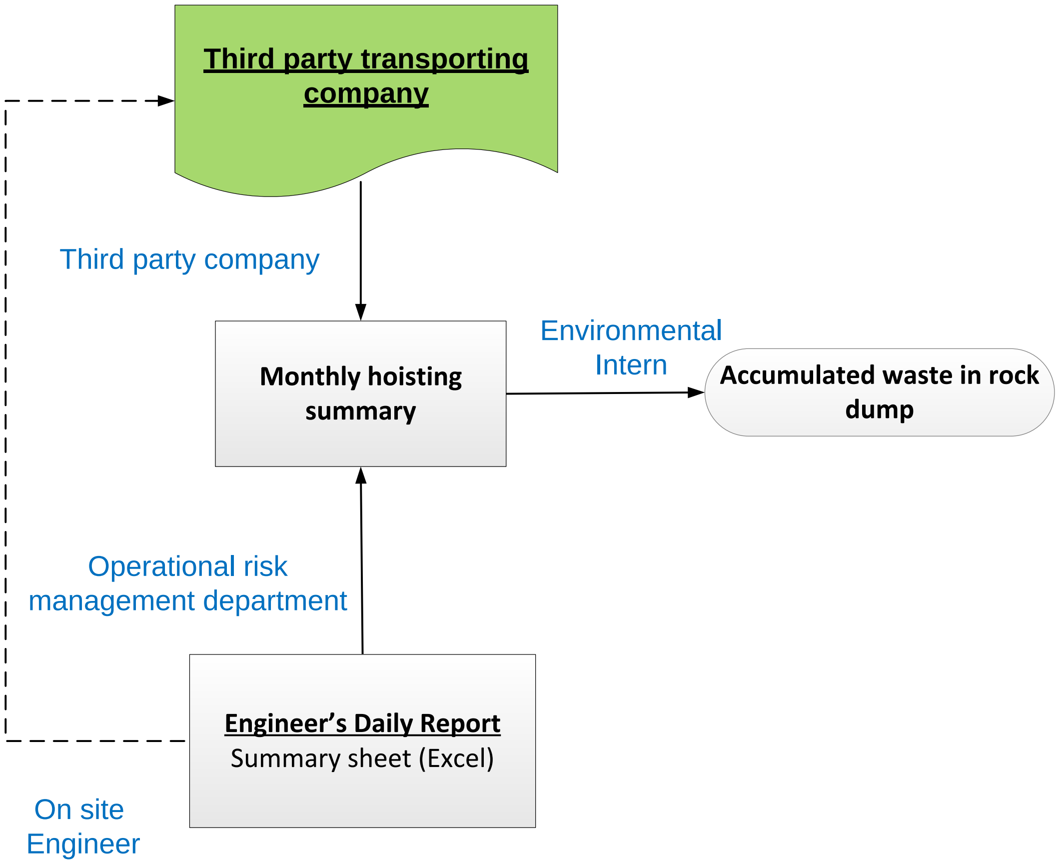

Figure 33: Waste rock reporting chain

The waste rock reporting chain is given in Figure 33. The reporting chain begins with the engineer compiling the daily report. The engineer simultaneously communicates to a third party company daily to transport the waste rock. After a month has passed, the third party company issues an invoice for the total tonnes of waste rock transported. Each daily report is sent to the operational risk management department. Both the third party company and the operational risk management department communicate the monthly waste rock to the environmental intern. The intern compiles a monthly hoisting summary and reports the monthly total. The outcome of this reporting chain is the monthly hoisted waste rock and the issued invoice by the third party company.

The strongest source document is the issued invoice by the third party company. This is due to it being a contract between two entities. Yet it was not the first point of recording given the engineer's daily report. The study still considers the invoice to be a stronger form of source document.

4.2.2 Information collection system

The outcome of the "Do" portion of the methodology is broken up into the collection of reported information and supporting documents. A web-based platform was used to centralise and collect reported information. The collection of supporting documents was achieved by implementing a standard schedule.

The web-based platform was based on an interlinked data tree structure. The two tree structures are an operation and KPI tree structure. The final configuration of the operation tree structure considers both the purpose of operation and location when it was developed. The final configuration of the business tree structure is given in Figure 35.

Additionally, the linked KPI tree structure is finalised because the selection of KPIs has been completed. A difference between KPI linked tree structures can occur due to differences in reporting, more specifically, between plants and shafts. The complete KPI tree structure was used for operation M. The complete KPI tree structure is given in Figure 34 below.

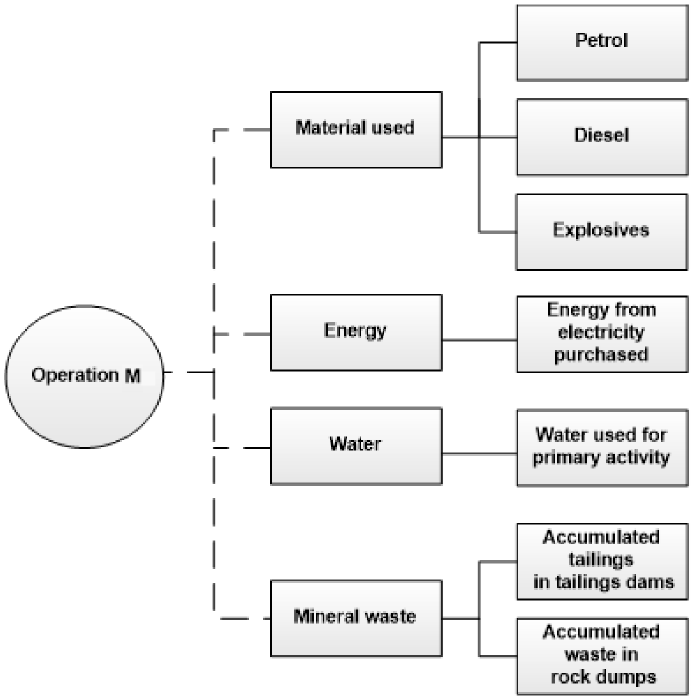

Figure 34: KPI tree structure

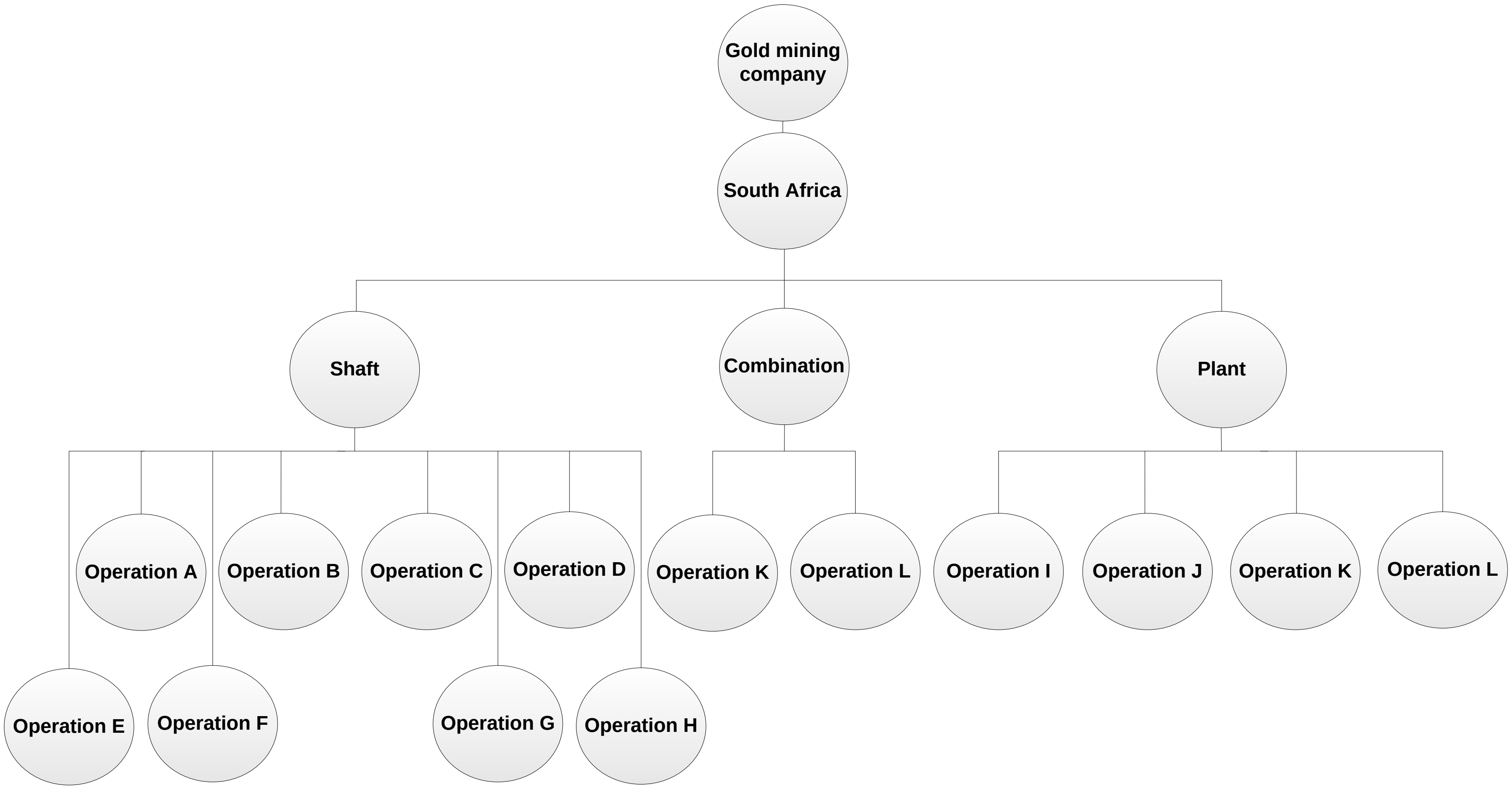

Figure 35: Business tree configuration

As mentioned in Section 3.3, both the reporting and collection of documents are stored on the tree structures. The next outcome of this section is the standard schedule for the collection of this information.

Figure 36 demonstrates the standard schedule for the first month of reporting. This schedule was followed every month in the financial year. There are seven potential reminders emailed to the environmental officer for the two-month schedule. The blue bar depicts the waiting period. The red bar represents the reminders. Only if there are outstanding documents or data, reminders will be sent. The schedule encompasses both the collection of supporting documents and web-based system reporting.

The schedule began with the collection of source documents. The first of the reminders initiated the submission of documents. Additionally it initiated the month waiting period for the documents to be submitted. After the waiting period, the next reminder was sent and another month waiting period began.

In parallel with the second reminder, a third was sent to initiate the web-based reporting which also marked the waiting period for reporting. The waiting period was ten days, followed by the fourth reminder for reporting. An additional waiting period of 20 days was added to the reporting on the web-based system.

The final reminders for the reporting and supporting documents are sent a month after the schedule began. The final waiting period is initiated for a period of four days for both collections. After that, if any documents or data are missing, upper management will be notified. The notification will inform the management about what has been received and what is still missing.

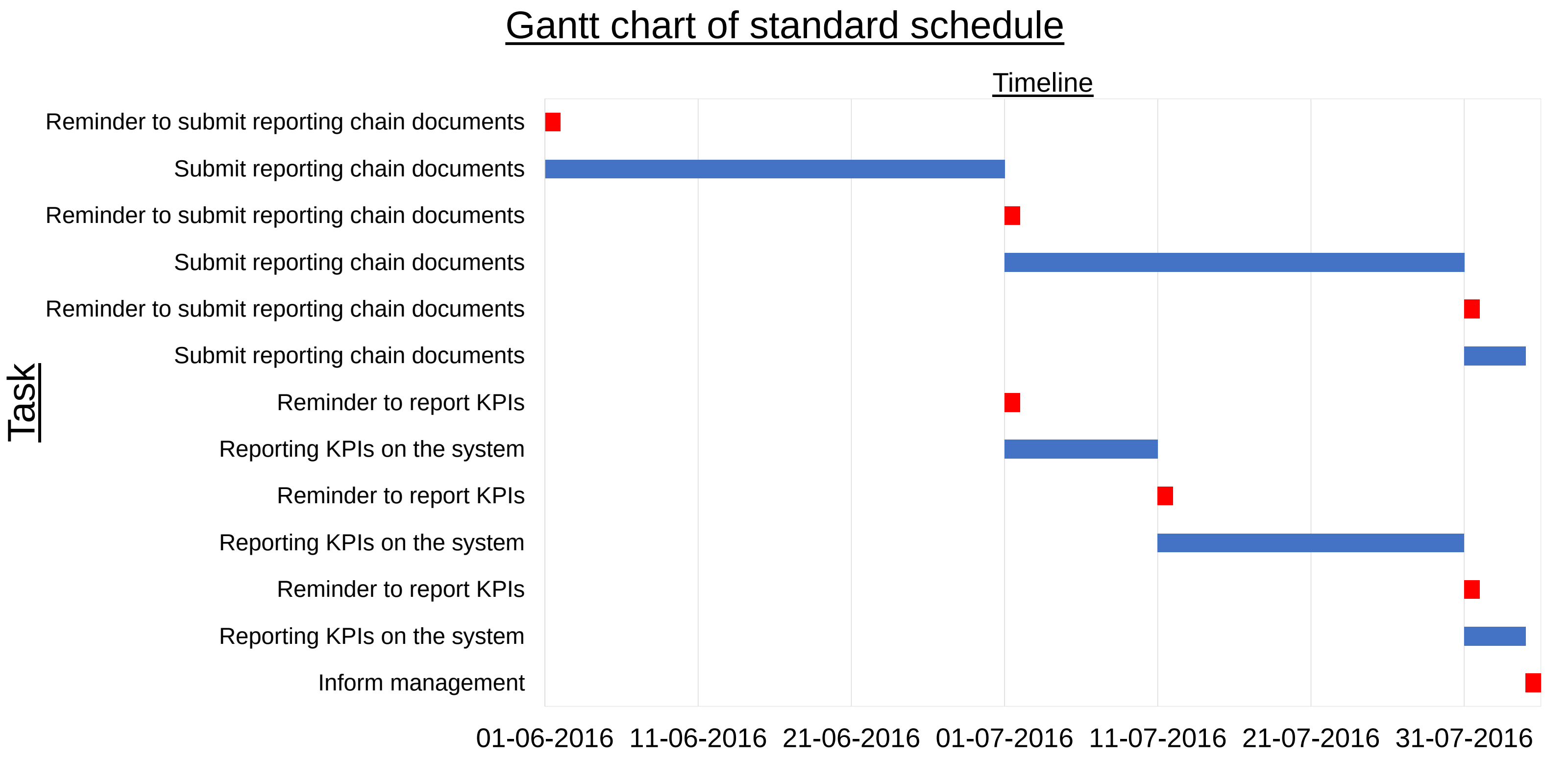

Figure 36: Gantt chart of standard schedule

4.2.3 Verification process

The first outcome is the identification of origin points for errors. The typical error points were applied to the reporting chains to determine all the points needed to employ the verification methods. The typical error points on a generic reporting chain are given in Figure 19.

As mentioned previously, the reporting chains for KPIs are very similar for each operation. The number of possible points where errors originate are consistent between operations, but differ between KPI's. Additionally, reporting chains did not change over the time of the financial year. Thus, the number of error origin points need only be determined for each KPI. The number of error points is indicated in Table 18 below.

Table 18: Number of possible error origin points per KPI

Reporting chain KPIs	Data gathering	Calculations	Data transfer
Energy from electricity purchased	2	1	1
Water used for primary activity	2	1	1
Accumulated tailings in tailings dams	1	1	1
Accumulated waste in rock dumps	1	1	1
Petrol	1	1	1
Diesel			
Explosives	1	1	1

The total number of origin error points for a single operation was 20. The total number of operations are 14.Therefore, the multiplication of 20 and 14 gives 280 points of verification in the gold mine's reporting chains. Each of these verifications must be considered in the construction of the procedure.

Additionally alterations will be done to the conservation laws. The alterations are done by altering equations (5), (6) and (7) to each KPI. The final product are equations (10), (11), (12), (13), (14) and (15).

$$E_{electricity\ purchased\ per\ operation} = \sum E_{Eskom\ invoices} - \sum E_{Debtor\ invoices} \tag{10}$$

$$V_{Potable\ water\ per\ operation} = \sum V_{Water\ invoices} - \sum V_{Debtor\ invoices} \tag{11}$$

$$V_{total\ fuel\ per\ operation} = \sum V_{fuel\ delivery\ note} \tag{12}$$

$$V_{total\ explosives\ per\ operation} = \sum V_{total\ explosives\ per\ operation} \tag{13}$$

$$V_{total\ slimes\ per\ operation} = \sum V_{daily\ metal\ account} \tag{14}$$

$$V_{total\ waste\ rock\ per\ operation} = \sum V_{daily\ hoising\ report} \tag{15}$$

Thus, the mirrored reporting chain was different for each indicator's reporting chain. In addition, the origin of the points of error change for each indicator's reporting chain, resulting in the verification procedure changing.

All the alterations made to the verification procedure to suit the energy indicator are depicted in Figure 37 for operation M. All the other KPI changes are given in Appendix E.

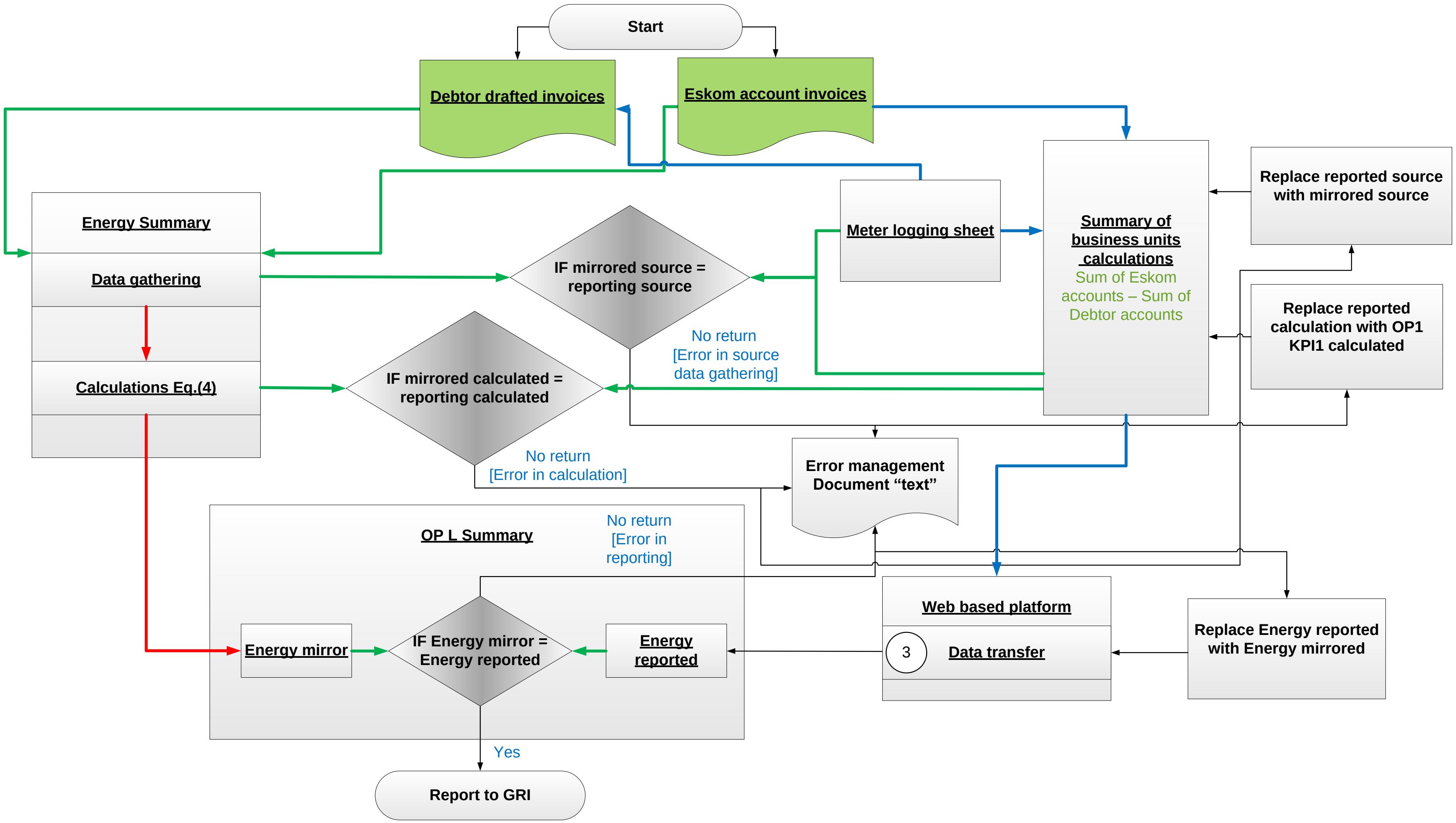

Figure 37: Operation M verification procedure for energy

4.2.4 Document and error reporting

As mentioned in the methodology, the results are based on documentation, documenting three outputs of the procedure – quantitative, qualitative and discrepancy of data.

The first output of the verification procedure deals with the quantitative output. The quantitative output is the actual values for the mirrored and original reporting chain. The final recording of these values is done in the operation summary. The first recording taken for the month of July is given in the table below.

Table 19: Output for operation M

Operation M	17-Jul		Units
GRI category	Mirrored reporting chain	Gold mine reporting chain	
Energy from electricity purchased	17 450 893.00	17 450 893.00	kWh
Water used for primary activity	83 618.00	67 826.00	litres
Accumulated tailings in tailings dams	109 483.76	109 483.76	tonnes
Accumulated waste in rock dumps	12 951.00	13 548.00	tonnes
Petrol	1 353.00	270.60	litres
Diesel	1 408.00	1 352.40	litres
Explosives	82.10	82.10	tonnes

These recordings are done for each month and every operation. Due to the massive number of outputs, only the first output for operation M will be given. This information was used to determine how much deviation is in the reported values.

The next outcome is qualitative. This outcome determines the number of errors identified by the methodology. The documentation was done sequentially each month before any corrections occurred. The documentation was done in the form of a tracking matrix. The first recorded tracking matrix for July 2017 is given in Table 20 below.

Table 20: July 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	PV	PV	V	V	PV	V	PV
Diesel	V	V	PV	V	V	V	V	PV	PV	V	V	PV	V	PV
Explosives	V	V	V	V	V	V	V						PV	V
Energy from electricity purchased	V	V	PV	PV	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	PV	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

The outcomes of the tracking matrix can be further evaluated. This is done by summing up all the “PV” and “V” conditions for each tracking matrix. The summing up of conditions leads to insight into the number of errors per month. Additionally, within a tracking matrix, columns and rows can be summed up. This leads to further insight into indicator or operations errors.

Error management follows after all the errors have been identified and documented. Error management consists of locating the error, correcting it and communicating. The locating and correcting of errors also change due to alterations made to the mirrored reporting chains.

The specific changes made to suit the error management for a particular KPI chain are given in Figure 38. All the other indicator changes in error management are given in Appendix E.

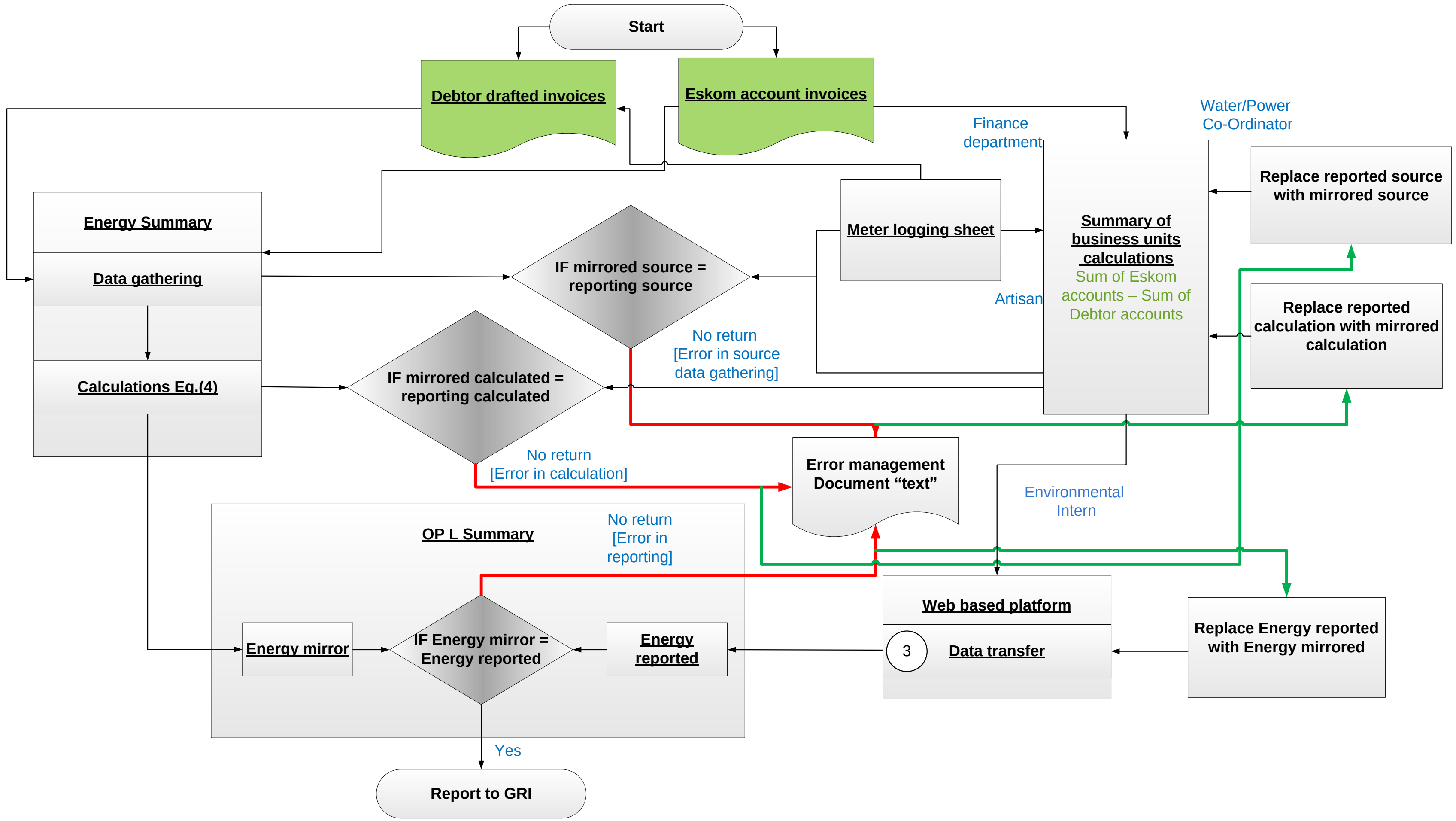

Figure 38: Operation M error management for energy

The final outcome of the procedure was the communication of the identified discrepancies. The communication of errors is done via a discrepancy report. The first discrepancy report issued for July 2017 is given in Table 21. All the other reports are given in Appendix F.

Table 21: July 2017 discrepancy report

Operation	Reported	Source	Unit	KPI
A	8 458	8 081	tonne	Accumulated waste rock to dumps
C	111 197	109 955	litre	Diesel
	15 451 223	16 849 039	kWh	Energy from electricity purchased
D	473	350	litre	Petrol
	11 948 345	12 414 625	kWh	Energy from electricity purchased
G	43 504	71 918	litre	Water use for primary activity
H	305.59	406	litre	Petrol
	188	1 702	litre	Diesel
I	411.98	928	litre	Petrol
	344	1 466	litre	Diesel
L	404	3 269	litre	Petrol
	1 511	381	litre	Diesel
	30 655	19 654	litre	Water use for primary activity
M	63 675	63	tonne	Explosives
N	1 353	270	litre	Petrol
	1 408	1 352	litre	Diesel
	83 618	67 826	litre	Water use for primary activity
	12 951	13 548	tonne	Accumulated waste rock to dumps

4.3 Verification of results

The verification of the methodology is divided up into two parts, the first being the reduction of the quantifiable impact of error, and the second being the reduction of the number of errors within the internal reporting structure.

The measurement of accuracy can be verified based on the Figure 26 methodology, where both forms of verification are used. The largest contributor to a valid verification is the proof verification. This involves checking all information based on source documents. Source documents themselves are further discussed in the literature review. The discussion provides evidence of their validity with representing the true representation of data.

Additionally, an auditing firm assures the environmental performance indicators. The outcome of this assurance is an assurance report. The assurance report contains the assured annual values being reported by a gold mine. These assured values are the direct outcome of the audit process and are not subjected to the low transparency of the assurance statement. Thus, a comparison was made between the assured annual values and detailed verification done by the study for a financial year.

The annual values included all the operation's verified information. Yet, the study did not verify all the operations reported information. Therefore, an assumption was made that the two operations' reported values are accurate in order to do the comparison. The assurance report is given in Appendix B.

Thus, the accuracy of the environmental reported values after the PDCA procedure can be verified against the assured values. The percentage error method will be utilised to represent the difference between these annual values. The annual total for each performance indicator is calculated using the equation (16). Then the percentage error equation is altered to compare the annual calculated and assured values in equation (17).

$$x_{reported\ annual\ value} = \sum x_{reported\ monthly\ value} \tag{16}$$

$$PE = \left| \frac{x_{reported\ annual\ value} - x_{assured\ value}}{x_{assured\ value}} \right| \times 100\% \tag{17}$$

The outcome of the percentage error comparison is graphically represented in Figure 39 below.

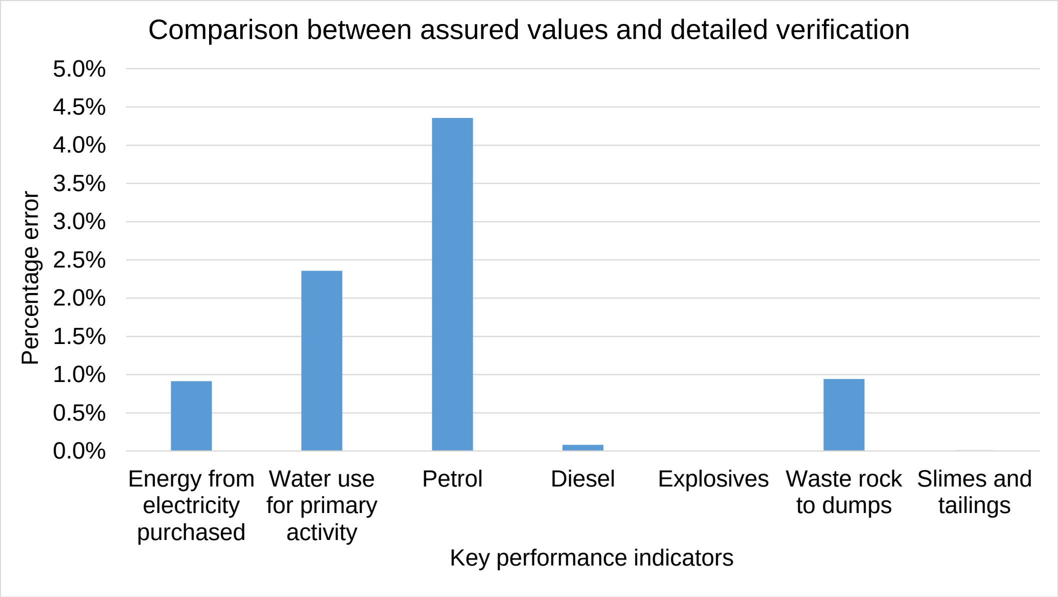

Figure 39: Comparison between assured values and verified values

Figure 39 assumes that the information from the auditing firm is more credible because of their experience in auditing information. The only issue researchers had, which was mentioned previously, was the actual assurance statement within the assurance report. Thus, the values being reported after the assurance procedure done by auditors are still viable. Yet, auditors use sampling methods with limitations, and the study goes into much more detail.

It can further be seen that there is minimal difference in quantity between the two total annual values. The average percentage error between all the reported annual values is 1.24%. The percentage error was small because both parties investigated each reported value. Even though the auditors did not investigate each value in detail their experience in auditing sample gives further insight into reported information. Therefore, the output quantity of the study's procedure has been successfully validated, making the quantity being reported by the procedure more credible than original reported values.

Additionally, the minimal difference between the two reported values reinforces that the artificial legitimacy claims stem from the communication of processes and not the actual assured values. Thus, the comparison done between the assured and verified values is valid.

Literature will be used to verify the improvement in accuracy of reported values. The literature is based on error rates found in reported information. The first statement is that reported error rates for typical enterprises range between 0.5-30% [35].The second statement found in literature was from a clinical trial where the study measured data quality. The findings were that a 5% error rate should be the gold standard for determining data quality in that specific setting [28].

Thus, literature can be used to verify improvement trends in error rates from the reported information. This can be done if the error rate of reported information clearly indicates the error rate moving from the typical range to the gold standard. Based on the gold standard stated, a prediction was made that the final reported rate will be within the gold standard.

The equation given in literature can be adapted to equation (18) given below. This equation will be used to verify the improvement in error rate.

$$ER = \left| \frac{y_{number\ of\ errored\ reporting\ chains}}{y_{number\ of\ reporting\ chains}} \right| \times 100\% \tag{18}$$

Using the tracking matrix and the two error rate ranges, a graphical comparison can be made. This comparison is represented in Figure 40.

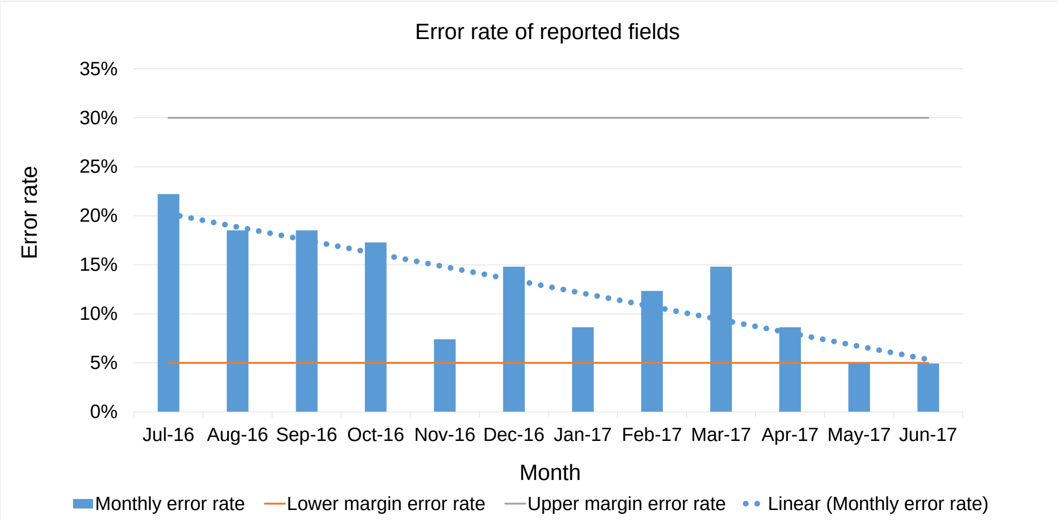

Figure 40: Error rate of reported fields

The figure indicates that most of the error rates fall into the normal range of typical disclosed information. Yet the last two months fall within the gold standard for quality of data, thus, validating the error rates produced by the gold mine's reporting chain. Figure 28 has a few anomalies which will be further discussed in Section 4.3.

4.4 Validation of objectives

The validation of objectives is broken up into two main improvements in quality, the first being the reduction of the quantifiable impact of error, and the second being the reduction of the number of errors within the internal reporting structure.

Figure 40 indicates there was a reduction of 17.3% in error rate from the beginning until the end of the study. This specifically points to a reduction in the number of errors originating from the gold mine's reporting structure, thus improving the qualitative performance of the internal reporting structure.

The second improvement needed in the reporting structure is the reduction of the quantifiable impact of error. This was measured by using the percentage error. The percentage error compares original reported quantities against the developed verification procedure's output. The average percentage error for all KPIs for each month is given in Figure 41.

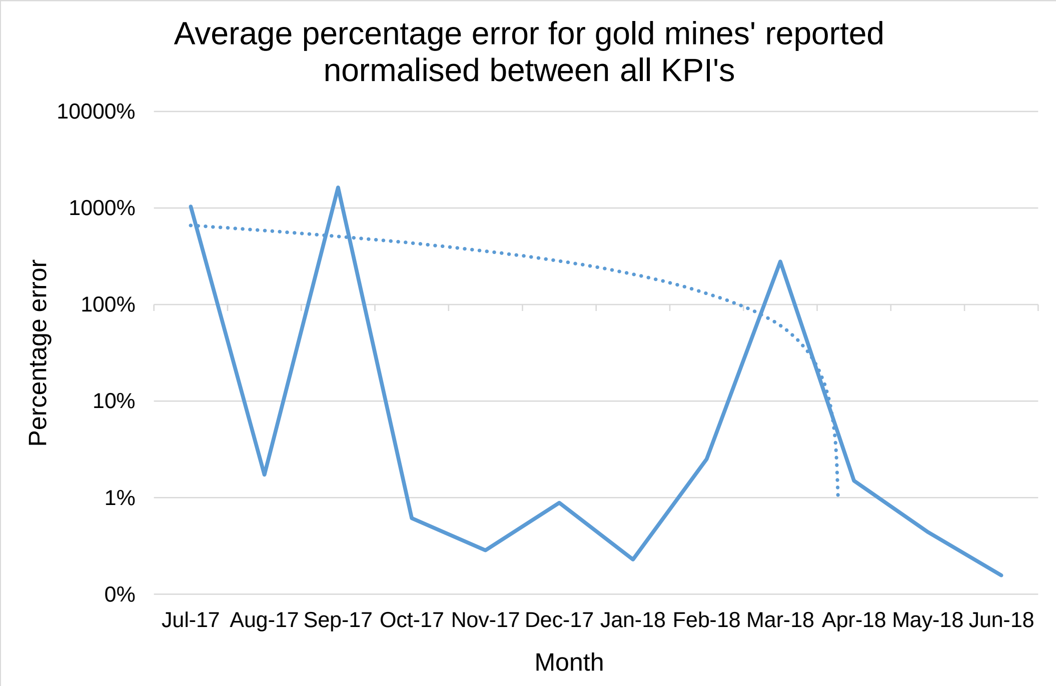

Figure 41: Average normalised percentage errors for reported KPI's

Based on Figure 41's observation, the average quantifiable percentage error for a financial year that was normalised between all KPI's was 246%. Thus, the study was successful in determining how accurately information was being reported by the gold mine. Further insights into the anomalies noticed will be discussed in Section 4.3.

Further observation indicated a continuous improvement in the accuracy of the quantity being reported. This is due to a trend of less deviation being observed per month in Figure 41. The percentage error reduction from the start to end of the study was 1035%.

The procedure improved the internal reporting accuracy over a financial year, thereby improving all aspects of the internal structure for reporting in a gold mine.

Some errors had major contributions to the high percentage errors, and will be investigated in Section 4.3.

4.5 Discussion

The three points that will be discussed are based on findings and insights derived from results and literature. The first discussion point comes about when questioning the implications of accuracy reporting on the budget. The following point is the difference between outcomes of auditors' assurance procedures and the study's method. The final point needing to be addressed is the specific reasons behind the outliers noticed in the result.

4.5.1 Budget allocation

There are two sets of reported information other than the outcome of the study's reported values. The two are the gold mine's original reported values and the assured values. The reporting of incorrect values will lead to allocating incorrect funding for the organisation's activities.

Thus, approximations were made based on the lowest and highest rate per rand to fund each KPI. The lowest and highest rate per rand are given in Appendix E.

By converting the margin error for each KPI into a rand value, the incorrect allocation of funds can be calculated. Table 22 represents the margin of error between the originally reported values and verified values.

Table 22: Rand over budget based on reported values

Performance indicators [unit]	Margin error between gold mine and study	Lowest rate resource per rand	Highest rate resource per rand	Total lowest rand allocated	Total highest rand allocated
Energy from electricity purchased [kWh]	-11 258 892.60	0.39	0.89	-R4 393 219.89	-R10 060 946.43
Water use for primary activity [m^3]	-25 489 964.60	5.22	16.45	-R133 057 615.21	-R419 309 917.67
Petrol [l]	-105.13	11.40	11.40	-R1 198.48	-R1 198.48
Diesel [l]	-54 475.03	11.38	11.38	-R619 925.84	-R619 925.84
Explosives [t]	-162 266.57	4.33	13.79	-R702 614.25	-R2 237 656.00
Slimes and tailings [t]	-1 596.07	0.00	0.00	R0.00	R0.00
Waste rock to dumps [t]	227.00	9.50	9.50	R2 156.50	R2 156.50
Over allocation of budget				-R138 776 730.20	-R432 231 800.90

The same will be done against the assured values. Table 23 represents the margin of error between the assured values and verified values. This will give further insight into the value of assurance provided by auditors.

Table 23: Rand over budget based on assured values

Performance indicators [unit]	Margin error between study and auditors	Lowest rate resource per rand	Highest rate resource per rand	Total lowest rand allocated	Total highest rand allocated
Energy from electricity purchased [kWh]	-23 709 306.90	0.39	0.89	-R9 246 629.69	-R21 101 283.14
Water use for primary activity [m^3]	-309 544.70	5.22	16.45	-R1 615 823.33	-R5 092 010.32
Petrol [l]	14 843.50	11.40	11.40	R169 215.90	R169 215.90
Diesel [l]	32 905.80	11.38	11.38	R374 468 .00	R374 468 .00
Explosives [t]	0.00	4.33	13.79	R0.00	R0.00
Slimes and tailings [t]	-1 596.10	0.00	0.00	R0.00	R0.00
Waste rock to dumps [t]	175 374.20	9.50	9.50	R1 666 054 .90	R1 666 054 .90
Over allocation of budget				-R8 652 714.22	-R23 983 554.65

The implications of poor data quality based on Table 22 and Table 23 results are quantified by the incorrectly allocated funds. The total rand indicated on the budget could have been used for other activities to increase profit for the organisation.

If the values originally reported by the mine are used to make decisions regarding the budget, it would result in over-budgeting of between R138 million and R432 million for resources, which could have been used more efficiently in production.

The same can be said for the assured values being used for budget purposes. Over-budgeting would be lessened by between the range of R8 million to R24 million.

In terms of timing, the original reporting values are on hand for use every month but the assured values only become known once every financial year. This waiting period is an insufficient timeframe to make use of such vital information for management decisions.

Therefore, the study makes information known directly after the reported month has past and the information itself is credible for use in allocating a budget for activities.

These potential financial benefits estimated from this section clearly indicates the need for external assurance. If this was communicated to any employee of an organisation they would fully comprehend the need for it in an organisation.

4.5.2 Anomalies

Anomalies can be identified in the outputs of the procedure. These anomalies can be broken down to the KPI level. In doing so, further insight can be gained about the reporting chain resulting in specialised error prevention that can further benefit the company.

The first anomaly was noticed in Figure 40 in Section 4.2. The error rate increases suddenly in December. This goes completely against the trend line of error reduction. Figure 42 then further breaks the error rate down to a KPI level. By doing so an appropriate reason can be provided for the spike in December.

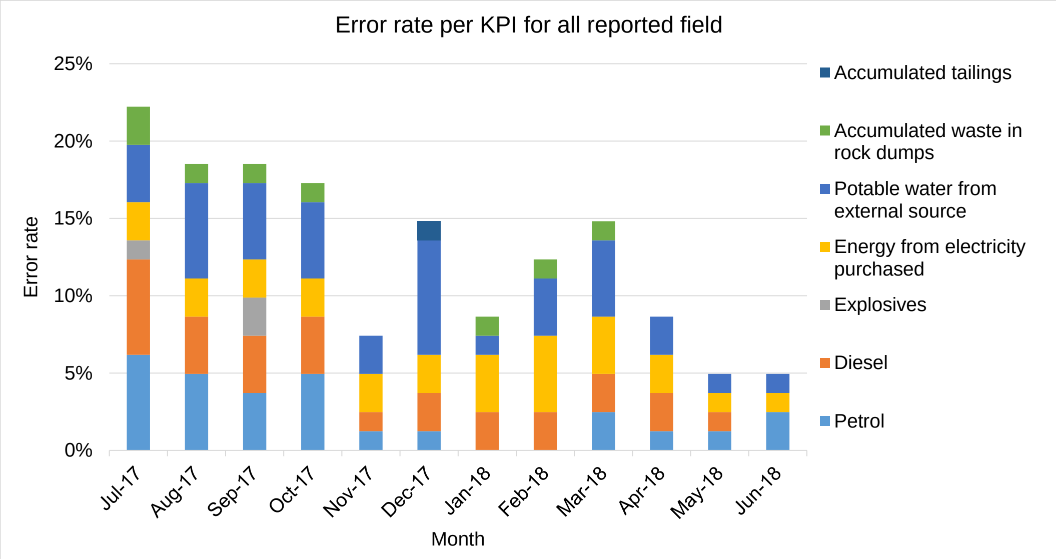

Figure 42: Error rate per KPI for all reporting fields

The contributors to the sudden spike in December were potable water, diesel and accumulated tailings. Potable water was the largest contributor with a 5% increase from the previous month. Afterwards there is a sudden reduction and again a gradual increase in errors for water. Thus, if an error prevention strategy was developed for water, further improvements could be achieved.

The last of these anomalies occurs in Figure 41. The graphic demonstrates large contributors to percentage error for specific months. The specific months are July, September and March. July is the most significant due to it being the starting point of the study and a reference point for evaluating improvement. Further investigations were done to identify which KPI resulted in such large deviations. The investigation led to the construction of a table which breaks down the KPI contributions. The average percentage error for each KPI is given in Table 24 below.

Table 24: Breakdown between KPI percentage contributions

Month	Energy from electricity purchased	Water use for primary activity	Petrol	Diesel	Slimes and tailings	Explosives	Waste rock to dumps
Jul-17	0.9%	0.1%	6.6%	0.0%	0.0%	7 241.1%	0.0%
Aug-17	3.8%	6.1%	2.1%	0.0%	0.0%	0.0%	0.1%
Sep-17	0.8%	1.0%	2.3%	0.0%	0.0%	11 399.8%	0.0%
Oct-17	0.6%	0.5%	3.0%	0.2%	0.0%	0.0%	0.0%
Nov-17	0.6%	0.1%	1.3%	0.0%	0.0%	0.0%	0.0%
Dec-17	0.6%	4.4%	1.1%	0.0%	0.1%	0.0%	0.0%

Month	Energy from electricity purchased	Water use for primary activity	Petrol	Diesel	Slimes and tailings	Explosives	Waste rock to dumps
Jan-18	0.7%	0.3%	0.0%	0.6%	0.0%	0.0%	0.0%
Feb-18	4.8%	11.9%	0.2%	0.6%	0.0%	0.0%	0.1%
Mar-18	4.8%	1949.5%	0.8%	0.4%	0.0%	0.0%	0.0%
Apr-18	5.1%	5.1%	0.3%	0.0%	0.0%	0.0%	0.0%
May-18	0.6%	1.8%	0.7%	0.0%	0.0%	0.0%	0.0%
Jun-18	0.7%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%

It is evident that the largest contributors for those months are water and explosives. Therefore, extra precautions can be implemented for those KPIs. This will ensure these deviations will not happen in the future.

4.5.3 Prediction

The study made a prediction based on literature findings of a clinical trial. The prediction was based on a gold standard for the quality of information. The prediction made was valid due to the final months of the study falling within the gold standard range. This further validates this study's claim that the internal reporting structure was improved.

4.6 Conclusion

The methodology that was developed produced outcomes that were further used to meet the objectives of the study. The reporting process section documented all reporting chains. The Information Collection system section developed source document equations that follow the law of conservation and the reporting chains. The Verification procedure section identified the errors based on a condition developed. The documentation and error management section compiled a tracking matrix and quantitative results for both reporting chains. This section further developed a discrepancy report by making use of errors identified and then investigated the reason behind them using the documented reporting chain.

The verification was successful both quantitatively and quantitatively. The quantitative percentage error based on assured values was 1.24%. The qualitative results were verified with the use of literature. The literature indicated two ranges of error rates: one was the typical range of disclosed values and the other was the gold standard for data quality. The results indicated improvement by moving from the typical range into gold standard of 5%, which verified the qualitative results.

The validation of the objectives was successful for both the reduction of the number of errors and the impact of each error. The impact of each error was reduced by an average of 1 035%. The number of errors per month was reduced by 17%. Therefore, an improvement in report quality was attained.

5 Conclusion

5.1 Summary

Gold mines have a corporate responsibility to report their environmental impact. The reporting of the environmental impact is done through a sustainability report. The gold mines use the most widely known sustainability-reporting framework, the GRI. This reporting framework recommends increasing the report's credibility by undergoing external assurance.

Report users still question the quality of information being reported and external assurance practices have flaws. The two main flaws found by researchers are the interpretation of the assurance statement and audit sampling.

The literature review investigated the data quality, auditing practices, GRI principles content, error management and continuous improvements. Data quality went into detail regarding the representation of data, verification and error measurement. Research into data quality led to a prediction being made that the final error rate recorded will be within the gold standard of 5%.The research done in present auditing practices resulted in the two critical topics being investigated – audit sampling and source documents. The GRI reporting content was explored in detail by multiple sources. Error management research consisted of investigating target estimation and the communication of errors.

A literature assessment was done on four continuous improvement methods to determine the best-suited method for the study. The four methods investigated were the lean thinking, PDCA cycle, Six Sigma and TOC methods. This led to the PDCA method being selected due to its characteristics of continuous improvement, verification, and corrective action.

The adapted four-step method is as follows: reporting process, information collection process, verification procedure, documentation and error management. Each of the steps outcomes are given below:

The reporting process outcomes was a selection of critical KPIs and their documented reporting chains. The critical KPIs were selected using the information gathered from the GRI reporting content principles, after which a cross-evaluation was done to determine the most critical KPIs for a detailed investigation and verification. The initial number of KPIs was 18 and was shortlisted to 7 KPIs. Thereafter each of the shortlisted KPIs reporting chains were investigated and all the relevant documents noted.

The information collection process consists of the representation of data, and the collection of data and documentation. The representation of data was developed based on the literature found for data structures. The data structure was implemented on a web-based platform. Additionally, further research explored into error management led to error prevention methods being used in the implemented data tree structure. The actions of collecting data and documentation was scheduled within a Gantt chart. Automated reminders was pushed to the relevant person to ensure the actions are completed timeously.

The verification procedure incorporates both the original reporting chain and its relevant source documents. The two forms of verification methods used within the procedure are double entry and source verification. The original reporting chain and web-based reporting platform, in combination with independent calculations done by the study, makes up the double verification method. The relevant source documents are used for the source verification method.

The documentation and error management step encompass documenting the results of the methodology and the reporting of errors. The results of the methodology consist of two parts – the reduction in the quantifiable percentage error of environmental KPIs and the error rate per month. The communication of errors was done using a monthly discrepancy report. The report informed the responsible person of the operation, reported value, source value and KPI that was incorrectly reported.

The verification of results was done through the use of literature and the assured values reported by the auditing firm. The literature verified that the error rate was reduced over the financial year, and that the gold standard prediction was met. The reported values produced by the verification procedure were verified against the assured auditor’s values. The percentage error between the two reported values was below 5% as anticipated.

The validation of the results is broken up into two parts: the reduction of the quantifiable impact of error and the rate of error each month. The objectives were validated by reducing the quantifiable impact of error tenfold, and the rate of error each month was reduced from 22.2% to 4.9%.

The financial consequence of this reduction in both aspects of errors led to a potential minimum of R138 million being allocated correctly to other needed resources. Thus, the study was successful in improving the quality of environmental reported data, which resulted in further financial benefit.

5.2 Recommendations

The recommendations are broken up into two sections, the first portion being possible adaptions to the study, which will bring further findings. The second portion is future work that utilises the information gained in this study.

5.2.1 Possible alterations to the study

The discovered possible alterations to the study are the identification of errors, the artificial legitimacy of assurance statements and the error management.

The range for the identification of errors can be increased to other possible error origin points. In the study, only human error within the reporting chain was considered. Further investigation into the actual measurement process and equipment can bring about the improvement of practices in the reporting of KPIs. In addition, information taken from outside sources can be investigated to increase the overall accuracy of the KPI.

The level of assurance can also be evaluated in terms of the errors found by the study. An example of this is by comparing the reasonable and limited KPIs with their corresponding error rates. This comparison will determine if the level of assurance has any relationship with errors found in these KPIs.

The error management can be further improved by adding more preventative actions and more detail in the discrepancy report. An additional preventative action can be the incorporation of workshops. These workshops can inform the responsible person of the previous errors and explain the reporting process. The discrepancy report can also give the reason for the errors. An example of this would be conversion errors made between different units.

5.2.2 Future work

Three opportunities for future work that builds on the understanding developed in this study were identified during the course of this study. The first opportunity identified was based on audit sampling, while the second is the financial benefits of improving the quality of environmental reported information. The last opportunity noticed was that the value of possible resource saving, due to the quality of information after the verification process insights into resource efficiency could be identified, resulting in financial savings in any organisation.

Audit sampling was identified as a possible risk. There have been multiple studies in sampling of information. Thus, a study that evaluates the best-suited sampling method for assurance of environmental data will be beneficial.

This study evaluates incorrect budgeting based on the poor data originally reported by gold mines. This led to a minimum budgeting error of R138 million. Future work can determine the actual poor budgeting being done due to inaccurate reporting and the implications of this on the profits of a gold mine.

5.3 Limitations of the study

There were two main limitations of the study.

Not all gold mine operations could be verified using source documentation. This is due to two of the operations not having the infrastructure to store and manage source documents.

A further limitation exists in the verification of measurement itself. Due to the quantity of work, only the first point of recording was verified. Yet, the measurement itself is susceptible to errors and the device taking the measurement. By ensuring these errors are addressed, more credible business intelligence can be achieved.

Additionally, each of the KPI's were normalised when calculating the total percentage error reported. The contribution of each KPI to the perceived accuracy of the reporting system can be developed to further understand the implications of these reporting errors.

Although these limitations were identified, the study makes use of assumptions to bypass these factors. In so doing, the study was still successful in achieving its objectives.

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Appendix A

Table 25: Energy KPI's

Energy		
Categories	Explanation	SI Symbol
Total energy consumed	The sum of energy from electricity, fossil fuels and renewables.	kWh
Energy from electricity purchased	Total amount of electricity purchased from the supplier. This excludes the electricity supplied to the third party users.	
Energy from fossil fuels	Total amount of energy generated from fossil fuels.	
Renewable energy	Total amount of energy generated from natural sources.	

Table 26: Water KPI's

Water used		
Categories	Explanation	SI Symbol
Water used for primary activity	Total volume of water that is drawn into the boundaries of the operation from all sources (including surface water, groundwater, rainwater and municipal water supply). This excludes internally recycled water, water discharged to environment and supply to third party users such as communities and businesses.	m^3
Potable water from external source	Total volume of clean water purchased from the municipality. This excludes the water supplied to the third party users.	m^3
Non-potable water from external source	Total volume of water retrieved from natural sources at the operation.	m^3
Surface water	Water retrieved from natural above ground sources at the operation.	m^3
Groundwater	Water retrieved from underground natural sources at the operation, e.g. boreholes.	m^3
Water recycled in process	Water that is reused and recycled within the boundaries of the operation.	m^3

Table 27: Materials used KPI's

Materials Used		
KPI	Explanation	SI Symbol
Ore mined	All the rock extracted from the shaft. This includes reef and waste.	t
Reef mined	Rock mined from the reef and sent to the plant to be processed.	t
Waste rock recycled	Waste rock from the waste dumps sent to the plant to be processed.	t
Slimes re-processed	Slimes from the slimes dams pumped to the plant to be reprocessed.	t
Tonnes treated	Total amount of rock (reef and waste) milled and processed at the plant.	t
LPG	Liquid petroleum gas used at the operation.	t
Grease	Thick oily substance used as a lubricant.	t
Petrol	Fuel used for machinery and transport at the operation.	l
Diesel	Fuel used for machinery and transport at the operation.	l
Polyfuel	Fuel used as a burning material for the boilers.	l
Lubricating oil	A thick fatty oil, used to lubricate machinery.	l

Materials Used		
KPI	Explanation	SI Symbol
Hydraulic oil	Oils used to convey power and to lubricate hydraulic machinery.	l
Explosives	Materials used to blast rock underground.	t
Liquid cyanide	Total amount of cyanide (at 100% strength) used to extract the gold from the rock.	t
Timber	Wood used as support structures underground.	t

Table 28: Mineral waste

Mineral waste		
Categories	Explanation	SI Symbol
Accumulated tailings in tailings dams:	Total amount of slimes produced by the plant and pumped into the slimes dams.	t
Accumulated waste in rock dumps:	Amount of waste rock produced and hoisted from the shaft to be added to the waste rock disposal sites.	t
Hazardous to landfill:	Hazardous materials (non-mineral) disposed to the landfill.	t
Hazardous to incineration:	Hazardous materials (non-mineral) being disposed of by thermal treatment.	t

Mineral waste		
Categories	Explanation	SI Symbol
Non-hazardous to incineration:	Non-hazardous materials (non-mineral) being disposed of by thermal treatment.	t
Scrap steel:	Off cut materials consisting of steel, sub grade steel and wire rope.	t
Scrap timber:	Off cut wood from building support structures.	t
Scrap plastic:	Off cut plastic, e.g. PVC pipes.	t
Earth waste/Rubble:	Earth waste containing domestic waste as well as rubble.	t

Appendix B

[redacted]

[redacted]

[redacted]

28 August 2017

Dear Sir/Madam

<u>Confirmation of final reportable information to be published in the Integrated Report of [redacted] for the financial year ended 30 June 2017</u>

This representation letter is provided in connection with our assurance engagement on selected sustainability key performance indicators of [redacted] to be presented in the Integrated Report for the financial year ended 30 June 2017. We therefore kindly request you to confirm the final reportable figure for each of the following sustainability indicators for the [redacted] and selected sites for the year ended 30 June 2017.

On completion please return the confirmation to our auditors at the following address:

E-Mail [redacted]

Your prompt attention will be greatly appreciated.

Yours faithfully

[redacted]

Manager: Financial Accounting/Integrated Reporting and Sustainability

Figure 43: Front page of assurance report

Reply sheet

KPI	Level of Assurance	Group and sites	
Total Scope 1 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO_2e)	Limited	Diesel (litres)	40 470 027.40 litres
		Petrol (litres)	340 706.69 litres
		Explosives (tonnes)	11 486.33 tonnes
Total Scope 2 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO2e)	Reasonable	RSA	2 537 944 377 kWh
		PNG	52 538 500 kWh
Total Scope 3 Carbon Emissions (tCO_2e) Note: Quantities before conversion to (tCO2e)	Limited	Explosives	11 486.33 tonnes
		Cement	17 515.90 tonnes
		Timber	41 953.53 tonnes
		Cyanide	20 974.16 tonnes
		Caustic soda	2 965.70 tonnes
		Lime	36 427.60 tonnes
		Business travel	1 494 970kms
		Air travel	Domestic = 136 Flights
			International = 166 Flights
Volume of Mineral Waste Disposed (tonnes)	Limited	Slimes/Tailings	19 815 451.46 tonnes
		Waste Rock	18 576 920.24 tonnes
Electricity Purchased (kWh)	Reasonable	RSA	2 537 944 377 kWh
		PNG	52 538 500 kWh
Water Used for Primary Activity (kilolitres)	Limited	Group	13 123 544.10 kilolitres
Land rehabilitated	Limited	Group	98.53 Hectares

Figure 44: Reply sheet of assurance report

Appendix C

Table 29: July 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	PV	PV	V	V	PV	V	PV
Diesel	V	V	PV	V	V	V	V	PV	PV	V	V	PV	V	PV
Explosives	V	V	V	V	V	V	V						PV	V
Energy from electricity purchased	V	V	PV	PV	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	PV	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 30: August 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	PV	PV	V	V	PV	V	PV
Diesel	V	V	PV	V	V	V	V	PV	PV	V	V	PV	V	PV
Explosives	V	V	V	V	V	V	V						PV	V
Energy from electricity purchased	V	V	PV	PV	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	PV	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 31: September 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	V	PV	V	V	V	V	PV
Diesel	V	V	V	V	V	V	V	PV	PV	V	V	V	V	PV
Explosives	V	V	V	V	V	V	PV						V	PV
Energy from electricity purchased	V	V	PV	V	V	V	V	V	V	PV	V	V	V	V
Potable water from external source	V	V	PV	V	V	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 32: October 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	PV	PV	V	V	V	V	PV
Diesel	V	V	V	V	V	V	V	PV	PV	V	V	V	V	PV
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	PV	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	PV	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	V
Accumulated tailings								V	V	V	V	V	V	V

Table 33: November 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	V	V	V	V	V	V	V	V	V	V	PV
Diesel	V	V	V	V	V	V	V	V	V	V	V	V	V	PV
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	V	V	V	V	V	PV	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	PV	V	V	V	V	V	V	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	V
Accumulated tailings								V	V	V	V	V	V	V

Table 34: December 2017 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	V	V	V	V	V	V	V	V	V	V	PV
Diesel	V	V	PV	V	V	V	V	V	V	V	V	V	V	PV
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	V	V	V	V	V	PV	V	V	V	V	V
Potable water from external source	V	V	PV	V	V	V	PV	V	V	PV	V	PV	PV	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	V
Accumulated tailings								V	V	V	V	V	V	PV

Table 35: January 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Diesel	V	V	PV	V	V	PV	V	V	V	V	V	V	V	V
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	V	V	V	V	V	PV	V	V	V	V	PV
Potable water from external source	V	V	V	V	V	V	V	V	V	V	V	PV	V	V
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 36: February 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Diesel	V	PV	V	V	PV	V	V	V	V	V	V	V	V	V
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	PV	PV	V	V	V	V	V	PV	V	V	V	V	PV
Potable water from external source	V	PV	V	PV	V	V	V	V	V	V	V	PV	V	V
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 37: March 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	V	PV	V	V	V	V	V
Diesel	V	V	V	V	V	PV	V	V	PV	V	V	V	V	V
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	PV	PV	V	V	V	V	V	PV	V	V	V	V	V
Potable water from external source	PV	PV	V	V	V	V	V	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Table 38: April 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	V	V	V	PV	V	V	V
Diesel	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	V	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	V	V	V	V	V	V	V	PV
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	V
Accumulated tailings								V	V	V	V	V	V	V

Table 39: May 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	V	V	V	V	V	V	V
Diesel	V	V	V	V	V	PV	V	V	V	V	PV	V	V	V
Explosives	V	V	V	V	V	V	V						V	V
Energy from electricity purchased	V	V	PV	V	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	PV	V	V	V	V	V	V	V	V	V	V	V	V
Accumulated waste in rock dumps	V	V	V	V	V	V	V						V	V
Accumulated tailings								V	V	V	V	V	V	V

Table 40: June 2018 tracking matrix

Category	Operations													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Petrol	V	V	V	PV	V	V	V	PV	PV	V	V	PV	V	PV
Diesel	V	V	PV	V	V	V	V	PV	PV	V	V	PV	V	PV
Explosives	V	V	V	V	V	V	V						PV	V
Energy from electricity purchased	V	V	PV	PV	V	V	V	V	V	V	V	V	V	V
Potable water from external source	V	V	V	V	V	V	PV	V	V	V	V	PV	V	PV
Accumulated waste in rock dumps	PV	V	V	V	V	V	V						V	PV
Accumulated tailings								V	V	V	V	V	V	V

Appendix D

Eskom

[redacted]

[redacted]

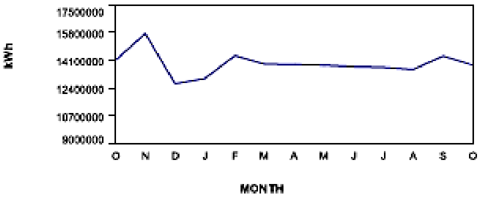
CONSUMPTION DETAILS (2017-09-19 - 2017-10-19)

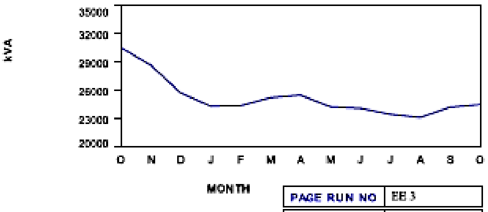
ENERGY CONSUMPTION OFF PEAK kWH	6,625,255.10
ENERGY CONSUMPTION STD kWh	5,331,496.46
ENERGY CONSUMPTION PEAK kWh	1,889,757.70
ENERGY CONSUMPTION ALL kWh	13,846,509.26
DEMAND CONSUMPTION - OFF PEAK	24,049.85
DEMAND CONSUMPTION - STD	24,514.33
DEMAND CONSUMPTION - PEAK	20,839.82
DEMAND READING - KW/KVA	24,514.33
REACTIVE ENERGY - OFF PEAK	1,022,736.42
REACTIVE ENERGY - STD	828,282.27
REACTIVE ENERGY - PEAK	297,348.21
LOAD FACTOR	77.00

PREMISE ID NUMBER [redacted] **TARIFF NAME:** Megaflex

[redacted]

Administration Charge @ R113.69 per day for 31 days	R	3,524.39
TX Network Capacity Charge 31,500 kVa @ R7.28 : = R7.28/kVA	R	229,320.00
Network Capacity Charge 31,500 kVA @ R14.51 : = R14.51/kVA	R	457,065.00
Network Demand Charge 24,514.34 kVA @ R27.52 : = R27.52 /kVA	R	674,634.64
Ancillary Service Charge 13,846,509 kWh @ R0.0036 /kWh	R	49,847.43
Low Season Standard Energy Charge 5,331,496 kWh @ R0.6151 /kWh	R	3,279,403.19
Low Season Peak Energy Charge 1,889,758 kWh @ R0.8938 /kWh	R	1,689,687.75
Low Season Off Peak Energy Charge 6,625,255 kWh @ R0.3902 /kWh	R	2,585,174.60
Affordability Subsidy 13,846,509 kWh @ R0.0287 /kWh	R	397,394.81
Electrification and Rural Subsidy 13,846,509 kWh @ R0.0708 /kWh	R	980,332.84
Premium Connection Charge @ R52,082.00	R	52,082.00
Residual Connection Charge @ R52,085.00	R	52,085.00
Fixed Charge @ R0.00	R	0.00
Residual Connection Charge @ R13,230.00	R	13,230.00
SERVICE CHARGE	R	110,353.49
TOTAL CHARGES	**R**	**10,573,135.04**





PAGE RUN NO	EE 3
BILL GROUP	
BILL PAGE	3 OF 5

Figure 45: Example of Eskom account

MERAFONG CITY LOCAL MUNICIPALITY
INVOICE 2017/0007

MERAFONG CITY
PLAASLIKE MUNISIPALITEIT

DEPARTEMENT VAN FINANSIES / DEPARTMENT FINANCE

[redacted] (018) 788-9500 FAX (018) 788-9562 [redacted]

BELASTING FAKTUUR
TAX INVOICE
BTW / VAT REG NO
4920193655

[redacted]

REK. NO. / A/C NO.	491430035001019	MAAND / MONTH	JULY 2017
BELASTING FAKTUUR / TAX INVOICE / BTW/VAT REG NO	4920193655	WAARDASIE / VALUATION	

ERF	AREA	STRAAT/STREET

BESKRYWING / DESCRIPTION	HEFFING / LEVY	BTW / VAT	TOTAAL / TOTAL
Balance B/Forward:			3 509 307.60
Payment Received			- 3 509 307.60
1751 TOWNSHIP 300 43.86 7126600 6987000 139600			
1752 MINE 300 43.86 1905200 1844200 61000			
1850 [redacted] GAME RESERVE 25 17.54 1 1 0			
OPERATIONAL 66198KL. @ 16.45	1 088 957.10	152 453.99	1 241 411.09
DOMESTIC 134402KL.@ 16.45	2 210 912.90	309 527.81	2 520 440.71
200600			
THIS ACCOUNT IS PAYABLE ON OR BEFORE 25 AUGUST 2017	CURRENT		3 761 851.80
	AGTERSTALLIG + HUIDIGE REK. / ARREARS + CURRENT AMOUNT		3 761 851.80

Figure 46: Merafong municipality water invoice

Sedibeng WATER

TAX INVOICE

VAT Reg Nr. 4540105923

Number:	IN0000107096
Page:	1
Date:	2017-08-31

To: [redacted]

Attn: Amanda Burger VAT Reg Nr. 4960164525

From: [redacted]

Tel: 056-515 0200

Attn: [redacted] 0369

Reference - P.O. #	Customer No.	Salesperson	Ship Via	Terms Code
	16011006			30DAYS

	Description/Comments				Amount
	[redacted] 7294480-7233500=60980				318,315.60
	[redacted] 18023-17970=53				276.66

Due Date	Amount Due	Disc. Date	Disc. Amount
2017-09-30	363,195.17	2017-09-30	0.00

Banking details:

Account Name:
Bank:
Branch Name:
Branch Number:
Acc. Number: [redacted]

SARS 44,602.91

Subtotal before taxes	318,592.26
Total taxes	44,602.91
Total amount	363,195.17
Payment received	0.00
Discount taken	0.00
Amount due	363,195.17

Please use your Customer ID **16011006** as reference on deposit.

Figure 47: Sedibeng municipality water invoice

[redacted]

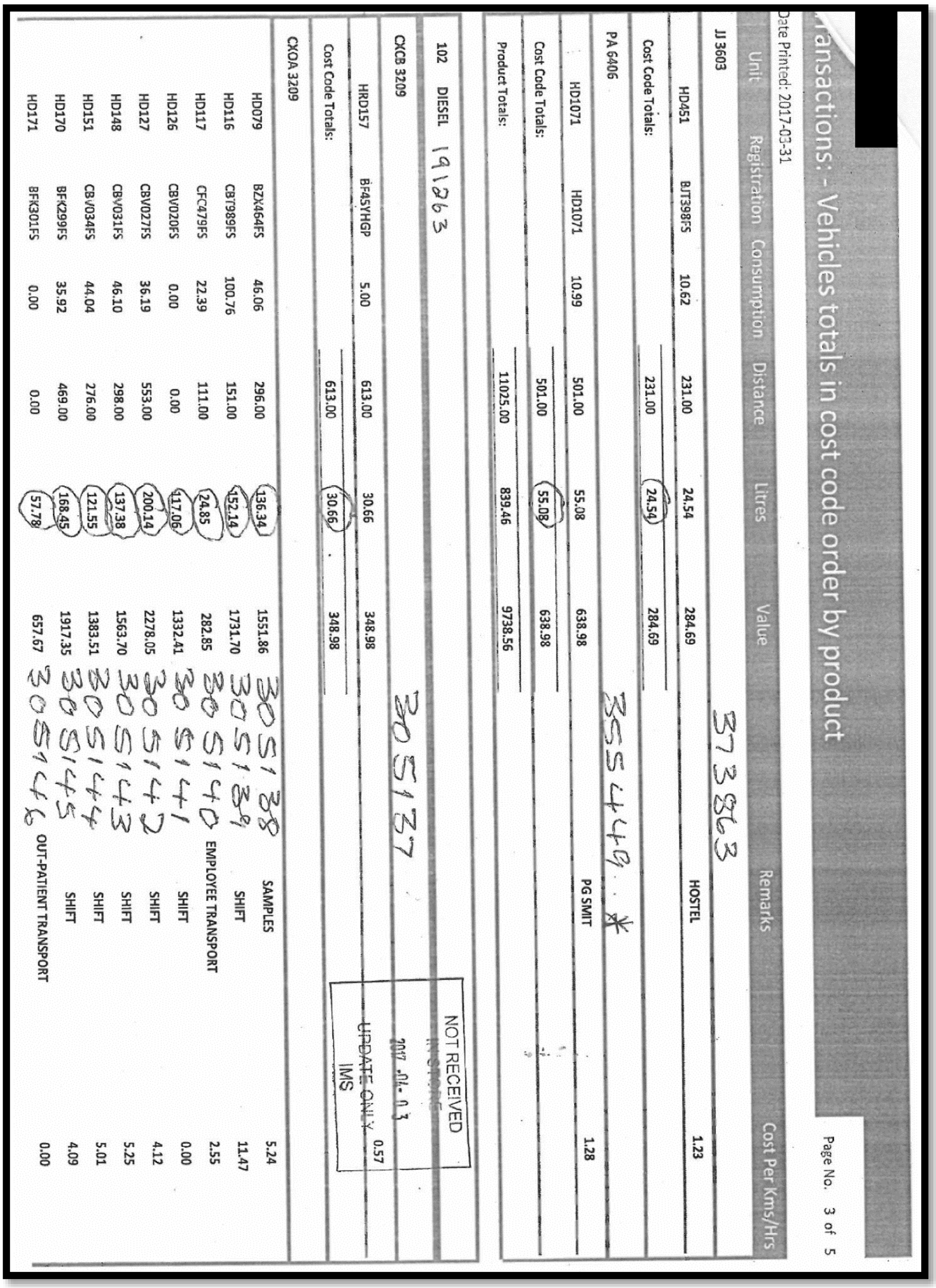
Transactions: - Vehicles totals in cost code order by product

Page No. 1 of 5

Date Printed: 2016-09-05

Unit	Registration	Consumption	Distance	Litres	Value	Remarks	Cost Per Kms/Hrs
101 PETROL	191260 FUEL!			J-49			
6				JB 3301	→ 347130		
3033	DRM3033	0.00	0.00	72.55	827.70	TRANSPORT	0.00
Cost Code Totals:			0.00	72.55	827.70	NOT RECEIVED IN STORE	
CXC 3701						288601 2016-09-06	
HD862	DNN962FS	7.95	440.00	34.97	398.96	IT UPDATE ONLY IMS	0.91
Cost Code Totals:			440.00	34.97	398.96		
CXO021 4157						288603	
HD632	CVJ299FS	14.40	170.00	24.48	279.28	T.CAMPBELL	1.64
Cost Code Totals:			170.00	24.48	279.28		
CXOA 3209							
HD183	BRD487FS	11.45	170.00	19.47	222.13	288604 POST	1.31
HD883	DSD674FS	10.86	407.00	44.18	504.04	288606 DISTRIBUTION	1.24
Cost Code Totals:			577.00	63.65	726.17		
CXOC 3206						288607	
HD953	DWC004FS	6.74	547.00	36.86	420.52	SECURITY	0.77
Cost Code Totals:			547.00	36.86	420.52		
CXOC 3851						288608	
HD1032	FFN288FS	10.19	382.00	38.92	444.03	DAN KRUGER	1.16
Cost Code Totals:			382.00	38.92	444.03		

Figure 48: Requisition for petrol ordered



[redacted]

Transactions: - Vehicles totals in cost code order by product

Page No. 3 of 5

Date Printed: 2017-03-31

Unit	Registration	Consumption	Distance	Litres	Value	Remarks	Cost Per Kms/Hrs
JJ 3603						373863	
HD451	BJT398FS	10.62	231.00	24.54	284.69	HOSTEL	1.23
Cost Code Totals:			231.00	24.54	284.69		
PA 6406						355449 *	
HD1071	HD1071	10.99	501.00	55.08	638.98	PG SMIT	1.28
Cost Code Totals:			501.00	55.08	638.98		
Product Totals:			11025.00	839.46	9738.56		
102 DIESEL 191263							
CXCB 3209						305137	
HRD157	BF45YHGP	5.00	613.00	30.66	348.98		0.57
Cost Code Totals:			613.00	30.66	348.98		
CXOA 3209							
HD079	BZX464FS	46.06	296.00	136.34	1551.86	305138 SAMPLES	5.24
HD116	CBT989FS	100.76	151.00	152.14	1731.70	305139 SHIFT	11.47
HD117	CFC479FS	22.39	111.00	24.85	282.85	305140 EMPLOYEE TRANSPORT	2.55
HD126	CBV020FS	0.00	0.00	117.06	1332.41	305141 SHIFT	0.00
HD127	CBV027FS	36.19	553.00	200.14	2278.05	305142 SHIFT	4.12
HD148	CBV031FS	46.10	298.00	137.38	1563.70	305143 SHIFT	5.25
HD151	CBV034FS	44.04	276.00	121.55	1383.51	305144 SHIFT	5.01
HD170	BFK299FS	35.92	469.00	168.45	1917.35	305145 SHIFT	4.09
HD171	BFK301FS	0.00	0.00	57.78	657.67	305146 OUT-PATIENT TRANSPORT	0.00

NOT RECEIVED IN STORE
2017 -04- 03
UPDATE ONLY
IMS

Figure 49: Requisition for diesel ordered

[redacted]

COMPUTER GENERATED TAX INVOICE

[redacted]

INVOICEE [redacted] VAT NO :	SUPPLY DEPOT [redacted]
CONSIGNEE [redacted]	ORDER DATE 12.05.2017 / ORDER NO 767082 / PAGE 1 of 1
	DELIVERY DATE 18.05.2017 / DELIVERY NOTE NO 8000813836
	CUSTOMER NO 100630 / CUSTOMER ORDER NO 308237-FG
INVOICE NO 90855313 / INVOICE DATE 18.05.2017	PAYMENT TERMS: NET 30 DAYS AFTER STATEMENT

DESCRIPTION OF PRODUCTS/SERVICES	QUANTITY	UNIT	PRICE	UNIT	AMOUNT
** ** Please use "Customer number" as reference ** for all future payments. Any other ** reference will be rejected by the bank **					
ANFEX 25KG MULTI-BAG **300058**	40	BAG	173.37	BAG	6,934.80
MAGNUM BUSTER GEL 28X300MM EX UEE DANTEX WATERGEL **203270**	26	CS	358.60	CS	9,323.60

NOTES:

SUB TOTAL IN ZAR	16,258.40
VAT AT 14.00 %	2,276.18
TOTAL IN ZAR	18,534.58

QUERIES:
CONTACT PERSON: Desiree Mothwa TEL NO: 011 606 0462

SUBJECT TO AEL MINING SERVICES LIMITED CONDITIONS OF SALE

Figure 50: Copy of tax invoice for explosives delivery

[redacted]

[redacted]

[redacted]

[redacted]

Matetrial Code	Details	UOM	km	T or hours	Rate	Amount
[redacted]	Shaft: Emty Silo and Cleaning inside shaft.					
	Dumper	T		22,277	9.50	211,631.50

[redacted]

Subtotal	211,631.50
Vat	29,628.41
Total	241,259.91

Figure 51: Copy of tax invoice for waste rock transporting

Appendix E

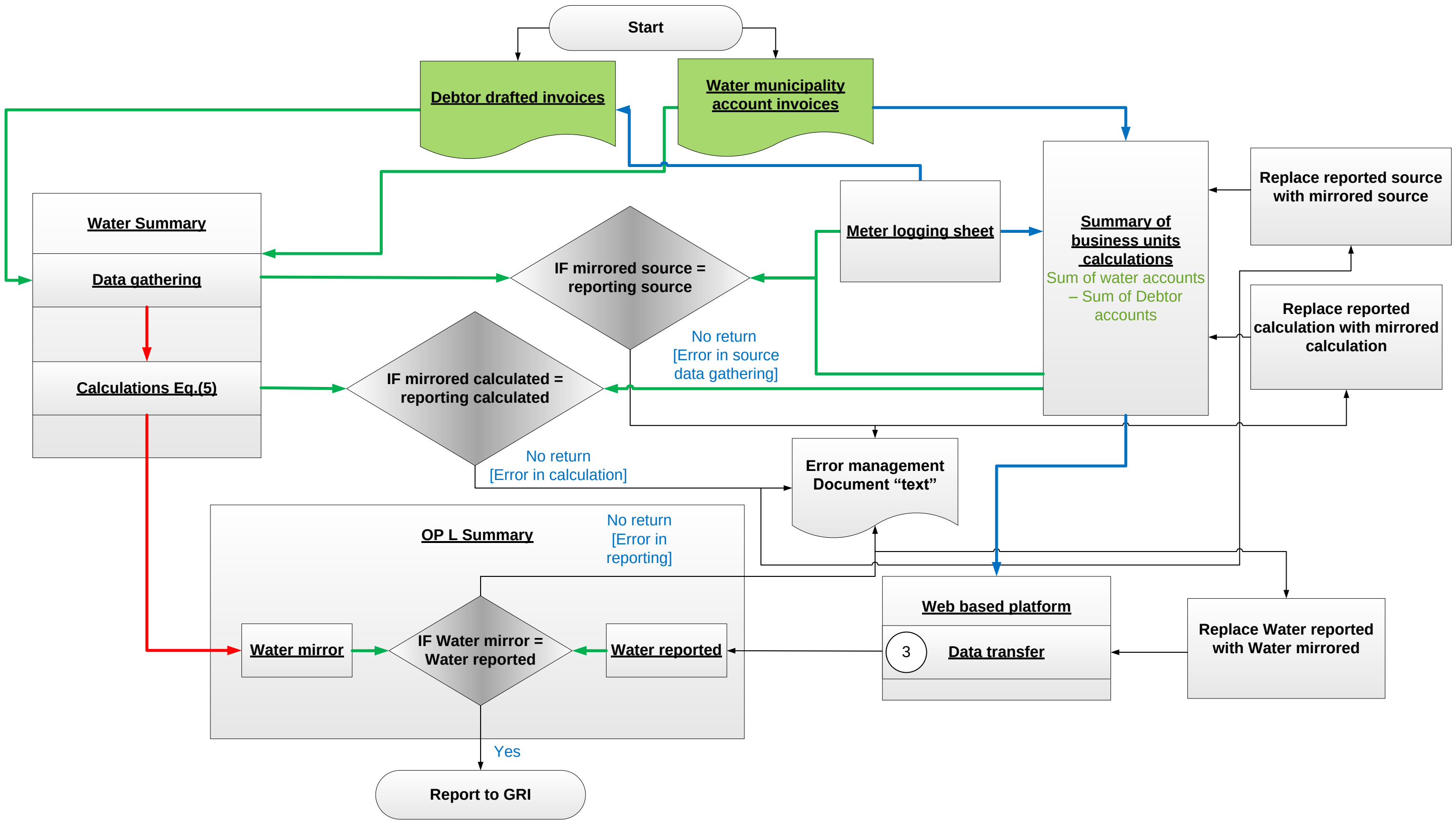


Figure 52: Verification procedure for water use for primary activity

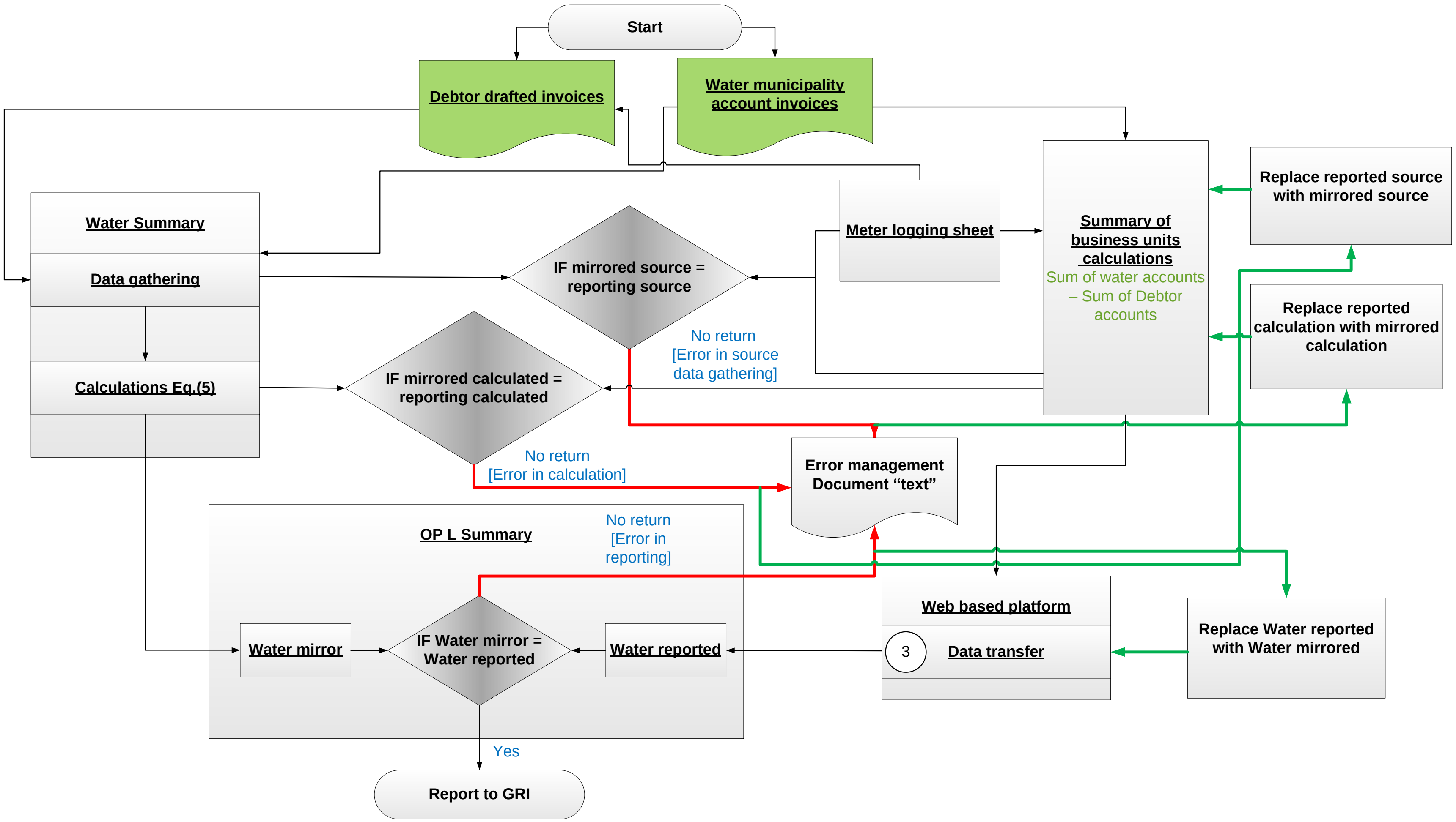


Figure 53: Error management for water use for primary activity

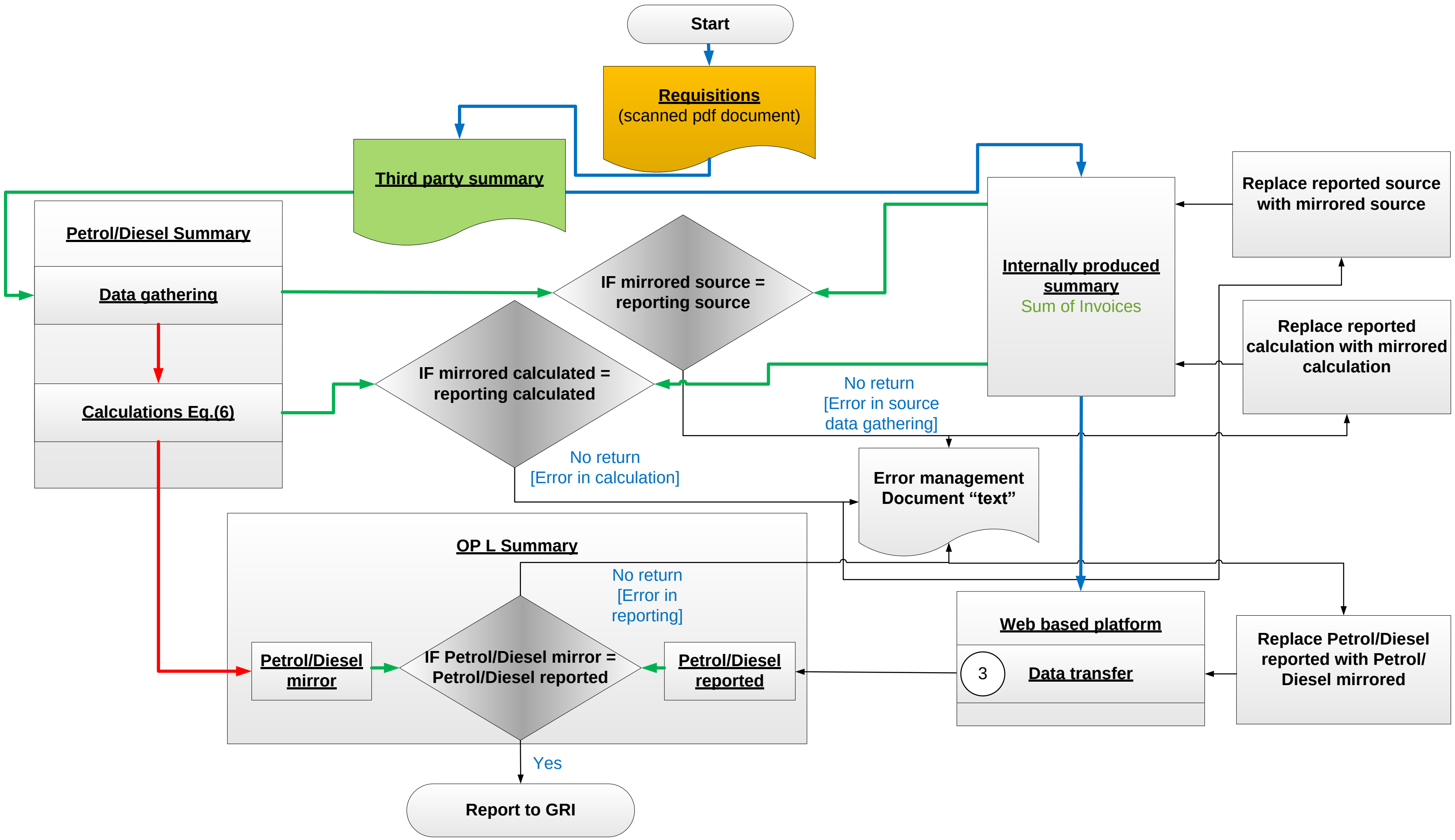


Figure 54: Verification procedure for fuel used

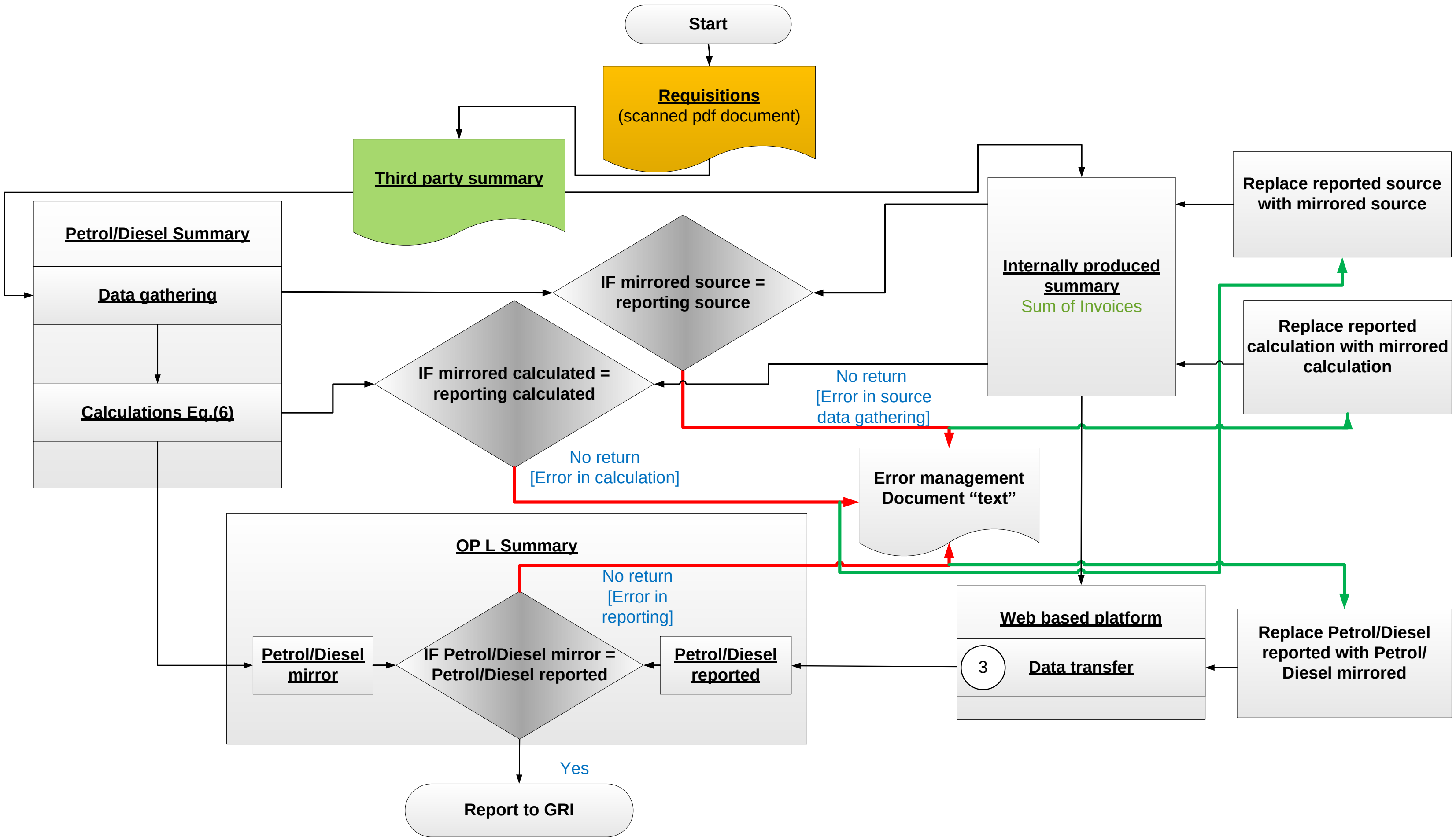


Figure 55: Error management procedure for fuel used

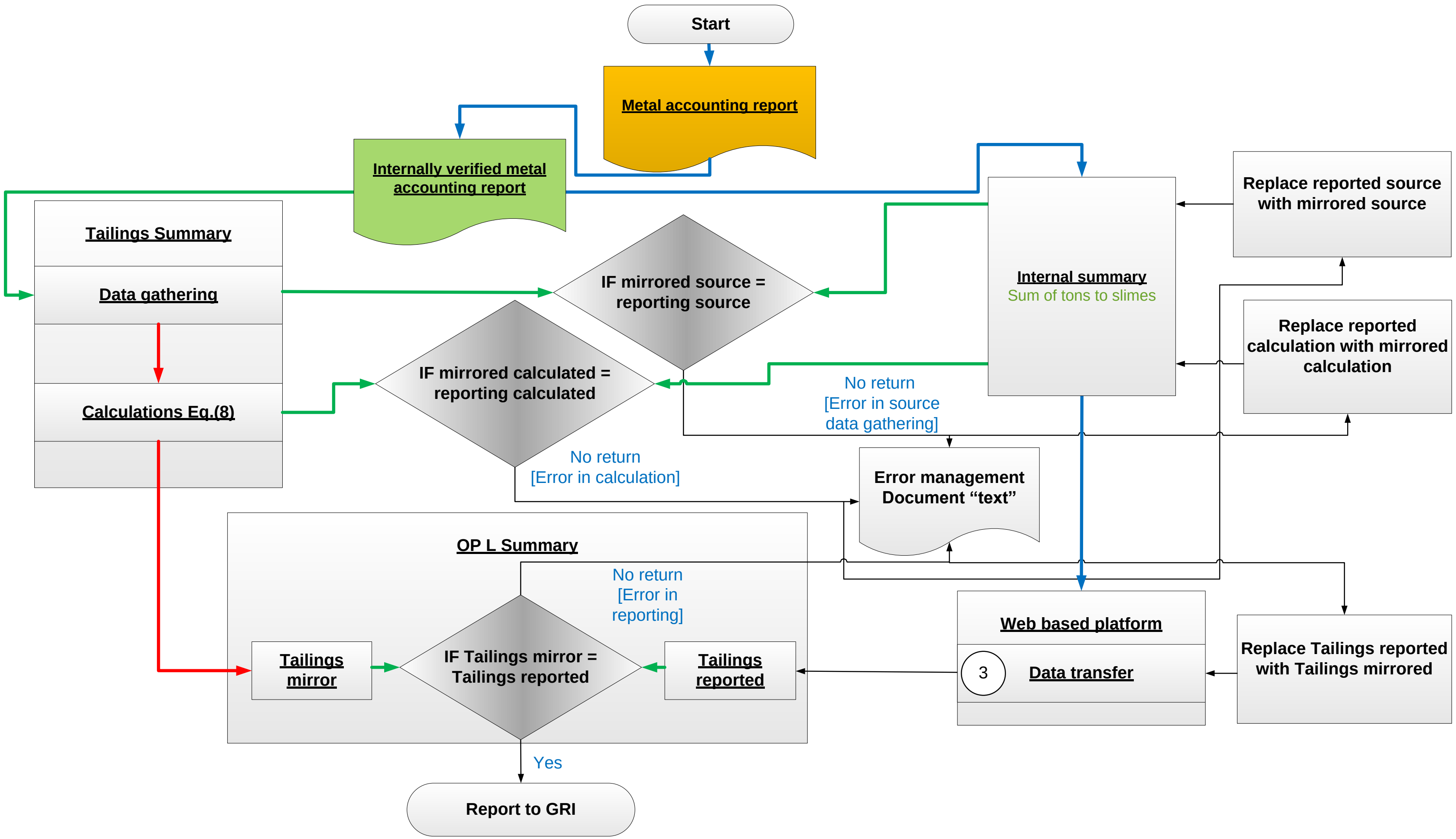


Figure 56: Verification procedure for tailings to tailings dam

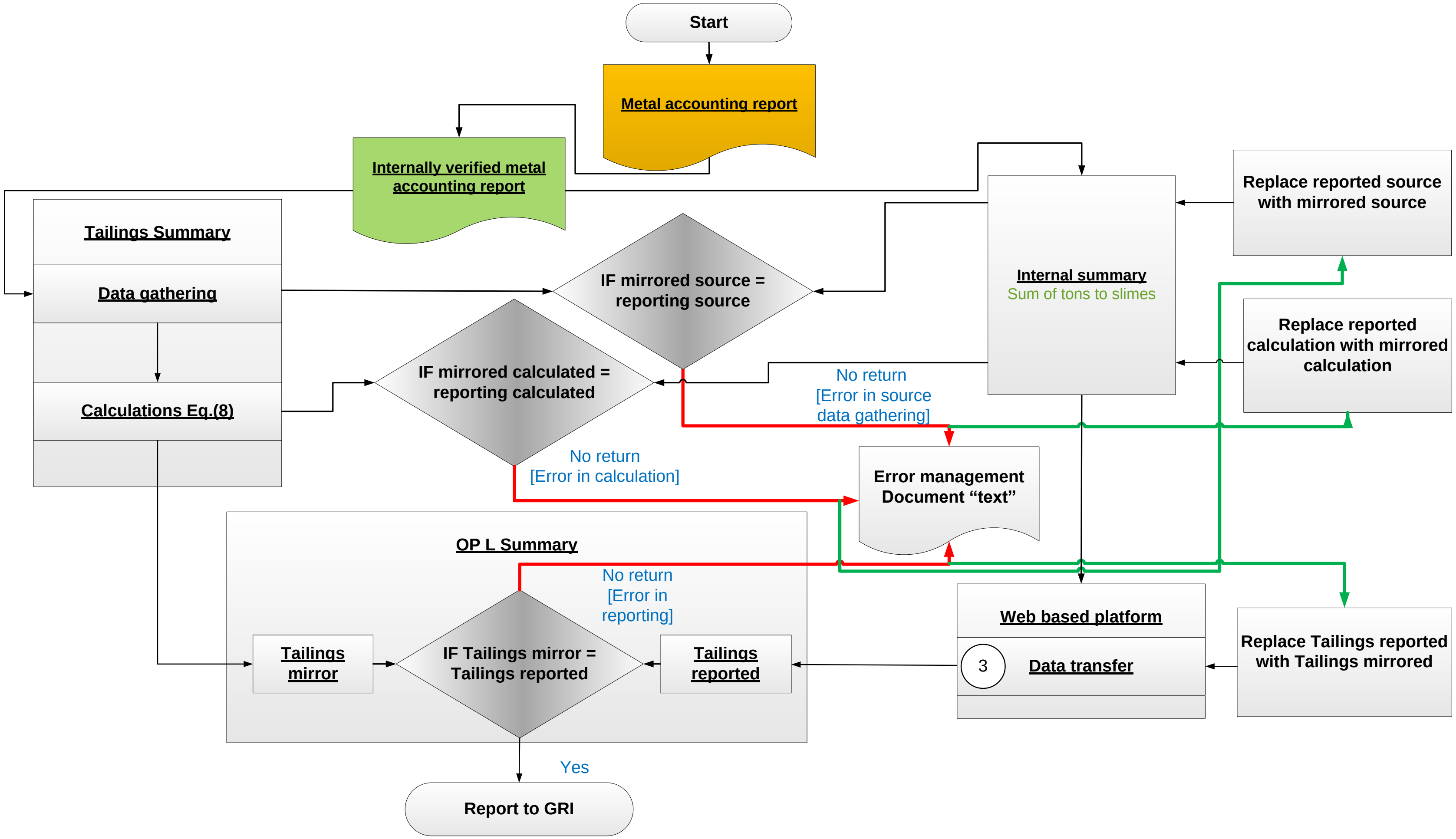


Figure 57: Error management for tailings to tailings dam

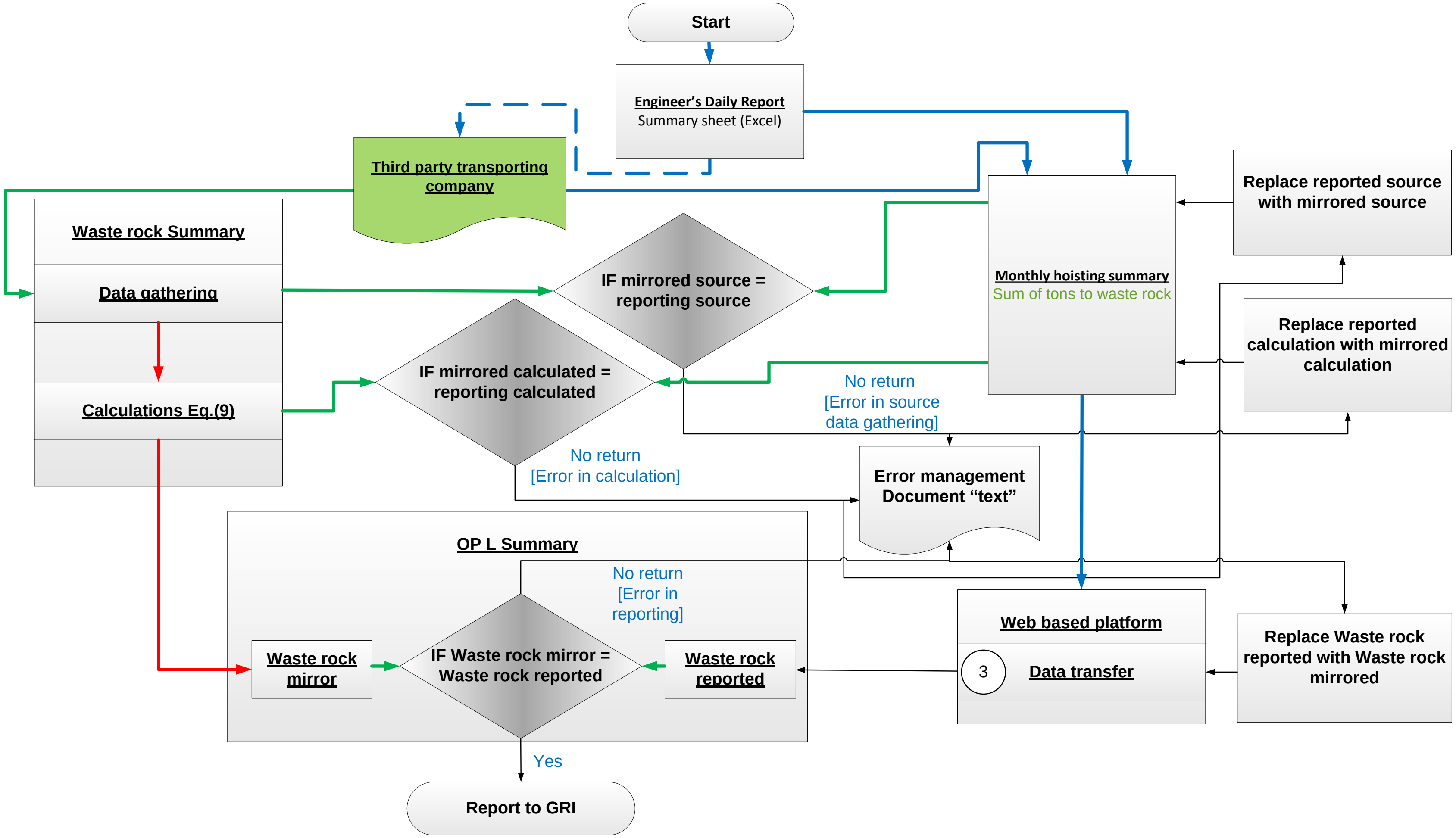


Figure 58: Verification procedure for waste rock to dumps

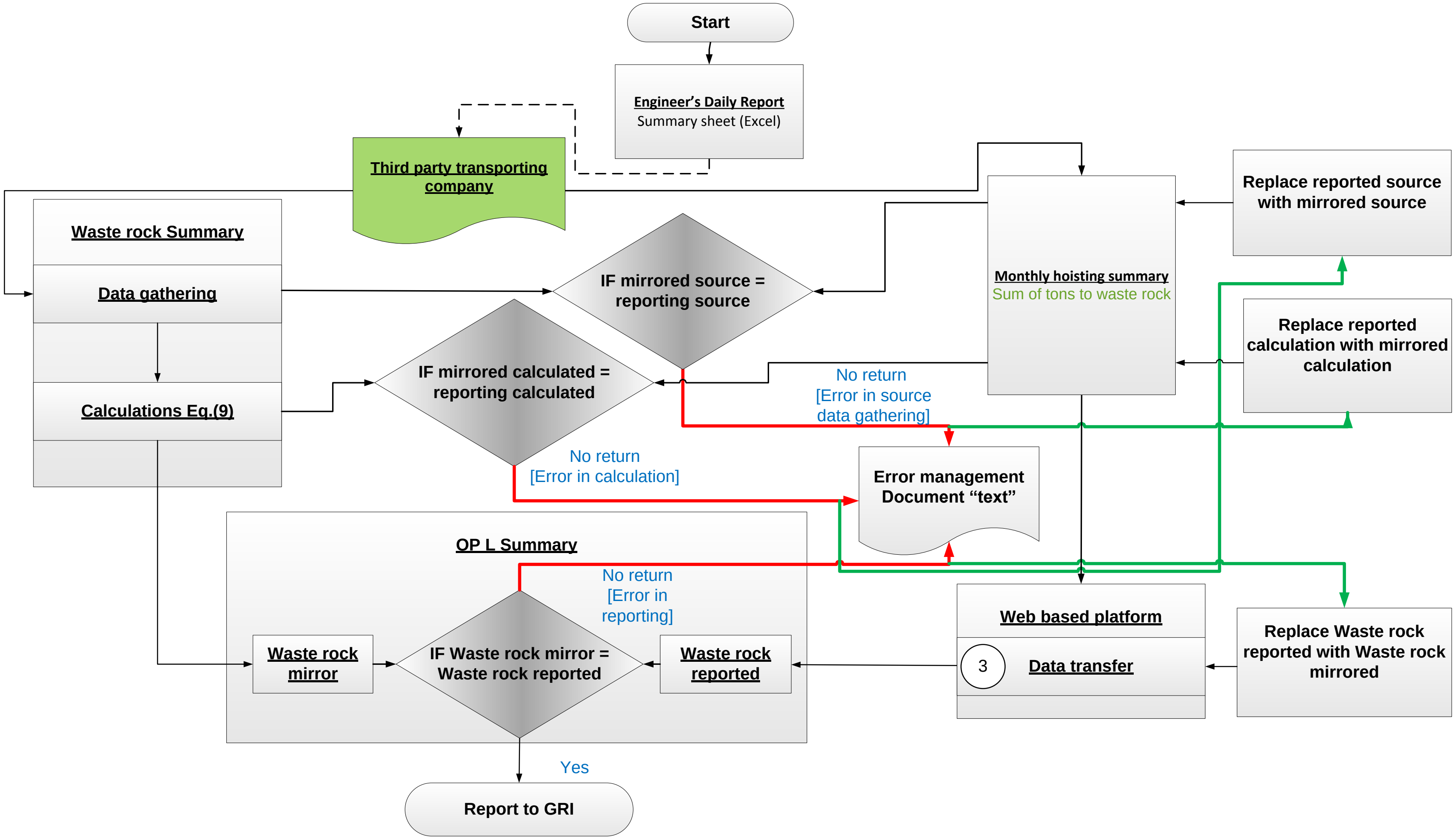


Figure 59: Error management for waste rock to dumps

Appendix F

Table 41: Discrepancy report August 2017

Operation	Reported	Source	Unit	KPI
A	98 380	78 834	litre	Potable water from external source
C	16 390 797	16 230 940	kWh	Energy from electricity purchased
D	392	277	litre	Petrol
	38 59 933	12 311 710	kWh	Energy from electricity purchased
E	27 190	23 210	litre	Potable water from external source
G	71 918	55 758	litre	Potable water from external source
H	517	431	litre	Petrol
	200	126	litre	Diesel
I	613	985	litre	Petrol
	837	1 700	litre	Diesel
L	28 600	30 655	litre	Potable water from external source
N	1 097	288	litre	Petrol
	684	714	litre	Diesel
	85 382	69 870	tonne	Potable water from external source
	20 494	20 976	tonne	Accumulated waste rock to dumps

Table 42: Discrepancy report September 2017

Operation	Reported	Source	Unit	KPI
C	14 697 864	16 036 218	kWh	Energy from electricity purchased
	52 242	53 446	litre	Potable water from external source
D	414	262	litre	Petrol
G	64	60	tonne	Explosives
	54 498	58 205	litre	Potable water from external source
H	291	212	litre	Diesel
I	512	982	litre	Petrol
	1 194.8	1 737	litre	Diesel

Operation	Reported	Source	Unit	KPI
J	4 130 167	4 556 068	kWh	Energy from electricity purchased
L	15 100	14 072	litre	Potable water from external source
N	1 278	257	litre	Petrol
	1 434	1 266	litre	Diesel
	98 750	98	tonne	Explosives
	90 787	76 919	litre	Potable water from external source
	22 085	22 277	tonne	Accumulated waste in rock dumps

Table 43: Discrepancy report October 2017

Operation	Reported	Source	Unit	KPI
A	9 349	9 762	tonnes	Accumulated waste in rock dumps.
C	14 178 035	15 475 381	kWh	Energy from electricity purchased
D	250	201	litre	Petrol
	11 618 709	11 608 859	kWh	Energy from electricity purchased
E	34 510	33 070	litre	Potable water from external source
G	56 481	76 357	litre	Potable water from external source
H	573	278	litre	Petrol
	243	3 409	litre	Diesel
I	528	807	litre	Petrol
	1 196	1 684	litre	Diesel
L	15 082	20 067	litre	Potable water from external source
N	869	175	litre	Petrol
	736	1 420	litre	Diesel
	89 712	72 003	litre	Potable water from external source

Table 44: Discrepancy report November 2017

Operation	Reported	Source	Unit	KPI
C	15 772 272	17 210 695	kWh	Energy from electricity purchased
G	50 060	65 512	litre	Potable water from external source
I	12 261 969	12 289 664	kWh	Energy from electricity purchased
N	602	118.6	litre	Petrol
	30 719	31 991.5	litre	Diesel
	91 884	77 251	litre	Potable water from external source

Table 45: Discrepancy report December 2017

Operation	Reported	Source	Unit	KPI
C	98 725	97 861	litre	Diesel
	12 675 830	13 902 015	kWh	Energy from electricity purchased
	44 008	44 757	litre	Potable water from external source
G	35 949	68 921	litre	Potable water from external source
I	10 486 118	10 508 590	kWh	Energy from electricity purchased
J	4 957	5 965	litre	Potable water from external source
L	16 075	13 948	litre	Potable water from external source
M	99 024	32 984	litre	Potable water from external source
N	506	202	litre	Petrol
	486	560	litre	Diesel
	92 339	80 360	litre	Potable water from external source
	99 252	97 656	tonne	Accumulated tailings

Table 46: Discrepancy report January 2018

Operation	Reported	Source	Unit	KPI
C	124 230	123 825	litre	Diesel

Operation	Reported	Source	Unit	KPI
	13 015 097	14 482 799	kWh	Energy from electricity purchased
F	21 562	1 562	litre	Diesel
I	10 416 167	10 441 246	kWh	Energy from electricity purchased
L	19 887	16 075	litre	Potable water from external source
N	15 450 795	15 450 315	kWh	Energy from electricity purchased
	20 555	20 558	tonnes	Accumulated waste in rock dumps.

Table 47: Discrepancy report February 2018

Operation	Reported	Source	Unit	KPI
B	9 359	1 419	litre	Diesel
	26 552 606	14 300 092	kWh	Energy from electricity purchased
	157 220	101 900	litre	Potable water from external source
C	14 443 624	15 752 329	kWh	Energy from electricity purchased
D	104 086	30 036	litre	Potable water from external source
E	11 148	1 148	litre	Diesel
I	11 739 794	11 764 769	tonnes	Energy from electricity purchased
L	21 395	19 886	litre	Potable water from external source
N	16 649 673	16 649 008	kWh	Energy from electricity purchased
	21 451	20 359	tonnes	Accumulated waste in rock dumps.

Table 48: Discrepancy report March 2018

Operation	Reported	Source	Unit	KPI
A	25 247 372	128 060	litre	Potable water from external source
B	24 458 724	13 067 010	kWh	Energy from electricity purchased
	191 610	135 170	litre	Potable water from external source
C	13 896 672	15 111 758	kWh	Energy from electricity purchased
D	535	481	litre	Petrol
F	21 425	1 424	litre	Diesel
I	279	607	litre	Petrol
	233	1 797	litre	Diesel
	11 355 369	11 378 404	kWh	Energy from electricity purchased
L	19 304	21 395	litre	Potable water from external source
N	87 856	74 924	litre	Potable water from external source
	23 072	23 081	tonnes	Accumulated waste in rock dumps.

Table 49: Discrepancy report April 2018

Operation	Reported	Source	Unit	KPI
B	24 073 148	12 629 586	kWh	Energy from electricity purchased
	166 440	117 160	litre	Potable water from external source
C	13 885 703	15 107 269	kWh	Energy from electricity purchased
	8 002	8 070	litre	Potable water from external source
D	478	390	litre	Petrol
	1 245	1 191	litre	Diesel
K	2 273	423	litre	Diesel

Table 50: Discrepancy report May 2018

Operation	Reported	Source	Unit	KPI
B	135 170	115 970	litre	Potable water from external source
C	13 842 112	15 056 896	kWh	Energy from electricity purchased
D	557	496	litre	Petrol
K	1 930	289	litre	Diesel

Table 51: Discrepancy report June 2018

Operation	Reported	Source	Unit	KPI
C	13 610 197	14 998 788	kWh	Energy from electricity purchased
D	638	514	litre	Petrol
K	289	520	litre	Petrol
N	88 706	88 786	litre	Potable water from external source