Environmental Management Systems: Appraising implementation in the mining industry

by

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EXECUTIVE SUMMARY

Environmental awareness has encouraged the implementation of environmental management systems (EMS) in many companies, including the mining industry. Although the general consensus is that “it must be good for the environment”, many companies are unsure whether it is worthwhile the effort to implement a creditworthy EMS. This holds true, especially for mining operations, under much pressure from green lobbyists and increasing strict legislation.

Rather than to blindly integrate an EMS into an existing management system or to implement a new one, this project offers an academic insight into the problem, clarity regarding some obstacles to implementation and available solutions for evaluating an EMS. A practical model is proposed which Exxaro’s Matla coal mine can use to justify their recent ISO 14001 integration, or to provide a decision framework for considering such integration into the existing quality management systems (QMS) of Exxaro’s remaining operations.

OPSOMMING

Omgewingsbewustheid het die instelling van omgewingsbestuurstelsels (OBS) in menige maatskappye aangemoedig, insluitende die mynbedryf. Hoewel die algemene veronderstelling gemaak word dat “dit mos goed is vir die omgewing”, is baie maatskappye onseker of dit werklik die moeite werd is om ’n kredietwaardige OBS te implementeer. Hierdie onsekerheid geld veral vir mynbedrywighede wat onder baie druk van omgewingsbewuste partye en toenemend strenger wetgewing verkeer.

Eerder as om blindelings ’n OBS in ’n reeds bestaande bestuurstelsel te integreer of ‘n nuwe een te implementeer, bied hierdie projek ’n akademiese insig in die probleem, duidelikheid rondom sommige struikelblokke in die pad van implementering en beskikbare oplossings vir die evaluasie van ’n OBS. ’n Praktiese model word voorgestel wat Exxaro se Matla steenkool myn kan gebruik om hulle onlangse ISO 14001 integrasie te regverdig, of om ’n raamwerk daar te stel ten einde ’n ingeligte besluit te neem rondom diesulke integrasie in bestaande gehalte bestuurstelsels van Exxaro se oorblywende bedrywighede.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AHP	Analytic Hierarchy Process
BSC	Balanced Score Card
CP	Cleaner Production
ECI	Environmental Condition Indicator
EMI	Environmental Management Indicator
EMS	Environmental Management System
EPE	Environmental Performance Evaluation
EPI	Environmental Performance Indicator
GIS	Geographical Information System
IPS	Impact Performance Indicator
ISO 9001	International Standard for Quality Management
ISO 14001	International Standard for Environmental Management Systems
ISO 14031	International Standard for Environmental Performance Evaluation
KPI	Key Performance Indicator
LCL	Lower Control Limit
OBS	Omgewingsbestuurstelsel (Afrikaans translation of EMS)
OPI	Operating Performance Indicator
PDCA	Plan-Do-Check-Act
PV	Performance Value
QA	Quality Assurance
QMS	Quality Management System
RA	Risk Assessment
SHE	Safety, Health and Environmental Protection Standards
UCL	Upper Control Limit

CHAPTER 1

INTRODUCTION

1.1. PROJECT INTRODUCTION

There has been a growing interest from the public in sustainable development and conservation of the environment. Consequently, organizations and industries are under pressure, not only to adopt an environmentally friendly management approach, but to prove their zeal in obtaining a green status. This holds true especially for mining industries, frequently criticized for the devastating impact they have on the environment, if careful management is not administered. This is because of their invasive exploitation of nature's reserves and their contribution to a substantial amount of pollution released in the air, ground and water. For example, if a mining company's operations licence is suspended due to environmental disobedience, production are forced to halt. Such a company can end up losing a fortune in revenue when suspended. The chances of negligence being exposed are increasing. No company can afford this type of risk, therefore it is understandable that many mining industries are eager to adapt an environmental management system (EMS) to achieve cleaner production (CP) and as a first step to satisfy a diverse group of stakeholders.

South African companies are none the wiser regarding this problem and, therefore, this project is also of relevance to the South African concept. To give an example as to why the trade-off between cost and environmental impact in the mining industry cannot be considered lightly: The South African mining company Exxaro's carbon footprint represents almost 1% of South Africa's total emissions and Exxaro's 2010 budget for their energy and carbon management programme was approximately R9 000 000 (Exxaro Resources Limited, 2010). Bearing this in mind, Exxaro's Matla coal mine (hereafter shortly referred to as "Matla") was selected to give the topic a local character.

To assist mining companies to better understand the true impact of EMS implementation, integration and/or certification of the EMS according to an internationally acknowledged standard, this project offers a methodology to evaluate and justify Matla's EMS.

1.2. COMPANY BACKGROUND - EXXARO RESOURCES LIMITED (EXXARO)

Exxaro, being the fourth-largest South African coal producer with a capacity of 45 million tonnes per year, is the largest South African-based mining group. In addition to their coal operations, Exxaro is the third-largest global producer of mineral sands and is a significant participant in base metals and industrial minerals. Exxaro also operates beyond South African borders with facilities and offices in other parts of Africa, Asia, Europe and Australia.

This dynamic company is well positioned for growth and presents exciting investment opportunities to investors. This is due to Exxaro's open minded, but focussed business approach and possession of excellent mining and mineral reserves. Their growth prospects are enhanced by the strong demand for Exxaro's chosen commodities, which is driven by international opportunities and developments in the manufacturing, mining and petrochemical industries. There is also the rising need for power generation from coal as a convenient source of fuel, especially in South-Africa, with Exxaro being one of the largest suppliers to Eskom.

Although Exxaro is a relatively new name, they boast with a rich history in the mining industry. They were formed as a result following the unbundling of Kumba Resources' iron ore assets in November 2006. Exxaro (focussed on coal, base metals, industrial minerals and mineral sands) and Kumba Iron Ore (focussed on iron ore) were relisted as two independent companies. It is worth noting that Exxaro still holds 20% interest in the iron ore operations of Kumba Iron Ore, ensuring a foot in the door for possible iron ore prospects.

1.3. PROBLEM STATEMENT - JUSTIFYING EXXARO'S MATLA COAL MINE (MATLA) ISO 14001 IMPLEMENTATION

As a result of Exxaro's commitment to the Safety, Health and Environmental Protection Standards (SHE), see clause 16 of (Exxaro Resources Limited, 2006), several of their operations are considered for ISO 14001 certification to enhance their current EMS. Some of their industries already received such accreditation of which the Matla coal mine is an example.

Exxaro's Matla mine, approximately 20km west from Kriel, is Exxaro's second largest mining operation. Matla employs about 1400 people in an environment already under heavy pressure. This coal mine received their ISO 14001 certification in January 2010. They still have to produce results following the ISO 14001 implementation to ascertain the impact on their environmental and, ultimately, overall performance. Therefore, this gives rise to the

question of whether such an implementation can be justified and whether it can be set as a model for the remaining Exxaro operations, or not.

1.4. PROJECT AIM

The aim of this project is twofold:

- It endeavours to justify the implementation of an ISO 14001 certified EMS into Matla by constructing and utilizing an appropriate model.
- The proposed model will be made as simple and flexible as is practically possible to allow for the generalisation of such a model to serve as a decision base to other mining operations. It will be applicable to mining operations at a cross-road for deciding on the implementation of an EMS, or to adjudicate existing implementations.

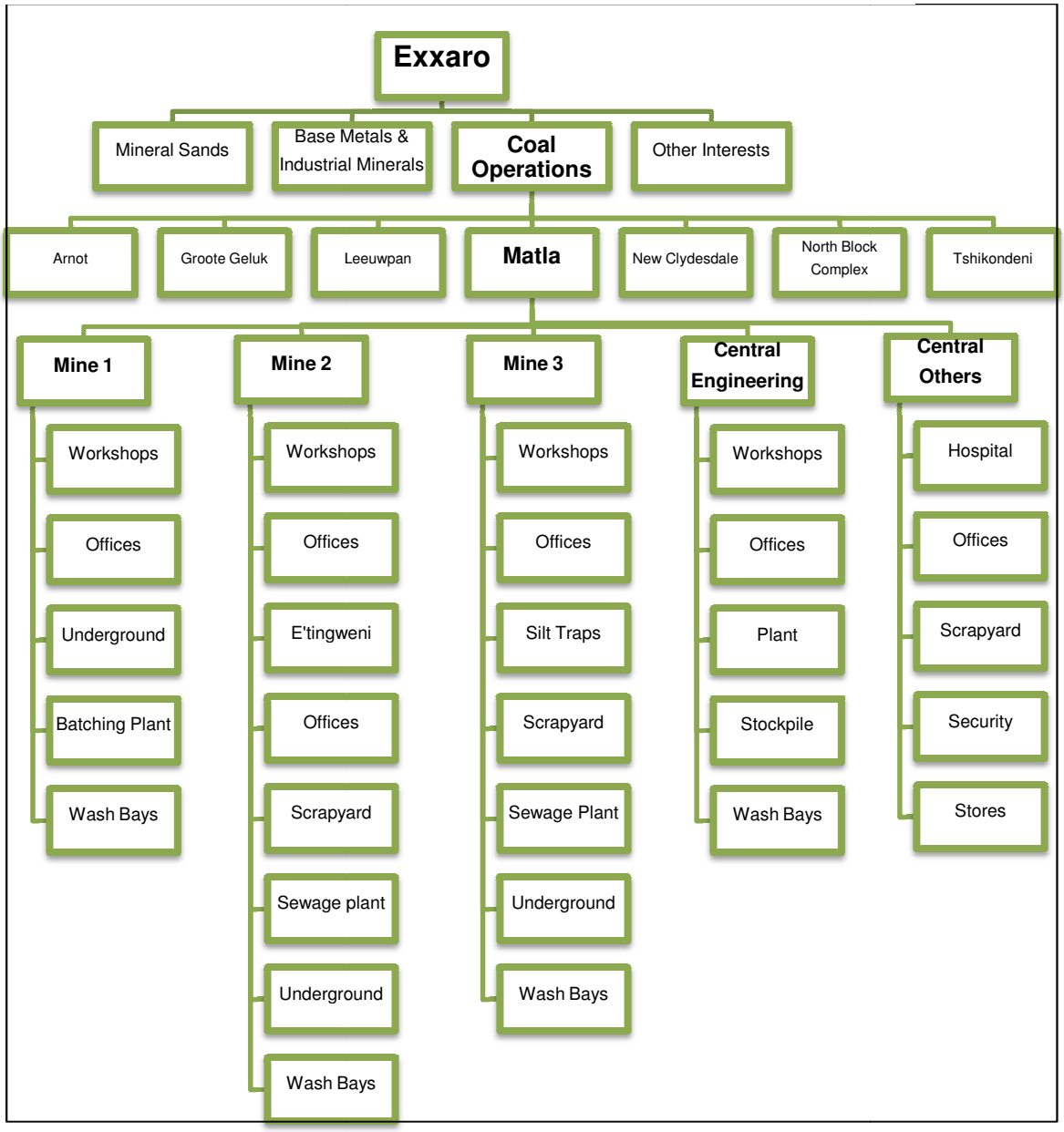
1.5. PROJECT SCOPE

Matla's operations, within the bigger context of the entire Exxaro structure, are outlined in *Figure 1* on the next page.

The complete evaluation and justification of ISO 14001 implementation is much more comprehensive than is required for a final years project for the degree BEng (Industrial Engineering). Some assumptions and exclusions are made to provide a narrowed scope. These assumptions and exclusions are as follows:

- Matla's EMS will be appraised as a recently ISO 14001 integrated system
- No barriers constrain the EMS (step 1)
- The ISO 14001 requirements are optimally integrated into the existing EMS (step 2)
- A description on CP is offered to guide evaluation in this step but will not be done in this project (step 3)
- Matla's operations are fully interdependent
- Only the data already available will be used

A narrowed scope (step 4 to 6) will be intensively examined. The procedures of the excluded steps 1-3 are provided. This will serve the purpose of explaining the fitting of the project scope within the bigger picture of a complete evaluation of Matla's EMS.



1.6. REPORT CONTENTS

A literature review in chapter 2 provides an academic insight into the problem scenario, barriers and solutions. The development of a conceptual design from a selection of appropriate tools, methods and technology is discussed in chapter 3. The approach and act of data gathering is then addressed in chapter 4. Chapter 5 forms the centre of this project by designing and developing a solution to the problem. The last chapter conclude the solution and recommend further study opportunities to the project.

CHAPTER 2

LITERATURE REVIEW

An EMS ensures that an organization's environmental targets are being pursued (Hilson & Nayee, 2002). Although certification is not necessary for pursuing an effective EMS, it does demonstrate a successful implementation of an acknowledged standard and can be used by an organization to assure interested parties that an appropriate EMS is in place (Technical Committee ISO/TC 207, 2004).

A good example of an internationally acknowledged EMS guideline is the ISO 14001 (International Standard for environmental management systems) which is the first attempt to have an international EMS standard (Darnall, 2006). ISO 14001 will be addressed throughout this project. An EMS, whether already integrated or a proposed implementation can be evaluated to assess the company's environmental performance. ISO 14031 provides a solid structure for evaluation and will be discussed later in this literature review.

This literature review starts with a problem statement to describe the hesitation in the mining industry to implement an ISO 14001 certified EMS despite of the obvious benefits. Next, three significant barriers are identified which could possibly hinder compliance to an international EMS standard. The last topic investigates and summarises existing solutions which can be applied to appraise an ISO 14001 certified EMS in a mining operation.

2.1. THE PROBLEM

The benefits of an ISO 14001 implementation are widely known, for example, cost reductions, limiting environmental impacts, improved relations with state environmental agencies and enhancing a company's competitive advantage (Kinsella, 1994); (Block & Marash, 1999). However, the decision-making process of EMS implementation, according to ISO 14001, is a critical step for a number of reasons. Firstly, most benefit and cost attributes are difficult to measure. Secondly, it requires a multidisciplinary approach and support and has to be coordinated within the various functions/departments of a company. Lastly, but by no means the least important, the pros and cons of an EMS require a very flexible approach because they depend on the specific situation or site where it is to be implemented. (Petroni, 2001)

Despite the benefits, there are concerns from companies that such integration will have a negative impact on their performance. Since ISO 14001 is a relatively new standard, with the

first publication in 1996, many companies have inadequate knowledge and exposure to ISO 14001. This, together with the possible cost involved with integration, the fear of extra paperwork and the concern that it might jeopardize their current QMS certification (such as ISO 9001) during an audit, makes some companies reluctant to integrate ISO 14001 (Block & Marash, 1999). Adding to this hesitation is the fact that most companies want to know whether the effort of implementing an EMS will be worthwhile, in addition to the prospect of better environmental conservation and satisfying some environmentally concerned parties.

2.2. BARRIERS TO IMPLEMENTATION

In some cases, a mining company may experience one or more limitations which discourage them to implement a functional EMS. It is important to know and overcome such obstacles before a successful EMS can be implemented. Even though these problems are real and, in many cases, unavoidable, it should never be used as a reason for not having some kind of efficient EMS in place. Three basic barriers can be isolated as the most relevant in the mining industry and are concisely explained below. They are economic, technological and legislative barriers (Hilson, 2000).

2.2.1. Economic

The considerable resources involved in implementing ISO 14001 are in most cases the primary apprehension encountered in companies, especially those with no existing EMS, since it seems to go synonymous to major alterations to an existing management system. For example, the frequent audits required to ensure ongoing compliance, done by external parties, contribute to an annual expense and the training involved to educate all levels of employment in the company absorb a lot of manpower which could otherwise be applied to production. If not managed carefully, the financial implications and human resource drain can escalate.

Companies in developing countries are especially vulnerable to this economic barrier since they have much less access to resources than those in developed countries (Massoud, Fayad, Kamleh, & El-Fadel, 2010). According to a study conducted by (Neumayer & Perkins, 2004) the per capita ISO 14001 counts relate to the income per capita as well as other factors in the economic structure of the specific country. This explains, to some extent, the disadvantage of companies operating in the developing world.

The economic implications are much less for a company with an effective EMS or other QMS already in place since it can be integrated fairly easily into the existing system as many

requirements correlate within each of the systems and therefore it is not necessary to reinitiate them, or they can simply be expanded with minimal effort (Block & Marash, 1999).

Even if a company doesn't have an overall cash flow problem, a company can be tempted to blame economic reasons (like a plunge in commodity prices, worldwide economic depression, etc.) to divert the responsibility from the company for not having an effective EMS system.

2.2.2. Technological

Technology is often associated with high costs and the need for expert skills to implement and maintain it; therefore some technologies associated with CP are not within the reach of some companies operating in developing countries. Such industries stay with older technologies which are known to have an adverse impact on the environment (Hilson, 2000).

2.2.3. Legislative

In various developing countries, there exists no efficient environmental laws or they are, at best, outdated. Companies operating in such countries might feel that the inability to comply with international standards prevent them from incorporating and maintaining an EMS. For example, ISO 14001 states that an EMS should comply with the environmental legislation of the country in which the operations take place (Technical Committee ISO/TC 207, 2004), but without appropriate environmental laws this is not possible and certification could fail.

However, mines operating in countries lacking environmental legislation should not be discouraged from implementing an effective EMS due to incompatibilities with international standards, since certification is not necessary in order to have a healthy EMS in place. (Hilson, 2000)

2.3. CURRENTLY AVAILABLE METHODS

Environmental management systems, and specifically ISO 14001, receive more and more attention and this is primarily spurred by a global awareness of the ecology. As this happens, studies are done to investigate, analyse and suggest guidelines for implementing an EMS into an existing or new management structure. Several methods exist and are best employed if combined.

2.3.1. Verifying the integrity of implementation/integration

The second logical step, after the destruction of barriers, towards an evaluation would be to verify the proper integration of ISO 14001 into an existing quality management system

(QMS), whether it is accomplished by partial or full integration (Block & Marash, 1999). Since most large companies already have some kind of QMS already in place, the guideline offered by (Block & Marash, 1999) can be utilized as an aid to ensure the integration with minimal effort and fuss, or to critically evaluate the existing integration for negligence. This method can identify and prevent the unnecessary, parallel execution of a requirement prescribed by both systems.

Specific application of such implementation in the mining industry is investigated and suggested in the article, (Hilson & Nayee, 2002). Several recommendations exist, but one is worth noting as a key contributing factor to a successful implementation: The multi-disciplinary support framework in which such an EMS should function. Careful attention should therefore be given to such a framework and its efficiency in maximising yield from an EMS.

A smooth integration / implementation provide a simple base for the evaluation of the EMS.

2.3.2. Cleaner Production

CP is a continuous strategy to prevent harmful emissions at the source and to minimise the impact of the production cycle and products on the environment. The close relationship between CP and ISO 14001 becomes apparent when these two strategies pursue a mutual goal in ensuring an environmentally friendly management system. Where ISO 14001 is mainly concerned with auditing the management system, CP tools provide a useful, systematic means for top management to measure and prevent pollution by means of input/output analysis. In other words, where ISO 14001 only guides and audits an EMS for compliance, it does not specify the instruments needed for an EMS. CP, however, can provide them. (Fresner, 1998)

Where ISO 14001 lacks clear prescriptions to control the effect of the company's operations on the environment, the implementation of CP technologies and methods allows the investigation of the company's environmental impact. For example, the application of Geographical Information System (GIS) technology, often employed in precision farming, can be used to constantly evaluate the quality of soil and water surrounding the mining operation. This will aid in a better understanding of the company's ecological impact and assessing their progress towards a cleaner environment. This goes hand-in-hand with environmental performance evaluation (see section 2.3.4).

2.3.3. Analytic Hierarchy Process

Perhaps the most straight forward theoretical method to analyse the company's management system prior to the integration of ISO 14001, or to justify an already implemented EMS is the AHP. This method provides an effective systematic model to appraise the application of an EMS in a company by weighting the costs and benefits against one another.

The specific application of AHP to ISO 14001 implementation in companies is illustrated in the research article, (Chin, Chiu, & Tummala, 1999). The article (Petroni, 2001) illustrates a useful formulation of a decision support methodology for multi-attribute analysis of ISO 14001 implementation. This comprises of a framework development of pros against cons, as well as the costs involved and structuring them into a specific order for the use of the AHP. In this way, a well-known comparison technique, the cost-benefit approach, can find useful application in the AHP.

2.3.4. Environmental Performance Evaluation

EPE is a term to describe the formal strategy which a company follows to measure, analyse and communicate their environmental performance against a predefined set of criteria. Although EPE is not explicitly required by international standards for EMS, it can greatly motivate and improves its EMS thanks to the numerous benefits it offers. Two of the most important objectives, with respect to this study, would be a better understanding of the company's impact on the environment, as well as benchmarking the company's management, operational and environmental performance. (Giagnorio, 2005).

EPE provides a valuable tool which a company can use to justify and assess an existing EMS or to motivate a proposed one. The ISO 14031standard is an international standard that provide a structured approach to EPE. It is not a standard for certification as is the case with ISO 14001, but supports the requirements and guidance given in ISO 14001 (Technical Commitee ISO/TC 207/SC4/JWG, 1999).

According to the first (planning) phase of the Plan-Do-Check-Act model, as projected by this standard, a set of environmental performance indicators (EPI) need to be identified. EPI's can be defined as analytical tools or criteria which can be used to assess and compare a company's performance from an environmental perspective (Tyteca, 1996). In principle, EPI's is similar to the better known key performance indicators (KPI's) except for focussing on the environmental aspect of a company's performance. ISO 14031 distinguish between 3 elements of EPE - Environmental Management Indicators (EMIs), Environmental Condition

Indicators (ECIs) and Environmental Performance Indicator (EPIs). EPIs may be further subdivided into Operating Performance Indicator (OPIs) and Impact Performance Indicators (IPSs) (Diakaki, Grigoroudis, & Stabouli, 2006). Selecting these indicators can be considered as the most critical and challenging step since poorly chosen indicators can lead to misleading information and the waste of resources (Giagnorio, 2005). According to (Jasch, 2000) EPI's serve the following purposes:

- Compare environmental performance over a given time period.
- Pointing out optimisation potential.
- Assist in the identification of environmental targets.
- Identification of market potential and cost reduction opportunities.
- Benchmarking of environmental performance between different companies.
- Provide a communicational tool for the compilation of environmental reports.
- Offer a feedback instrument for information and additional motivation of employees.

Various methods for selecting the appropriate EPI's exist in research papers on this topic, but it is essential to select EPI's to support the data and management structure of the company. A risk assessment (RA) approach has been selected for the intent of this study since it best supports the data available, and forms part of the risk management procedures at the recently ISO 14001 accredited Matla mine. The article (Diakaki, Grigoroudis, & Stabouli, 2006) investigates and propose such a methodology of selecting EPI's. They use RA as a tool to identify and prioritise processes which could have a negative effect on the environment. This, in turn, is used to assist decision making on the selection and assessment of appropriate EPI's.

In the second phase of ISO 14031, the "Do" step involves the evaluation of aforementioned EPI's. A number of available tools to do the evaluation are explained in the article by (Finnveden & Moberg, 2005).

During the last two phases (Check and Act) the EPE results should be evaluated on a regular basis to assess the company's environmental performance and to identify opportunities for improving it.

2.4. LITERATURE REVIEW CONCLUSION

Efficient environmental management plays a crucial role in sustainable development and the protection of the human habitat, earth. Although it seems to be a noble effort when a mining company implements and propagates their EMS, there is more to it than what meets the eye: If a company's existing or new EMS is carefully managed, it can greatly enhance the

company's environmental performance and contribute to the company's overall performance.

By offering a methodology to appraise the implementation or justification of an ISO 14001 certified EMS, mining industries can get an idea of what the implications of such major management alterations will be and to continually assess them. Ongoing improvement of the EMS will also be simplified. By being knowledgeable about the efficiency of the EMS, the potential advantages can be maximised to their full extent for the benefit of both the company and the environment.

CHAPTER 3

SELECTION OF APPROPRIATE METHODS, TOOLS AND TECHNIQUES

The literature in chapter 2 has been sifted and reviewed in order to identify the appropriate methods, tools and techniques sufficient to conduct the evaluation of Matla's EMS and to justify their integration. The inclusion of additional tools enhances these aforementioned methods.

3.1. METHODOLOGY

3.1.1. Construction of methodology from literature review

From the literature study in chapter 2, five logical steps to appraise an existing EMS were investigated:

1. Identify and overcome barriers hampering EMS efficacy.
2. Verification of the integrated EMS's efficiency.
3. CP as a means to evaluate EMS.
4. Using the AHP to assess the EMS.
5. EPE with the aid of ISO 14031.

3.1.2. Supplementing the methodology

A sixth step in addition to those obtained from the literature (see section 3.1.1) is proposed as follows:

6. Quality assurance (QA) of the product.

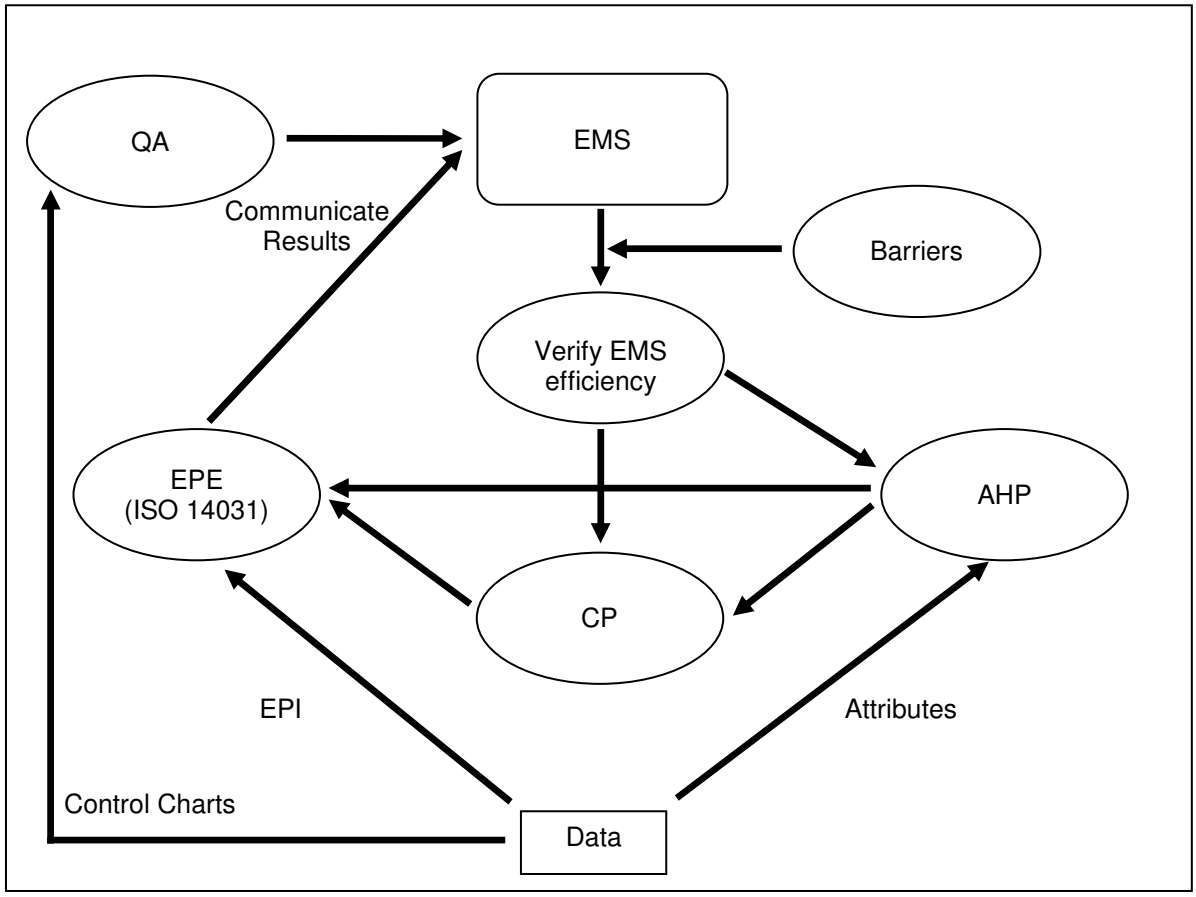
This final step uses the quality improvement / deterioration of the product as a means to assess the value of the EMS. The new EMS necessarily involve the additional training of operators as well as the implementation of CP technology to strive towards a more environmentally friendly operations process in the production of the product which could have an effect on the product quality itself. It is extremely important that the TQM structure is not compromised by the effort for green production. It is noted from the literature that a good EMS should benefit the overall production quality. To check the production process's

statistical stability, control charts will be employed. The textbook, (Gitlow, Oppenheim, Oppenheim, & Levine, 2005), is used to guide in conducting the QA of the process.

3.1.3. Concept design

The results obtained by following these 6 steps, give a good overview and understanding on the performance of an EMS. These steps are tightly intertwined with each other and their relationships are shown in *Figure 2*.

Figure 2: The interrelationships between the 6 steps of EMS appraisal



These steps are then expanded with the appropriate tools and techniques from the literature relevant to each step *(Table 1)*. The steps included in the project are highlighted with darker borders.

Table 1: Strategies and tools relevant to each step of EMS appraisal

BARRIERS	VERIFY IMPLEMENTATION	CP
• Identify • Investigate • Overcome, adapt or explore alternative options around obstacles	• Create a single, clearly identified group with responsibility of the integrated system • Identify EMS requirements • Determine previous Requirements • Review each element of EMS for discrepancy between theory and actual execution • Identify and solve procedural problems • Review and solve non-conformance • Audit the integrated system to both QMS and EMS standards	• Evaluate materials, processes and technology • Energy analysis • Material flow analysis • Analyse EPI • Employ technology to analyse environmental impact of production
AHP	**EPE (ISO 14031)**	**QA**

• Structure the problem and model building
• Data collection through pair-wise comparisons and measurement
• Calculation of priority weights of individual factors
• Analyse the priority weights and deriving solutions to the problem
	• PLAN
	  • Select EPI
	• DO
	  • Collect data
	  • Analyse & convert data
	  • Assess information
	  • Report & communicate results
	• CHECK & ACT
	  • Review the evaluation
		• Collection of production data
		• Identify the most appropriate type of control chart
		• Define the control limits
		• Define the three-sigma limits
		• Check with control chart whether the process is in statistical control
		• If not, identify and isolate causes of special variation
		• Stabilize process

The design of a conceptual model is done within the scope of the project and hold to the assumptions defined (see section 1.5). To be able to present a better visual description to the layman, a detailed process model was developed by using the BizAgi Studio software to explain the above named steps and their interrelationships with each other. For this process model refer to *Appendix E.*

CHAPTER 4

DATA MINING

IMPORTANT NOTICE:

Data Privacy

It is not authorised to publish real data throughout the report due to the sensitive and confidential nature of such data. Some of the data are adapted or changed to a more general concept, not pointing directly to Matla's activities. The *Risk Assessment Robot* and the concurring *Aspect and Impacts Register* are also the intellectual property of Exxaro, therefore it cannot be included in a public document such as this project report. These documents, however, were used to aid in the formulation of some procedures of the EPE with the permission of Exxaro.

4.1. ANALYTIC HIERARCHY PROCESS

Data is gathered by means of a questionnaire of which the first set of questions consists out of 50 questions (the sub-criteria). These questions are divided to fit into one of the following criteria:

- Ecological impact
- Efficiency
- Employee working climate
- Expenses
- Image and reputation
- Legislative requirements
- Manageability
- Risk assessment

These 50 questions test the feeling of the respondent regarding the ISO 14001 implementation - does he / she feel that it was a good thing or not to try improving the EMS by means of the ISO 14001 certification. The respondent has a scale of 1 to 7 *(Table 2)* with 7 indicating the best improvement and 1 the worst deterioration. 4 would indicate no change at all:

Table 2: Improvement scale

Scale	Explanation
1	Worst deterioration
2	Serious deterioration
3	Slight deterioration
4	No change / unsure
5	Slight improvement
6	Considerable improvement
7	Best improvement

In the second part of the questionnaire the respondent is asked to judge the relative importance of each criterion against each other. This judgement is assigned a number on a scale from 1 to 9. One frequently used scale, adapted from (Saaty, 1980), will be employed for the purpose of this AHP:

Table 3: Saaty importance scale (Adapted)

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement slightly favour one over the other.
7	Very much more important	Experience and judgement strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

This questionnaire was handed to employees working at the Matla, in such a way that it is representative of the administrative workforce at Matla. This group of employees were chosen as they have knowledge on the management and general issues regarding the management of Matla. Due care were taken to ensure the consistency on the rating of the criteria against each other. This means that the rating of any criteria should not influence the importance of another. An example from the automotive industry should illustrate this matter: Engine power output as opposed to fuel economy - the requirement of better strength necessarily means worse fuel economy.

The questionnaire is included as *Appendix A.* The completed form is exported to a Microsoft Excel spreadsheet to assist with the calculations needed for the AHP. These calculations can be seen in *Appendix B.*

4.2. ENVIRONMENTAL PERFORMANCE EVALUATION

The guideline presented by ISO 14031 in the Plan-Do-Check-Act (PDCA) cycle is to be followed. The most important part would be to identify the EPI's (For the sake of simplicity, only EPI's are addressed). The risk assessment methodology proposed by (Diakaki, Grigoroudis, & Stabouli, 2006) will primarily be used. Therefore, this selection of EPI's will be based on the principles of the RA technique.

According to the ISO 14001 standard (Technical Committee ISO/TC 207, 2004) certain principles are laid down for the derivation of EPI's. It should be:

- *Comparable:* It must be possible to effectively compare the indicators against each other and should clearly reflect changes in the environmental performance of the company.
- *Target orientated:* The selected EPI's should be chosen so they can act towards specific goals as laid down by the company.
- *Balanced:* The EPI's must give a brief, but clear indication of the environmental performance and be able to display problem areas as well as benefits in a balanced way.
- *Continuous:* To be able to compare it, the EPI's must be derived by the same criteria and in corresponding time periods.
- *Frequent:* EPI's must be evaluated and measured as frequently as is necessary to be able to act on them in time.
- *Comprehensible:* These EPI's should be user-friendly and adhere to the user's informational needs. The EPE system should also concentrate on the most important figures.

Due to the recent certification of ISO 14001 in January 2010, data for EPI's after the implementation only exist for 8 months (January to August). For the sake of conformity and comparability, as stated in the above principles, data will be assessed over the same time period regardless of the information available before the implementation. This is why 8 months has been selected in some cases instead of annually.

To determine the importance rating of each EPI, another questionnaire *(Appendix C)* was sent out to industry experts. In this questionnaire, respondents were asked to rate the importance of each EPI on a scale of 1 to 5 with 1 being the least important and 5 being extremely important. Unlike the pair-wise comparison of the AHP (the rating scale in *Table 3*) the rating of each EPI is independent.

4.3. QUALITY ASSURANCE

The actual monthly production data from Matla's commodity - power generation coal - are gathered and assessed as the *total amount of coal produced* against the *total amount of saleable product produced*. The units are measured in tonnes (kg * 10^3). These data are then constructed in appropriate control charts to verify the stability and overall quality of the production cycle. This data analysis will determine whether the quality has deteriorated or improved due to operations management following the integration of ISO 14001 at Matla.

CHAPTER 5

DESIGN & PROBLEM SOLVING

5.1. ANALYTIC HIERARCHY PROCESS

5.1.1. Problem statement

Can the recently implemented ISO 14001 based EMS be justified?

5.1.2. In depth view on the objective of the problem

The AHP multi-decision assessment on the justification of the EMS at Matla provides an Eigen value approach to the pair-wise comparison of the questionnaire data to get clarity on the two alternatives, based on the opinions of the respondents:

- Justify and advocate the EMS
- Criticise and oppose the EMS

5.1.3. Criteria

The set of criteria (into which each of the 50 questions fit) influencing the decision on the measures to be included for the purpose of the AHP are stated and explained as follows:

Ecological impact (EI)

What is the effect of the adapted management system on the immediate environment? Does it ease the burden on the environment or not?

Efficiency (EF)

A company's profitability depends heavily on the efficiency of its management structure, which in turn influences the business processes of the company. This goes hand-in-hand with the manageability criteria. A good EMS should improve efficiency.

Employee working climate (EC)

A successful management structure contributes to the joy of employees at a company. Does it hold true for Matla's ISO 14001 accreditation?

Expenses (EX)

Sometimes being the most important factor in decision making, can the costs be ratified for the green effort?

Image and reputation (IR)

Along with a growing environmental consciousness, companies start to adapt their management policy towards a more environmentally friendly approach to satisfy the stakeholders. Does the company's "green" image appeals to the stakeholders due to the implementation?

Legislative requirements (LR)

The company's competitiveness depends, to a large extent, on how much the company's EMS complies with government regulations. For instance, it could have an adverse impact on the company's profitability and ability to do business should they not adhere to government laws. In other words, is the company a "better" citizen after implementation?

Manageability (MA)

Companies might be reluctant to integrate or implement a change to their existing management system for the fear of complicating their management system. Does the implementation simplify or complicate the company's management structure?

Risk assessment (RA)

This is the company's overall process of identifying possible risks pertaining to certain activities and assessing the perceived impact of these risks on human health and the environment. For the purpose of the AHP, it also explains the ability of the company to predict and handle different levels of emergencies.

5.1.4. Weighting of criteria

Pair-wise Comparison

The second set of questions in the questionnaire *(Appendix A)* is exported to a MS Excel spreadsheet into the following pair-wise comparison matrix *(Table 2).*

Table 4: Pair-wise comparison matrix of relative importance

	EI	EF	EC	EX	IR	LR	MA	RA
EI	1	5	1	3	1/5	1/3	3	3
EF	1/5	1	1/3	1	1/9	1/7	1/5	1/5
EC	1	3	1	1	1/3	1/3	1	1
EX	1/3	1	1	1	1/5	1/3	1	1/3
IR	5	9	3	5	1	3	1	3
LR	3	7	3	3	1/3	1	3	1
MA	1/3	5	1	1	1	1/3	1	1
RA	1/3	5	1	3	1/3	1	1	1

5.1.5. Calculations

Eigen Vector

To obtain the relative ranking of each criterion:

1. Convert the fractions to decimals
2. Square the pair-wise matrix successively
3. Calculate and normalise the row sums
4. Stop the algorithm when two consecutive iterations yield a difference (the normalised row sums) smaller than four decimal places.

Determining the criteria weights

To determine the preference of each alternative:

5. The last (the fourth) iteration's normalised row sums indicate the weight of each criterion with relation to the other. In this case, the following importance has been allocated to each criterion:

Table 5: Criteria importance ratings

Criteria	Importance
IR	0.3070
LR	0.1911
EI	0.1397
RA	0.1027
MA	0.0996
EC	0.0811
EX	0.0523
EF	0.0265

5.1.6. Interpretation of the sub-criteria

The first set of questions in the questionnaire *(Appendix A)* was also exported to a MS Excel spreadsheet. Each question was allocated to a relevant criterion based on the 1-7 scale *(Table 2)*. The averages of the criteria resulting from this first set of questions are:

Table 6: Criteria averages

Criteria	Total	Question Count	Average
EI	11	3	3.67
EF	8	2	4.00
EC	30	7	4.29
EX	62	13	4.77
IR	46	10	4.60
LR	16	3	5.33
MA	33	7	4.71
RA	18	4	4.50

Much can also be learnt from the average of each criterion, for example, one can see that there has been a slight deterioration with regards to the environmental impact criterion. On the other hand, no change has been experienced in the operational efficiency of Matla and a slight to considerable improvement in the legislative requirements aspect.

5.1.7. Decision making

Finally, each criterion's weight is multiplied by its average and is then summed with the other criteria's results to obtain a number between 1 and 7, indicating whether the implementation can be justified based on the opinions of informed persons.

The conclusion from this AHP is seen in the next table:

Table 7: Conclusion results for the AHP

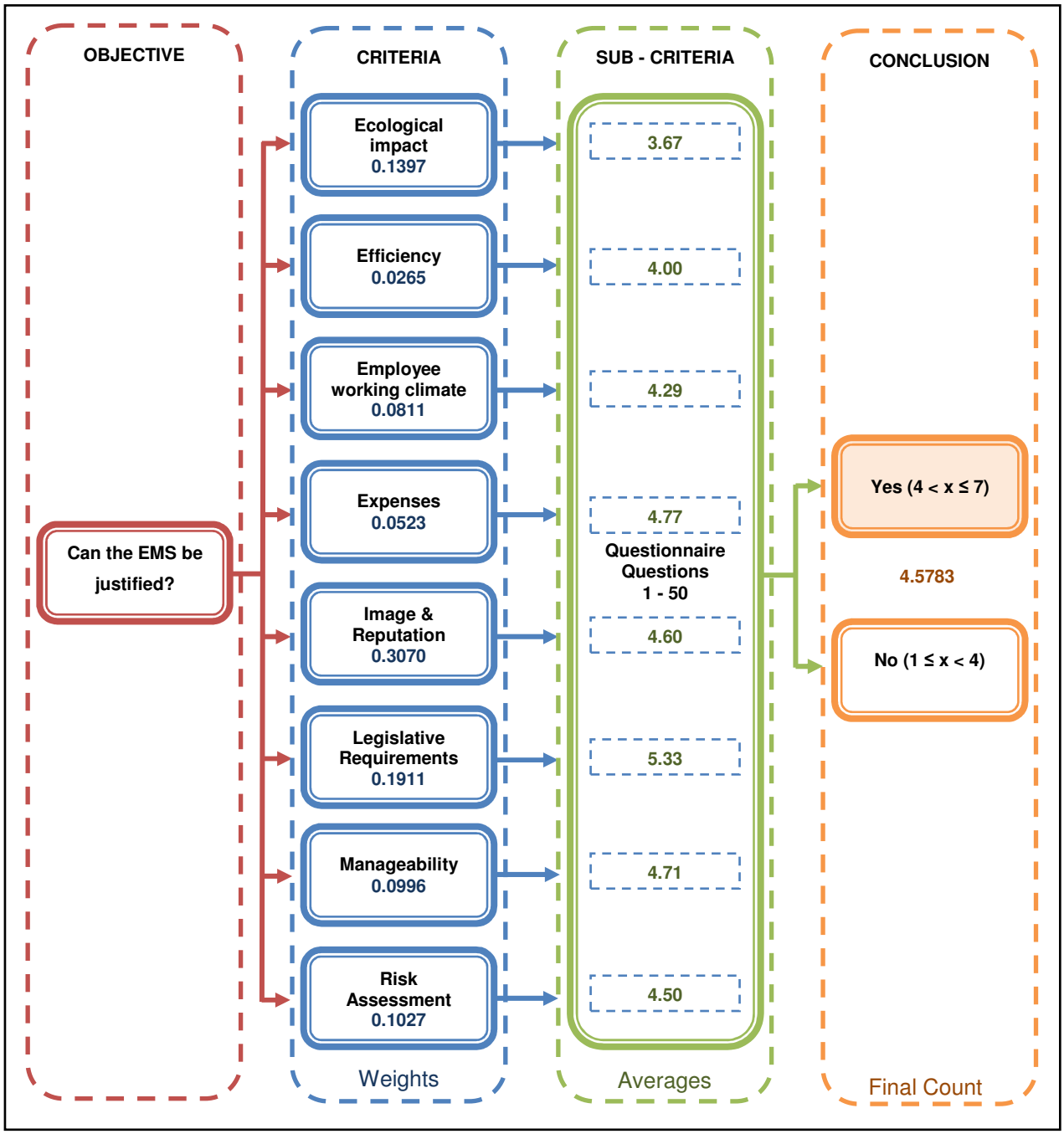
Criteria	Relative Weight	Question Average	Criteria Count
EI	0.1397	3.67	0.5122
EF	0.0265	4.00	0.1060
EC	0.0811	4.29	0.3476
EX	0.0523	4.77	0.2494
IR	0.3070	4.60	1.4122
LR	0.1911	5.33	1.0192
MA	0.0996	4.71	0.4695
RA	0.1027	4.50	0.4622
		Total count	**4.5783**

The total count of **4.5783** is slightly more than 4. It indicates an improvement of 0.5783.

5.1.8. Hierarchy of the problem

The following figure *(Figure 3)* provides a visual interpretation on the structure of the AHP as done in this study.

Figure 3: Hierarchy of the problem



5.2. ENVIRONMENTAL PERFORMANCE EVALUATION

5.2.1. Selection of EPI's

The final output of Matla's risk assessment is the estimated measure of risks of all Matla's operations which could possibly have a negative impact on the environment. A risk assessment profile robot exists in a matrix form, which Matla's EMS uses to construct a profile of each risk by combining the following criteria versus frequency and effect category:

- Hazard Description
- Estimated Maximum Loss
- Effect on Plant Personnel
- Public Property Damage
- Effect on Town Residence
- Public Reaction
- Effect on the environment

The risks, which are assessed in a document (Aspect and Impacts Register) are used to name the indicators in order to monitor the progress towards environmental performance of each activity. The abovementioned criteria are used to assign relevant weights to the various EPI's to be able to execute the EPE procedure by analysis and comparison of the data.

Based on the aforementioned RA technique and the availability of data, several EPI's are selected. It is important to note that this EPE technique only propose a model which serves as an example. More EPI's should be included over time as the EMS becomes established. The EPI's used in this project are described in *Table 4* and allocated to their relevant perspectives as explained in the next section.

5.2.2. Analysis and conversion of data

Relative weight against all EPI's

Depending on the EPI importance scale *(Table 6)*, the relative weights of each of the EPI's are calculated from their values measured before the ISO 14001 implementation, compared to their values since this implementation. This relative weight serves the purpose to indicate the priority of the specific EPI. For instance, if the EPI has been allocated the most significant weight, this EPI should be first attended to since it means that this EPI, considering the importance rating of 1-5, is in the worst condition. This offers a systematic method to continually attend to the EPI's to achieve better environmental performance. The

steps performed to achieve this relative weight per EPI against all available EPI's will be explained next.

1. Performance value (PV)

To be able to compare the performance of the different EPI's, with their diverse units and measurements, it is necessary to allocate a common value to them. This value must assess the EPI's performance on a joint scale with 0 as the worst performance, 10 as the break-even value with no change experienced and 20 as an indication of exceptional performance. This value can exceed 20 to allow for continuous improvement. To determine this value, the following two formulas are used in a Microsoft Excel spreadsheet:

- For "less is better":

$$\mathrm{IF}(((1+(1-\tfrac{x}{y}))\times 10)<0,0,1+(1-\tfrac{x}{y}))\times 10) \qquad (\textit{Equation 1})$$

- For "more is better":

$$\mathrm{IF}((\tfrac{x}{y}\times 10)<0,0,\tfrac{x}{y}\times 10) \qquad (\textit{Equation 2})$$

Where: x is the measured value of the EPI after implementation and
y is the measured value of the EPI before implementation.

2. Score

This score is calculated by multiplying the PV with the importance rating of the EPI

3. Relative weight against all EPI's

$$\text{Relative Weight} = \frac{\text{Score of the EPI}}{\text{Sum of scores of all EPI's}} \qquad (\textit{Equation 3})$$

5.2.3. Assessment of information

The Balanced Score Card (BSD)

Using a proposed adaptation of the balanced score card framework by (Kaplan & Norton, 1992), the EPI's fit into four perspectives to translate the environmental vision and strategy of the organisation (Dias-Sardinha & Reijnders, 2005):

1. **Triple bottom line value creation perspective**

   This term refers to the environmental and social aspects of performance and the financial aspects thereof. This perspective indicates that a company, in order to remain sustainable, should also focus on creating value in terms of ecological and social aspects and not only on the financial aspects. This includes specific objectives and measurements relating to management, compliance, social and environmental issues and the financial implications thereof.

2. **Stakeholders' perspective**

   EPI's fitting into this perspective gives a company an idea on how the various stakeholders view the company in terms of their environmental performance. It could refer to issues regarding business ethics and the company's relations with the broader society and whether the company's environmental strategies appeal to the stakeholders.

3. **Internal perspective**

   This perspective focuses on the processes internal to the company which should be measured, regarding environmental issues to achieve its overall environmental objectives.

4. **Learning and growth perspective**

   This perspective answers questions about the continuous improvement, learning and innovation skills inherent to the company, with respective to its environmental aims.

Table 8: Description of EPI's

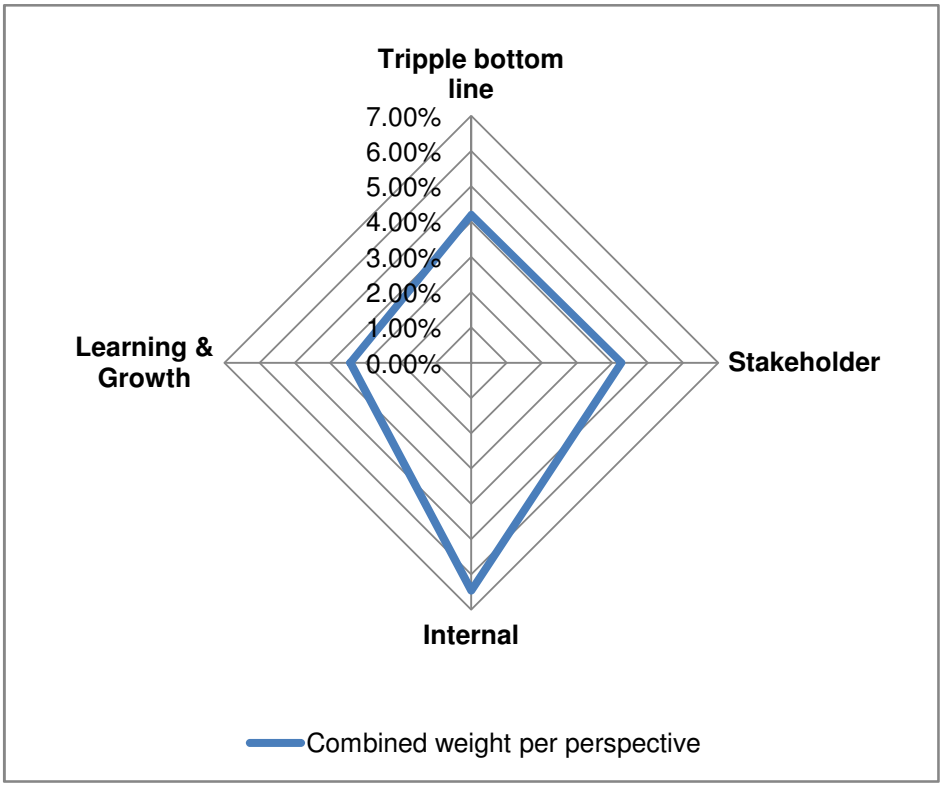
Perspective	EPI	Units
Triple bottom line	Environmental Budget	Rands per year (R/year)
	Air emissions	Average tonnes for Jan-Aug (kg * 10^3)
	Noise	Decibels (dB)
	Number of fines/violations per year	Total number Jan-Aug (#/8months)
Stakeholder	Market Leadership	Ranking on "most green companies"
	Number of complaints from public or employees	Total number Jan-Aug (#/8months)
	Incidents (Not reportable)	Total number Jan-Aug (#/8months)
	Land disturbed	Average hectares for Jan-Aug (m^2 * 10^4)
	Non-recyclable waste	Average percentage of total waste (%)

Internal	Diesel consumption	Average litres for Jan-Aug (l)
	Electricity consumption	Average mega watt hours for Jan-Aug (MWH)
	General waste	Average tonnes for Jan-Aug (kg * 10^3)
	Hazardous waste	Average tonnes for Jan-Aug (kg * 10^3)
	Quality	Average percentage of non-conforming product for Jan-Aug
	Petrol consumption	Average litres for Jan-Aug (l)
	Production output	Average tonnes for Jan-Aug (kg * 10^3)
	Water usage	Average cubic metres for Jan-Aug (m^3)
Learning & Growth	Budget spent on R&D to improve environmental conditions	Percentage of total budget (%)
	Employees trained	Prospected number of employees trained per year (#/year)
	Number of contractors contacted about environmental management	Total number for Jan-Aug (#/8months)

The relative weights of these perspectives are also calculated and traded off against each other which can be visually presented in a spider graph *(Figure 4)* generated in a MS Excel spread sheet. To obtain the combined relative weights of each perspective, the average of all EPI's relative weights in a specific perspective are determined which yield:

- Triple bottom line perspective » 4.19%
- Shareholders perspective » 4.25%
- Internal perspective » 6.46%
- Learning & growth perspective » 3.43%

Figure 4: Balanced score card combined weights of the four perspectives



From this spider graph it can be seen that the internal perspective is carrying the largest weight and should be deemed as the most important perspective in since it has the biggest impact on the environment. The internal perspective, therefore, also presents the best opportunities to increase Matla's environmental performance and need to be prioritised in the EPE effort.

5.2.4. Review and conclusion of the evaluation

Each individual EPI and the four perspectives have been evaluated, but to be able to reach a conclusion on the EPE system, a collective PV needs to be calculated. This PV is calculated from *Formula 4*:

$$\text{Average PV} = \frac{\text{Average EPI score}}{\text{Average EPI importance}} \qquad \textit{(Formula 4)}$$

This yields an average PV of **11.62** which indicates a slightly better performance than the break-even value of 10. Note that the calculations are included as *Appendix D*.

This evaluation differs from the AHP's "informed opinions" by assessing real time data, providing a more factual insight to the evaluation of Matla's EMS. This offers a means for Matla's management to continually assess the environmental performance and to communicate the bare facts to concerned stakeholders.

5.3. QUALITY ASSURANCE

By adapting the well-known Deming cycle, a structure can be formed to construct and interpret control charts and the quality definition of Matla's production operations.

5.3.1. Plan

The Problem

Matla's commodity consists of power generation coal which defines the lowest grade (below the superior qualities of metallurgical and export coal) for commercial coal in South Africa. If the specification limits set by Eskom (Matla's largest customer) is not satisfied it results in rejected coal. Should this occur, one of three things could happen:

- Remix
  Matla mines on different locations, yielding coal of high quality and coal of lower quality. These different grades of quality is mixed together to obtain a mixed, more average quality suitable for use by Eskom. It is tried to remix these unsold coal into better quality coal with the purpose of a resale attempt to Eskom.

- Sale to "less fussy" customers
  This means selling to anyone willing to buy this inferior quality of coal. These customers usually are general dealers which, for example, sell to people living in informal settlements without access to electricity.
- Waste
  The rejected coal, after attempts have been made to sell it, is piled on "waste" ground for storage until something sensible can be done with it. It is this option which has the potential for causing most harm to the environment and should be avoided at all cost. The "waste" ground is lost to ecological and economic use except to store waste. In the South African summers the temperature reaches such high levels that spontaneous combustion of the coal could occur with the concurring release of uncontrolled pollutants into the air, having an adverse effect on the environment and the health of humans. To give an illustration on the extent of this problem, imagine the burning of 1000 tonnes of inferior quality coal in the open air.

The complex meaning of quality in mining should also be taken into account. According to (Euromines, 2005) a QMS in a mining company is more complicated to interpret than for a manufacturing company. This is because mining industries extract and refine a natural resource, meaning that the size and volume ratios are mostly inconsistent. This, for

example, includes the ground quality, chemical composition and contamination levels of the mined substance.

In this project, for the sake of simplicity, it is assumed that the processes and external influences, which might affect the uniformity of quality remained constant for the trial period during which the data were taken.

To wrap up the importance of quality definition in a mining company and the reason quality should not be ignored as a decisive factor in the implementation of an EMS; a mining company cannot afford to forfeit quality in exchange for a better EMS. The adverse impact on the environment due to the production of rejected coal should go hand in hand with the considerable loss of financial and human resources.

Purpose

The fraction of saleable coal lost, due to the non-conformances within the coal production, will be classified and evaluated. In this way it can be seen whether quality has improved or deteriorated after the implementation of the EMS. This step will review the ISO 14001 integration by assessing influence of the ensuing process changes on the ongoing quality of the product.

Subgroup characteristics

Twenty-four monthly subgroups, spanning a period of two years, 2008-2009, (before the ISO 14001 certification) as well as 8 subgroups defining the months of 2010 from January up to and including August (after the ISO 14001 certification) are investigated. The exact production changes each month, therefore subgroup sizes vary.

Control chart type

The use of a p-chart as an attribute classification control chart will be suitable for the purpose of this project. This control chart type proved to be the easiest to give an overall indication of the process capability without going into too much detail.

5.3.2. Do

Data collection

The collection of data (see section 4.3) is recorded electronically onto a MS Excel spread sheet to aid in the calculation and analysis of the data as well as in the construction of the control charts.

Calculations

For the calculations done, with the aid of MS Excel, refer to *Appendix F.*

- Fraction of non-conformities
  The fraction of non-conformities was obtained by subtracting each sub-group's total production with the total saleable product to obtain the rejected coal amount. This amount were divided by the total coal produced.
- Average value - Centerline
  The centerline represents the process average. This centerline (ṗ) is calculated as

$$\dot{p} = \frac{\text{Total fraction of non-confomancies in all subgroups}}{\text{Total count of examined subgroups}} \qquad \textit{(Equation 5)}$$

- Control limits - Upper control limit (UCL) & Lower control limit (LCL)
  This control limits provides information on the process variation. This equals three times the standard error of each individual subgroup and its calculations are seen in the following formulae:

$$\text{UCL}\,(\text{p}) = \dot{p} + 3\sqrt{\frac{\dot{p}(1-\dot{p})}{n}} \qquad \textit{(Equation 6)}$$

$$\text{LCL}\,(\text{p}) = \dot{p} - 3\sqrt{\frac{\dot{p}(1-\dot{p})}{n}} \qquad \textit{(Equation 7)}$$

  with *n* being the specific subgroup size.

- Three-sigma limits
  The area between the UCL and LCL is divided into 6 bands or zones, each being one standard error wide. The lines dividing the C and B zones equal the mean (ṗ) plus and minus one standard error where the lines between the B and A zones are (ṗ) plus and minus twice the standard error.

- Enter the data points of the "before" and "after" state on the control charts *(Figures 7 - 8)*

Figure 5: p Chart for the fraction of rejected coal, 2008-2009

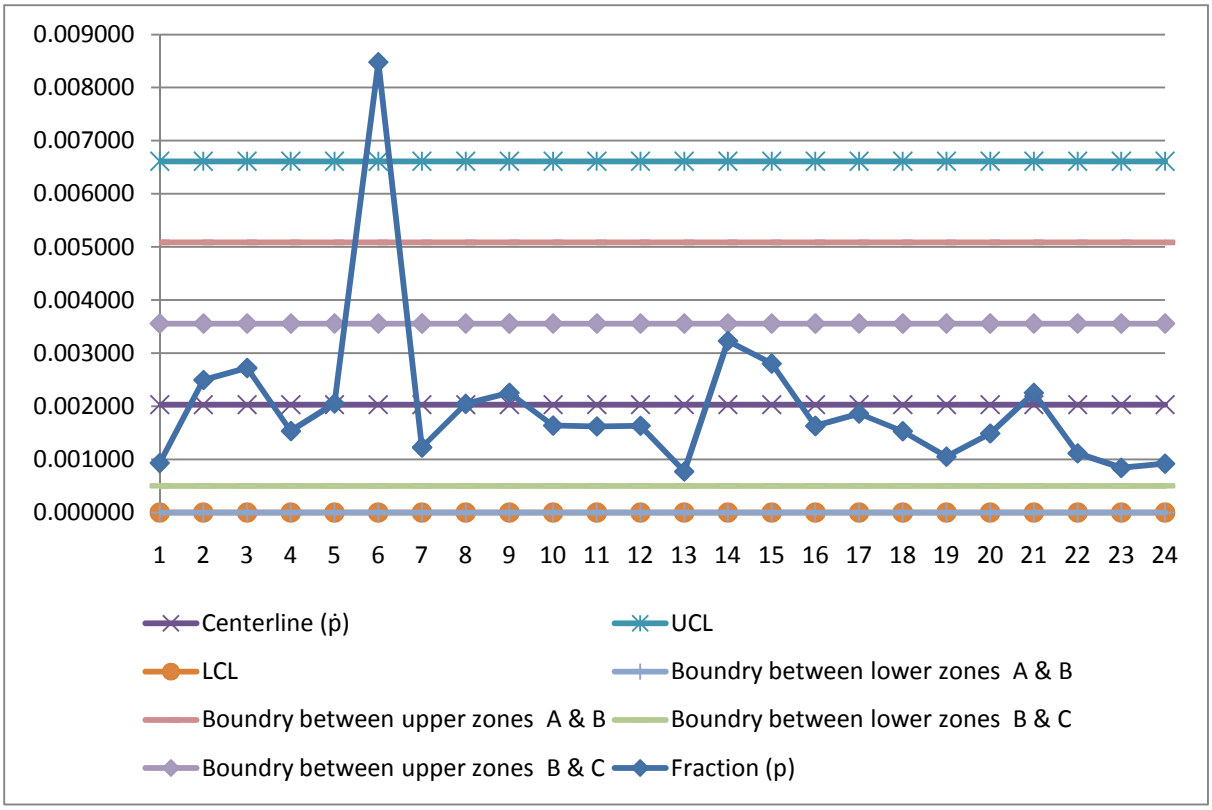
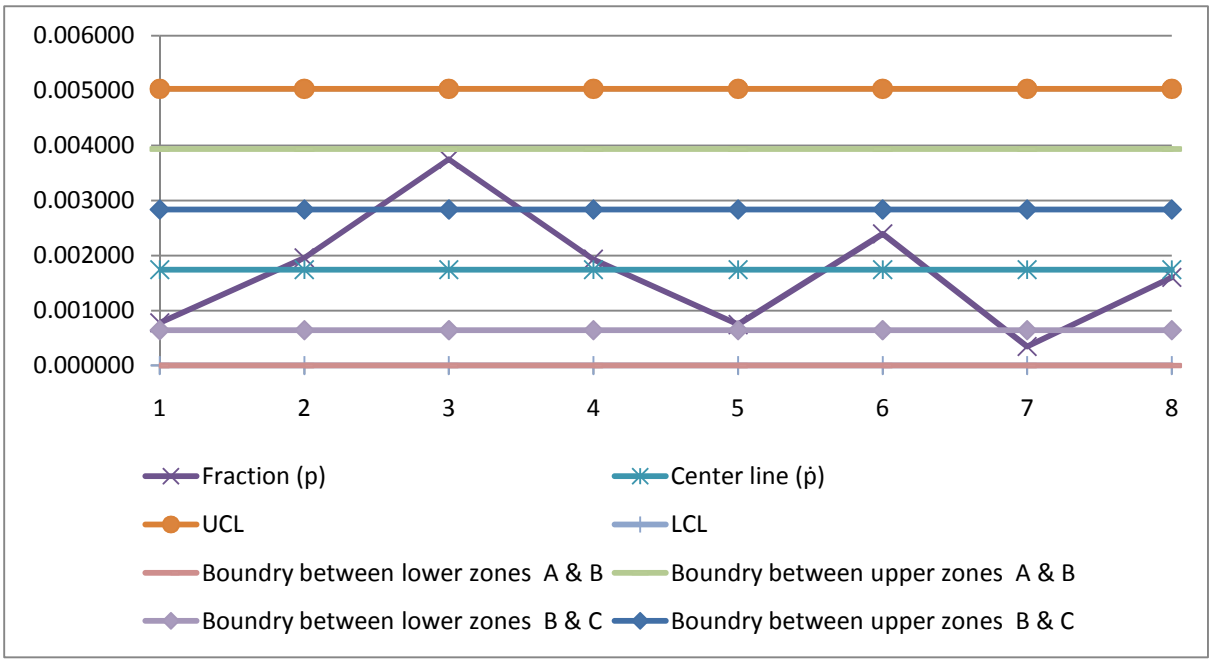


Figure 6: p Chart for the fraction of rejected coal, January - August 2010



5.3.3. Study

- Examination for indications of lack of control in the process

  The textbook by (Gitlow, Oppenheim, Oppenheim, & Levine, 2005) explains 9 rules for identifying out-of-control points. The examination of the control charts pointed out the following:

  - In Figure 7 it is subgroup 6 (June 2008) which can be identified as out of control for lying outside the UCL.
  - In Figure 8 no out of control points were present, indicating that the process is already under control.

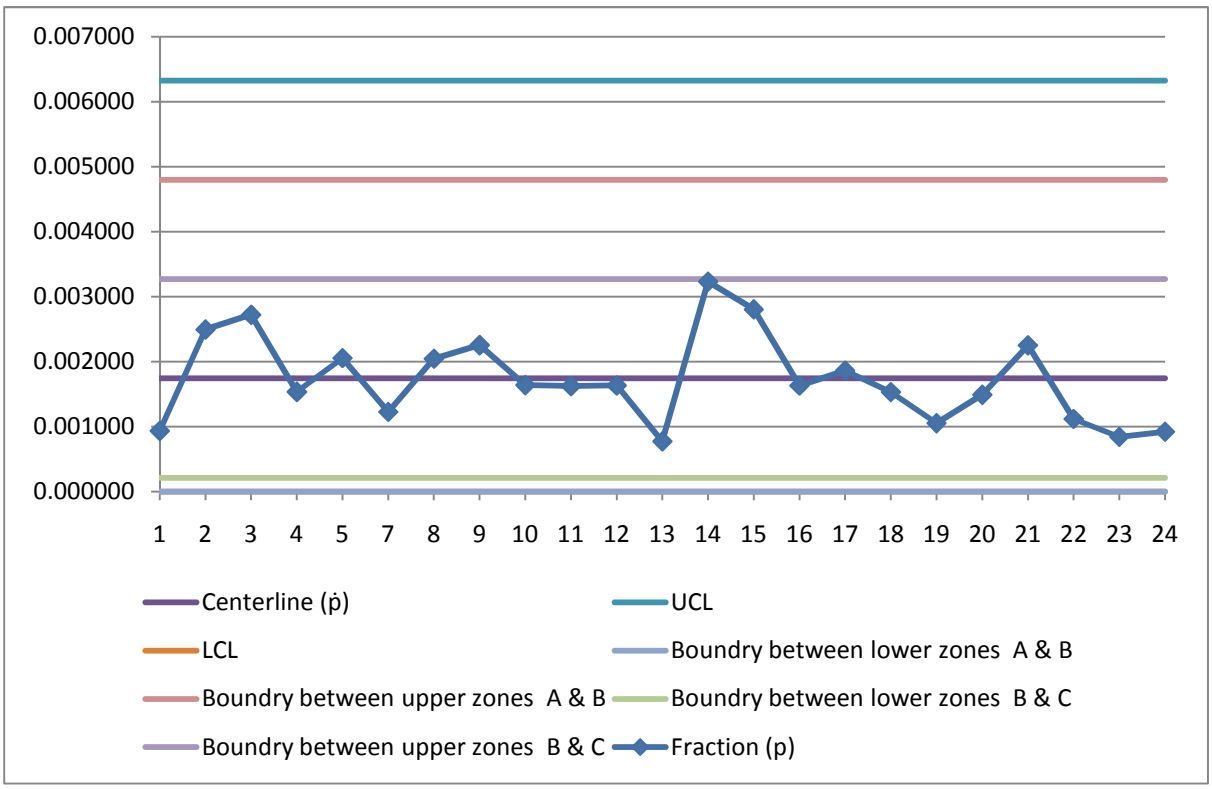
- Causes of special variation

  Subgroup 6 in *Figure 7* could be a wrong indication on the real data accumulated from the production of coal due to a SAP software problem. This is a non-repetitive issue which has been corrected without much trouble. Therefore this out of control point was eliminated.

- Review the centerline, control limits and zone boundaries

  With the out of control points eliminated from the original p-charts, the centerline, control limits and zone boundaries were recalculated and rechecked for out of control points. *Figure 9* presents the p-chart for the stabilised process, before January 2010.

Figure 7: Stabilised p Chart for the fraction of rejected coal, 2008-2009



5.3.4. Act

The stabilised process allows one to determine the process capability and indicates that the process is capable of improvement. According to (Gitlow, Oppenheim, Oppenheim, & Levine, 2005) the centerline (ṕ) of an attribute p-chart indicates the process capability. This aids in understanding the extent to which Matla is able to produce products complying with Eskom's standards, specifying the quality conformance of the product.

The ṕ value for each time period is as follows:

- January 2008 - December 2009 » 0.001726
- January 2010 - September 2010 » 0.001687

Before the certification and implementation of the ISO 14001 standard into Matla's EMS the process capability was a fraction of 0.001726 rejected coal out of the total coal produced. As from January 2010, the period after the implementation, this value was 0.001687. This is an improvement of 0.000039 in the process capability.

5.3.5. Concluding the QA

By studying the quality of the product delivered, a modest improvement of **2.26%** was noted after the ISO 14001 implementation.

CHAPTER 6

RESULTS & RECOMMENDATIONS

6.1. THE RESULTS UNDER ONE ROOF

To visually present all results of the AHP, EPE and QA steps at a glance, as well as to continually monitor changes in the EMS system and its current performance, a dashboard was created using Sisense's Prism BI Studio software. A screenshot of this dashboard is shown in *Figure 10.* To view a legible PDF export of this dashboard, refer to *Appendix G.*

Figure 8: Screenshot of a Sisense Prism EMS Performance dashboard

All steps (steps 3-6) studied within this project, with consideration of the assumptions defined in *section 1.5,* indicated a minor improvement in Matla's environmental performance. See *table 9* for a summary on this results.

Table 9: Summary of results

Step	Result	Meaning	Section
AHP	4.58	Slight improvement (1 = worst, 4 = indifferent, 7 = best)	Section 5.1
EPE	11.62	Slight improvement (0 = worst, 10 = indifferent, 20 or more = exceptional)	Section 5.2
QA	2.26%	Slight improvement (Less than 0% = deterioration, 0% = no improvement, more than 0% = improvement)	Section 5.3

6.2. TESTING AND VALIDATION

The results have been discussed with top management individuals at the Exxaro group, as well as some people responsible for the management of the EMS at Matla. These results and the methodology were confirmed by them as practical and correct. This project should be an ongoing effort at Matla, resulting in refinement of the methodology and data. With the encouraging short term outcome of this project, the long term feasibility of this project looks promising.

6.3. INFORMED RECOMMENDATIONS ON MATLA'S EMS

At first, the results might seem to be disappointingly lower than one would expect for all the effort done to improve Matla's environmental performance and to get positive results from the enhancement of the existing EMS by the ISO 14001 certification. However, it should be realised that the adapted EMS system has been very recently (January 2010) implemented. Modifications to a management system generally take a long time to yield positive results, sometimes with a decline at first because of the need to adapt to the new requirements.

For example, the AHP test the employees' attitude to the new EMS. Because most people are reluctant to change, they would normally view the new environment with much scepticism and even with resent. This tends to give a rather negative outcome at first and it can be expected that an opinion poll, as analysed by means of a questionnaire and the AHP, would yield a dreary outcome. Even with consideration of this fact, the AHP tool indicated a better than "no-change" result.

If viewed in this perspective, Matla's EMS is doing exceptionally well and has great potential to lessen the impact on the environment by increased environmental performance. That is if they hold to the following recommendations:

- Careful administration of cost to sufficiently maintain the EMS.

- Effective administration of time to minimise the effect on the work load.
- Carefully adhering to the efficiency of the implementation.
- Sufficient but not redundant documentation.
- Continued enthusiasm from the people involved despite the lack of positive effect on the short term.
- Explanation and the cultivating of a positive attitude from all employees to minimise resistance from the staff against change
- Involvement of employees from all levels in Matla
- Careful organisation to minimise organisational resistance to change.
- Employing QA to ensure ongoing customer satisfaction (Section 5.3)
- Careful monitoring of progress (Section 5.2)

6.4. COMMUNICATING THE RESULTS

Effective communication has always been crucial in determining the success of any system. This especially holds true for a complex EMS at a mining company. Therefore, to optimise success, communication should be unambiguous and adequate to all relevant departments. The ideas, results and responsibilities should be conveyed to everyone in an appropriate way so that all stakeholders have the information that is relevant to them.

As an example, management would typically have all information without too much technical detail. The specialists would deal with more technical documentation and shareholders would want financial data to know how this EMS benefitted their shares as well as positive figures on sustainability.

All such communication should be carefully noted down in meeting minutes, information posters, illustrative computer software and annual reports. These documents should be frequently assessed to ensure relevance and be readily identifiable.

6.5. RECOMMENDATIONS FOR FURTHER STUDIES

Since the evaluation of an EMS at a mining company is an ongoing quest for improvement and excellence of the company's environmental performance, this project laid the foundation for many exciting research opportunities. The generalised approach of this project simplifies the adaptation of the EMS evaluation concept to be suitable for other mining companies as well.

Where the last three steps (AHP, EPE and QA) were investigated in detail, the first three steps (Barriers to implementation, Verification of the implementation and CP) were only

introduced, outlined and assumed to be already in place. Each of these first steps can be examined to ensure the efficiency of the EMS. For example, the Journal of Cleaner Production offers many insightful articles on the application and development of CP strategies and technologies for the benefit of the environment and effective management practices.

As for the EPE aspect, more EPI's can be introduced and analysed to better control, evaluate, monitor and communicate the environmental performance of a company. Extensive KPI and EPI dashboard software exist to suit the individual needs of most firms.

QA itself present an extensive field of study and should always be an integral part of any company's internal processes. Not only to deliver goods satisfactory to the customer's needs, but also to improve the efficiency of processes and reduce costs associated with non-conforming products. In this project, attribute control charting was used to investigate and gain a comprehensive view on the process capability without going into too much detail. This is a recommended start-off point for introducing QA. However, by continuously decreasing causes of common variation, an attribute control chart can become increasingly more expensive and tedious due to the need of getting more samples to meaningfully distinguish between causes of special and common variation.

Variables control charting provides a more refined QA methodology from which more can be learned from the product quality and process capability. Therefore, as the QMS of the mine improves, exploring and implementing variables control charts deserves, at least, a try. This will allow for more technical refinement of data such as the introduction of customer specification levels, grading of coal ect.

It is recommended that the p-charts, used in this project *(section 5.3),* are used at first to evaluate and reduce the causes of variation. This is a simple process by evaluating the standard deviation of the p-charts. The lower this deviation is, the less common variation exist which indicates an improved stability in the process. From this study, for example, the standard deviation before 2010 equalled 0.00067406 against the 0.0010969 of deviation obtained after January 2010. This indicates that, although the quality improved after January 2010, the process became less stable than before, pointing out the need for attention to prevent the process from further deterioration and eventually entering a state of total chaos.

CONCLUSION

The troublesome question regarding the effectiveness of an EMS has been addressed in an academic as well as in a practical way. Six steps were identified from a literature review as appropriate to evaluate a change in the management system towards a more sustainable approach. This holds for either implementing a new EMS or enhancing a current one. In Matla's case, they improved their EMS structure by becoming ISO 14001 certified.

The first three steps (Barrier identification, verification of integration efficiency and CP) were assumed to be already done and in place. The next step, the AHP decision analysis were employed to assess informed employees' interpretation of the impact of the EMS implementation / integration. Step 5, EPE, was conducted by following the ISO 14031 standard's guidelines. The analysis of real data concerned with environmental performance (EPI's), within the frame of the ISO 14031 guidelines, were done using a BSC approach. This step provides a factual analysis and means of reporting a company's performance towards certain goals. The last step, QA considered the impact of the EMS change on the quality of the product to ascertain whether the operations processes improved or not.

Both Exxaro's Matla coal mine and the environment proved to benefit from this effort of Exxaro to adhere to human needs in line with a better attitude of responsibility towards Nature. This fact highlighted the phenomenon of a positive environmental attitude spilling over to production and stakeholders.

This study confirmed that the implementation / integration of a better EMS can be justified and, if administrated correctly, presents an optimistic prospect of a continuous reduction in the impact of the company on the environment and improved environmental performance. By being more sustainable, the future success of the company can be expected to continue for generations to come.

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APPENDICES

APPENDIX A

QUESTIONNAIRE TO EVALUATE MATLA'S EMS AFTER ISO 14001 CERTIFICATION USING THE AHP

What on earth?!

As you probably know, Exxaro's Matla operations are ISO 14001 certified as of the beginning of 2010. This quick quiz will test your feeling on this new ride.

The AHP (Analytic Hierarchy Process) is a weird but valuable tool used to make a decision by playing the benefits off against the costs. Everyone's feedback will be thrown together in the same hat, shuffled and used as the data in the AHP methodology to assess Matla's EMS (Environmental Management System) after the ISO 14001 implementation.

The composer of this extra trouble is a poor student trying to finish his degree (at last) by doing a project on how to evaluate an EMS in the mining industry. Your help will be tremendously appreciated and you can be sure that you had done a fair square of good today!

Don't worry, be happy!

You can have a good night's sleep as you won't get your results nor will someone else be that lucky. However, if you do have an uncontrollable urge to know the general outcome of this survey, please feel free to contact me. This opinion poll is completely anonymous and any effort to hunt you down will be extremely tiresome. Oh yes - and against the law! So, rest assure that your identity will remain a mystery. Another bonus is that you are in no way obliged to do it and can throw in the towel at any time. Just for in case you are looking for extra pocket money opportunities - check the following little square:

☐ I hereby give my informed consent to participate in the study on a voluntary basis

Okay, let's help you to help me...

Fortunately, these few questions have no right or wrong answer as it will only assess your opinion on the advantage of the ISO 14001 integration and importance of certain factors with respective to the company.

The first set of questions (50):

Do you feel the integration was a good thing or do you wonder why someone ever meddled with the good old system?

You have a scale of 1 to 7 with 1 being most pathetic and 7 most admirable.4 sits right in the middle, which indicate that you experience no change (or if you are clueless). It would be the best if you try to avoid using 4 as most things will, at least, be a little worse or better. Don't brood too long on each question - you have much better things to do at this moment! - It should not take more than 15 minutes of your time.

The next quiz will be explained after you have completed the first one.

	Question	Worst deterioration	Serious deterioration	Slight deterioration	No change / unsure	Slight improvement	Considerable improvement	Best improvement
1	Negative publicity due to environmental complaints	1☐	2☐	3☐	4☐	5☐	6☐	7☐
2	Your “feeling of guilt” towards the environment, being an employee at Matla	1☐	2☐	3☐	4☐	5☐	6☐	7☐
3	Reportable environmental incidents	1☐	2☐	3☐	4☐	5☐	6☐	7☐
4	Dislodging of indigenous species in and around Matla’s operational area	1☐	2☐	3☐	4☐	5☐	6☐	7☐
5	Pollution	1☐	2☐	3☐	4☐	5☐	6☐	7☐
6	Pleasurable environmental conditions to work in	1☐	2☐	3☐	4☐	5☐	6☐	7☐
7	Employees awareness of the organisation as a system	1☐	2☐	3☐	4☐	5☐	6☐	7☐
8	Employees morale	1☐	2☐	3☐	4☐	5☐	6☐	7☐
9	Match between employees and the organisational values	1☐	2☐	3☐	4☐	5☐	6☐	7☐
10	Employees understanding of responsibility	1☐	2☐	3☐	4☐	5☐	6☐	7☐
11	Cooperation between management and employees	1☐	2☐	3☐	4☐	5☐	6☐	7☐
12	Increased product quality	1☐	2☐	3☐	4☐	5☐	6☐	7☐
13	Assurance of conformity	1☐	2☐	3☐	4☐	5☐	6☐	7☐
14	Elimination of conflicting administrative requirements	1☐	2☐	3☐	4☐	5☐	6☐	7☐
15	Procedure standardisation via documentation and written procedures	1☐	2☐	3☐	4☐	5☐	6☐	7☐
16	Increases in process yields	1☐	2☐	3☐	4☐	5☐	6☐	7☐
17	Less downtime through more careful monitoring and maintenance	1☐	2☐	3☐	4☐	5☐	6☐	7☐
18	Reduction in waste disposal costs	1☐	2☐	3☐	4☐	5☐	6☐	7☐
19	Reduction in fines and/or penalties	1☐	2☐	3☐	4☐	5☐	6☐	7☐
20	Reduction in environmental liability costs	1☐	2☐	3☐	4☐	5☐	6☐	7☐
21	Reduction in litigation (lawsuits) expenses	1☐	2☐	3☐	4☐	5☐	6☐	7☐
22	Re-use or recycling policy	1☐	2☐	3☐	4☐	5☐	6☐	7☐
23	Conservation of resources used in processes	1☐	2☐	3☐	4☐	5☐	6☐	7☐
24	Energy savings	1☐	2☐	3☐	4☐	5☐	6☐	7☐
25	Reduction in material storage and handling costs	1☐	2☐	3☐	4☐	5☐	6☐	7☐
26	Lower insurance premiums	1☐	2☐	3☐	4☐	5☐	6☐	7☐

27	Risk analysis capabilities	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
28	Emergency preparedness and response procedures	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
29	Identification and implementation of specific pollution prevention projects	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
30	Increase in the attitude towards environmental responsibility	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
31	Capability to analyse laws and Regulations	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
32	Ability to follow regulatory guidance	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
33	Ability to follow regulatory auditing of performance	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
34	Perceived reduction of environmental liability exposure	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
35	Opportunities of “green” lobbying	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
36	Effective communication of environmental friendliness towards customers	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
37	Perception of the company operations quality (From customer point of view)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
38	Perception of the products quality (From customer point of view)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
39	Investor opinions	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
40	Shareholders opinions	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
41	Reduction in travel and lodging expenses	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
42	Reduction in auditing cost (Internal and External)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
43	Reduction in amount of Paperwork/Documentation	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
44	Analysis of procedures/processes	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
45	Decrease in amount of employee training needed	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
46	Capabilities scanning (Understanding the capabilities of Matla)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
47	Definition and understanding of employee roles	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
48	Decreased need of acquirement of new equipment/facilities for environmental purpose	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
49	Decreased need of operational procedures changes	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐
50	Opportunities to join government projects	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐

The second set of questions (24):

What do you consider as most important with respective to the company?

This time you have a scale of 1 to 9, and it has a totally other meaning - I know you had been enjoying and becoming an expert on the first set of questions, but sometimes change is good. This questions will determine what you consider as important and what you would like to see flying out of the window. A 1 would indicate something equally as important as the relative criterion where 9 would indicate an

unsurpassed importance. This is based on the Saaty importance scale. (TL Saaty was the brain behind the AHP). Refer to the next table whenever in doubt. The criteria is also explained should you need to be educated in it as well.

This should not take more than 2-5 minutes of brain activity.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement slightly facour one over the other.
7	Very much more important	Experience and judgement strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

Explanation of criteria:

Ecological impact (EI)

What is the effect of the adapted management system on the immediate environment? Does it ease the burden on the environment or not?

Efficiency (EF)

A company's profitability depends heavily on the efficiency of its management structure, which in turn influences the business processes of the company. This goes hand-in-hand with the manageability criteria. A good EMS should improve efficiency.

Employee working climate (EC)

A successful management structure contributes to the joy of employees at a company. Does it hold true for Matla's ISO 14001 accreditation?

Expenses (EX)

Sometimes being the most important factor in decision making, can the costs be ratified for the green effort?

Image and reputation (IR)

Along with a growing environmental consciousness, companies start to adapt their management policy towards a more environmentally friendly approach to satisfy the

stakeholders. Does the company's "green" image appeals to the stakeholders due to the implementation?

Legislative requirements (LR)

The company's competitiveness depends, to a large extent, on how much the company's EMS complies with government regulations. For instance, it could have an adverse impact on the company's profitability and ability to do business should they not adhere to government laws. In other words, is the company a "better" citizen after implementation?

Manageability (MA)

Companies might be reluctant to integrate or implement a change to their existing management system for the fear of complicating their management system. Does the implementation simplify or complicate the company's management structure?

Risk assessment (RA)

This is the company's overall process of identifying possible risks pertaining to certain activities and assessing the perceived impact of these risks on human health and the environment. For the purpose of the AHP, it also explains the ability of the company to predict and handle different levels of emergencies.

	Ecological impact	Efficiency	Employee working climate	Expenses	Company image & reputation	Compliance to legislative requirements	Manageability	Risk assessment
Ecological impact	**1**	Select...	Select...	Select...	Select...	Select...	Select...	Select...
Efficiency		**1**	Select...	Select...	Select...	Select...	Select...	Select...
Employee working climate			**1**	Select...	Select...	Select...	Select...	Select...
Expenses				**1**	Select...	Select...	Select...	Select...
Company image & reputation					**1**	Select...	Select...	Select...
Compliance to legislative requirements						**1**	Select...	Select...
Manageability							**1**	Select...
Risk assessment								**1**

Again, thank you very much for your precious time - it is much valued!

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FIRST SET OF QUESTIONS - IMPROVEMENT / DETERIORATION

Question	Response
ns1:nr1	2
ns1:nr2	3
ns1:nr3	3
ns1:nr4	4
ns1:nr5	4
ns1:nr6	4
ns1:nr7	5
ns1:nr8	4
ns1:nr9	4
ns1:nr10	5
ns1:nr11	5
ns1:nr12	4
ns1:nr13	4
ns1:nr14	5
ns1:nr15	5
ns1:nr16	4
ns1:nr17	4
ns1:nr18	5
ns1:nr19	5
ns1:nr20	5
ns1:nr21	5
ns1:nr22	5
ns1:nr23	4
ns1:nr24	6
ns1:nr25	5
ns1:nr26	4
ns1:nr27	3
ns1:nr28	5
ns1:nr29	5
ns1:nr30	5
ns1:nr31	6
ns1:nr32	5
ns1:nr33	5
ns1:nr34	5
ns1:nr35	4
ns1:nr36	5
ns1:nr37	4
ns1:nr38	4
ns1:nr39	5
ns1:nr40	5
ns1:nr41	4
ns1:nr42	4
ns1:nr43	4
ns1:nr44	5
ns1:nr45	4
ns1:nr46	5
ns1:nr47	5
ns1:nr48	5
ns1:nr49	5
ns1:nr50	6

SECOND SET OF QUESTIONS - PAIR-WISE COMPARISON

Criteria	Response
ns1:EI-EF	5
ns1:EI-EC	1
ns1:EF-EC	0.3333
ns1:EI-EX	3
ns1:EF-EX	1
ns1:EC-EX	1
ns1:EI-IR	0.2
ns1:EF-IR	0.1111
ns1:EC-IR	0.3333
ns1:EX-IR	0.2
ns1:EI-LR	0.3333
ns1:EF-LR	0.1429
ns1:EC-LR	0.3333
ns1:EX-LR	0.3333
ns1:IR-LR	3
ns1:EI-MA	3
ns1:EF-MA	0.2
ns1:EC-MA	1
ns1:EX-MA	1
ns1:IR-MA	1
ns1:LR-MA	3
ns1:EI-RA	3
ns1:EF-RA	0.2
ns1:EC-RA	1
ns1:EX-RA	0.3333
ns1:IR-RA	3
ns1:LR-RA	1
ns1:MA-RA	1

CONSENT GIVEN			
Criteria	**Total**	**Question Count**	**Average**
EI	11	3	3.67
EF	8	2	4.00
EC	30	7	4.29
EX	62	13	4.77
IR	46	10	4.60
LR	16	3	5.33
MA	33	7	4.71
RA	18	4	4.50

Scale	Explanation
1	Worst deterioration
2	Serious deterioration
3	Slight deterioration
4	No change / unsure
5	Slight improvement
6	Considerable improvement
7	Best improvement

PAIRWISE COMPARISON MATRIX - Relative importance of criteria

	EI	EF	EC	EX	IR	LR	MA	RA
EI	1	5	1	3	1/5	1/3	3	3
EF	1/5	1	1/3	1	1/9	1/7	1/5	1/5
EC	1	3	1	1	1/3	1/3	1	1
EX	1/3	1	1	1	1/5	1/3	1	1/3
IR	5	9	3	5	1	3	1	3
LR	3	7	3	3	1/3	1	3	1
MA	1/3	5	1	1	1	1/3	1	1
RA	1/3	5	1	3	1/3	1	1	1

RELATIVE IMPORTANCE OF CRITERIA

Criteria	Importance
IR	0.3070
LR	0.1911
EI	0.1397
RA	0.1027
MA	0.0996
EC	0.0811
EX	0.0523
EF	0.0265

SAATY IMPORTANCE RANKING

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement slightly favour one over the other.
7	Very much more important	Experience and judgement strongly favour one over the other. Its
9	Absolutely more important	The evidence favouring one over the other is of the highest possible
2,4,6,8	Intermediate values	When compromise is needed.

EIGENVECTOR - FIRST ITERATION

								Row Totals	Normalise
8.0000E+00	5.0133E+01	1.4267E+01	2.6001E+01	5.9999E+00	7.3143E+00	1.5200E+01	1.2933E+01	1.3985E+02	0.1415
2.1842E+00	8.0000E+00	3.0287E+00	4.7176E+00	8.8759E-01	1.3968E+00	3.0731E+00	2.3428E+00	2.5631E+01	0.0259
6.2666E+00	2.7333E+01	8.0000E+00	1.4667E+01	2.8444E+00	4.0952E+00	8.9333E+00	8.2666E+00	8.0406E+01	0.0814
4.3111E+00	1.7466E+01	5.6000E+00	8.0000E+00	2.1333E+00	2.5205E+00	5.7332E+00	4.7999E+00	5.0564E+01	0.0512
2.6801E+01	9.7997E+01	3.2002E+01	5.6003E+01	8.0000E+00	1.4953E+01	3.8800E+01	3.1467E+01	3.0602E+02	0.3097
1.4401E+01	6.4000E+01	1.9334E+01	3.2667E+01	6.9776E+00	8.0000E+00	2.3734E+01	2.0401E+01	1.8951E+02	0.1918
9.3334E+00	3.2001E+01	1.0000E+01	1.8000E+01	3.5999E+00	6.1589E+00	8.0000E+00	8.6666E+00	9.5760E+01	0.0969
8.6671E+00	3.2665E+01	1.2001E+01	1.8668E+01	3.5555E+00	5.4922E+00	1.1334E+01	8.0000E+00	1.0038E+02	0.1016
								9.8813E+02	**1.0000**

EIGENVECTOR - SECOND ITERATION

								Row Totals	Normalise
8.9509E+02	3.6112E+03	1.1663E+03	1.9518E+03	3.8828E+02	5.6538E+02	1.2268E+03	1.0369E+03	1.0842E+04	0.1397
1.6716E+02	6.8993E+02	2.2029E+02	3.7108E+02	7.5124E+01	1.0768E+02	2.3062E+02	1.9647E+02	2.0584E+03	0.0265
5.1343E+02	2.1044E+03	6.7706E+02	1.1347E+03	2.2878E+02	3.2946E+02	7.0752E+02	5.9822E+02	6.2936E+03	0.0811
3.3080E+02	1.3593E+03	4.3594E+02	7.3524E+02	1.4672E+02	2.1276E+02	4.5796E+02	3.8800E+02	4.0667E+03	0.0524
1.9350E+03	7.9909E+03	2.5595E+03	4.2989E+03	8.7817E+02	1.2562E+03	2.6478E+03	2.2544E+03	2.3821E+04	0.3068
1.2175E+03	4.9546E+03	1.5970E+03	2.6814E+03	5.3750E+02	7.8279E+02	1.6573E+03	1.4045E+03	1.4833E+04	0.1911
6.1979E+02	2.5977E+03	8.2916E+02	1.3929E+03	2.8263E+02	3.9926E+02	8.8082E+02	7.4234E+02	7.7446E+03	0.0998
6.4587E+02	2.6738E+03	8.5244E+02	1.4367E+03	2.9096E+02	4.1606E+02	8.9600E+02	7.6358E+02	7.9754E+03	0.1027
								7.7634E+04	**1.0000**

First Eigenvector **Second Eigenvector**

Are the eigenvectors equal to 4 decimal places?

0.1415	FALSE	0.1397
0.0259	FALSE	0.0265
0.0814	FALSE	0.0811
0.0512	FALSE	0.0524
0.3097	FALSE	0.3068
0.1918	FALSE	0.1911
0.0969	FALSE	0.0998
0.1016	FALSE	0.1027

EIGENVECTOR - THIRD ITERATION

								Row Totals	Normalise
5.5190E+06	2.2694E+07	7.2778E+06	1.2229E+07	2.4653E+06	3.5460E+06	7.6245E+06	6.4644E+06	6.7820E+07	0.1397
1.0471E+06	4.3059E+06	1.3808E+06	2.3203E+06	4.6778E+05	6.7281E+05	1.4465E+06	1.2265E+06	1.2868E+07	0.0265
3.2030E+06	1.3171E+07	4.2238E+06	7.0975E+06	1.4309E+06	2.0580E+06	4.4248E+06	3.7516E+06	3.9361E+07	0.0811
2.0677E+06	8.5028E+06	2.7267E+06	4.5819E+06	9.2370E+05	1.3286E+06	2.8565E+06	2.4219E+06	2.5410E+07	0.0523
1.2130E+07	4.9878E+07	1.5995E+07	2.6878E+07	5.4186E+06	7.7940E+06	1.6755E+07	1.4206E+07	1.4905E+08	0.3070
7.5524E+06	3.1055E+07	9.9590E+06	1.6734E+07	3.3736E+06	4.8525E+06	1.0433E+07	8.8455E+06	9.2805E+07	0.1911
3.9339E+06	1.6178E+07	5.1879E+06	8.7176E+06	1.7576E+06	2.5278E+06	5.4350E+06	4.6081E+06	4.8346E+07	0.0996
4.0561E+06	1.6680E+07	5.3488E+06	8.9879E+06	1.8120E+06	2.6062E+06	5.6033E+06	4.7509E+06	4.9845E+07	0.1027
								4.8551E+08	**1.0000**

Second Eigenvector **Third Eigenvector**

Are the eigenvectors equal to 4 decimal places?

0.1397	TRUE	0.1397
0.0265	TRUE	0.0265
0.0811	TRUE	0.0811
0.0524	FALSE	0.0523
0.3068	FALSE	0.3070
0.1911	TRUE	0.1911
0.0998	FALSE	0.0996
0.1027	TRUE	0.1027

EIGENVECTOR - FOURTH ITERATION

								Row Totals	**Normalise**
2.1572E+14	8.8706E+14	2.8447E+14	4.7801E+14	9.6367E+13	1.3861E+14	2.9801E+14	2.5267E+14	2.6509E+15	0.1397
4.0929E+13	1.6830E+14	5.3973E+13	9.0693E+13	1.8284E+13	2.6298E+13	5.6541E+13	4.7939E+13	5.0296E+14	0.0265
1.2520E+14	5.1483E+14	1.6510E+14	2.7742E+14	5.5929E+13	8.0443E+13	1.7295E+14	1.4664E+14	1.5385E+15	0.0811
8.0822E+13	3.3235E+14	1.0658E+14	1.7909E+14	3.6106E+13	5.1931E+13	1.1165E+14	9.4666E+13	9.9320E+14	0.0523
4.7411E+14	1.9496E+15	6.2520E+14	1.0506E+15	2.1180E+14	3.0463E+14	6.5496E+14	5.5531E+14	5.8262E+15	0.3070
2.9519E+14	1.2139E+15	3.8927E+14	6.5410E+14	1.3187E+14	1.8967E+14	4.0779E+14	3.4575E+14	3.6275E+15	0.1911
1.5378E+14	6.3235E+14	2.0278E+14	3.4075E+14	6.8696E+13	9.8806E+13	2.1244E+14	1.8011E+14	1.8897E+15	0.0996
1.5854E+14	6.5195E+14	2.0907E+14	3.5131E+14	7.0826E+13	1.0187E+14	2.1902E+14	1.8570E+14	1.9483E+15	0.1027
								1.8977E+16	**1.0000**

Third Eigenvector **Fourth Eigenvector**

Are the eigenvectors equal to 4 decimal places?

0.1397	TRUE	0.1397
0.0265	TRUE	0.0265
0.0811	TRUE	0.0811
0.0523	TRUE	0.0523
0.3070	TRUE	0.3070
0.1911	TRUE	0.1911
0.0996	TRUE	0.0996
0.1027	TRUE	0.1027

Criteria	Relative Weight	Question Average	Criteria Count
EI	0.1397	3.67	0.5122
EF	0.0265	4.00	0.1060
EC	0.0811	4.29	0.3476
EX	0.0523	4.77	0.2494
IR	0.3070	4.60	1.4122
LR	0.1911	5.33	1.0192
MA	0.0996	4.71	0.4695
RA	0.1027	4.50	0.4622

CONCLUSION - Can the implementation be justified?	
Criteria total count	4.5783

Legend
Yes (4 < x < 7)
No (1 < x < 4)
Indifferent (x = 4)

APPENDIX C

QUESTIONNAIRE TO RATE THE IMPORTANCE OF MATLA'S ENVIRONMENTAL PERFORMANCE INDICATORS (EPI's) FOR USE IN THE EPE PROCEDURE

EPI	Lowest importance	Low importance	Intermediate importance	High importance	Highest importance
Environmental Budget	1☐	2☐	3☐	4☐	5☐
Air emissions	1☐	2☐	3☐	4☐	5☐
Noise	1☐	2☐	3☐	4☐	5☐
Number of fines/violations per year	1☐	2☐	3☐	4☐	5☐
Market Leadership	1☐	2☐	3☐	4☐	5☐
Number of complaints from public or employees	1☐	2☐	3☐	4☐	5☐
Incidents (Not reportable)	1☐	2☐	3☐	4☐	5☐
Land disturbed	1☐	2☐	3☐	4☐	5☐
Non-recyclable waste	1☐	2☐	3☐	4☐	5☐
Diesel consumption	1☐	2☐	3☐	4☐	5☐
Electricity consumption	1☐	2☐	3☐	4☐	5☐
General waste	1☐	2☐	3☐	4☐	5☐
Hazardous waste	1☐	2☐	3☐	4☐	5☐
Quality	1☐	2☐	3☐	4☐	5☐
Petrol consumption	1☐	2☐	3☐	4☐	5☐
Production output	1☐	2☐	3☐	4☐	5☐
Water usage	1☐	2☐	3☐	4☐	5☐
Budget spent on R&D to improve environmental conditions	1☐	2☐	3☐	4☐	5☐
Employees trained	1☐	2☐	3☐	4☐	5☐
Number of contractors contacted about environmental management	1☐	2☐	3☐	4☐	5☐

QUESTIONS - RATING EPI IMPORTANCE

	EPI	Average Rating
ns1:Nr1	Environmental Budget	3
ns1:Nr2	Air emissions	5
ns1:Nr3	Noise	2
ns1:Nr4	Number of fines/violations per year	4
ns1:Nr5	Market Leadership	5
ns1:Nr6	Number of complaints from public or employees	3
ns1:Nr7	Incidents (Not reportable)	1
ns1:Nr8	Land disturbed	4
ns1:Nr9	Non-recyclable waste	2
ns1:Nr10	Diesel consumption	4
ns1:Nr11	Electricity consumption	4
ns1:Nr12	General waste	3
ns1:Nr13	Hazardous waste	4
ns1:Nr14	Quality	5
ns1:Nr15	Petrol consumption	4
ns1:Nr16	Production output	5
ns1:Nr17	Water usage	2
ns1:Nr18	Budget spent on R&D to improve environmental conditions	1
ns1:Nr19	Employees trained	4
ns1:Nr20	Number of contractors contacted about environmental management	1

ID	Perspective	EPI	Importance	Relative Weight in perspective	Relative weight against all EPI's
1	Triple bottom line	Environmental Budget	3	28.96%	4.86%
2	Triple bottom line	Air emissions	5	45.05%	7.56%
3	Triple bottom line	Noise	2	15.68%	2.63%
4	Triple bottom line	Number of fines/violations	4	10.30%	1.73%
5	Stakeholder	Market Leadership	5	38.09%	8.10%
6	Stakeholder	Number of complaints from public or employees	3	12.19%	2.59%
7	Stakeholder	Incidents (Not reportable)	1	7.11%	1.51%
8	Stakeholder	Land disturbed	4	26.36%	5.60%
9	Stakeholder	Non-recyclable waste	2	16.25%	3.45%
10	Internal	Diesel consumption	4	10.49%	5.42%
11	Internal	Electricity consumption	4	13.44%	6.94%
12	Internal	General waste	3	11.08%	5.73%
13	Internal	Hazardous waste	4	13.18%	6.81%
14	Internal	Quality	5	24.14%	12.47%
15	Internal	Petrol consumption	4	13.50%	6.98%
16	Internal	Production output	5	7.77%	4.02%
17	Internal	Water usage	2	6.39%	3.30%
18	Learning & Growth	Budget spent on R&D to improve environmental conditions	1	13.99%	1.44%
19	Learning & Growth	Employees trained	4	67.13%	6.91%
20	Learning & Growth	Number of contractors contacted about environmental management	1	18.88%	1.94%

SPIDER GRAPH CALCULATIONS

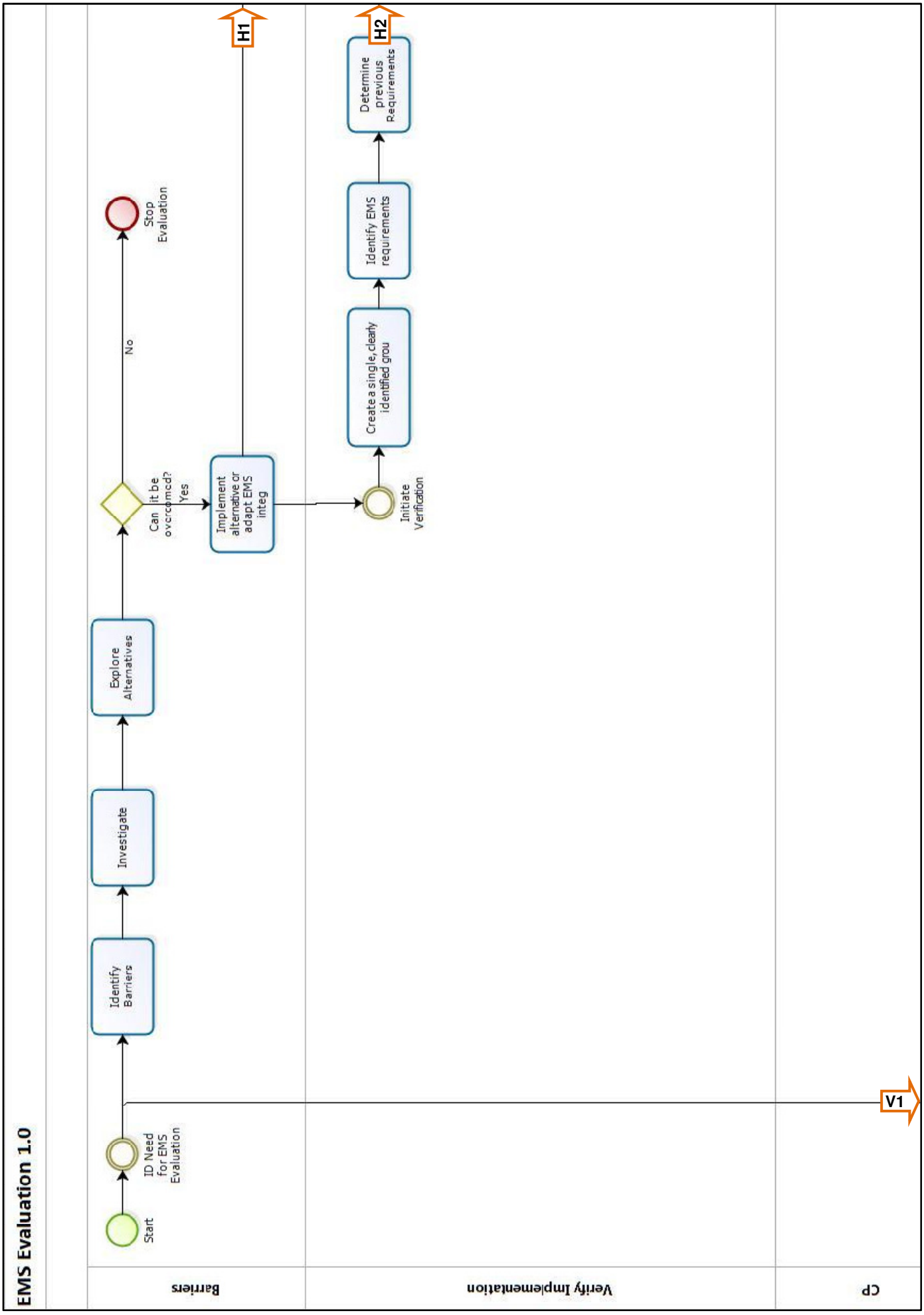
Perspective	Combined weight per perspective
Tripple bottom line	4.19%
Stakeholder	4.25%
Internal	6.46%
Learning & Growth	3.43%

CONCLUSION

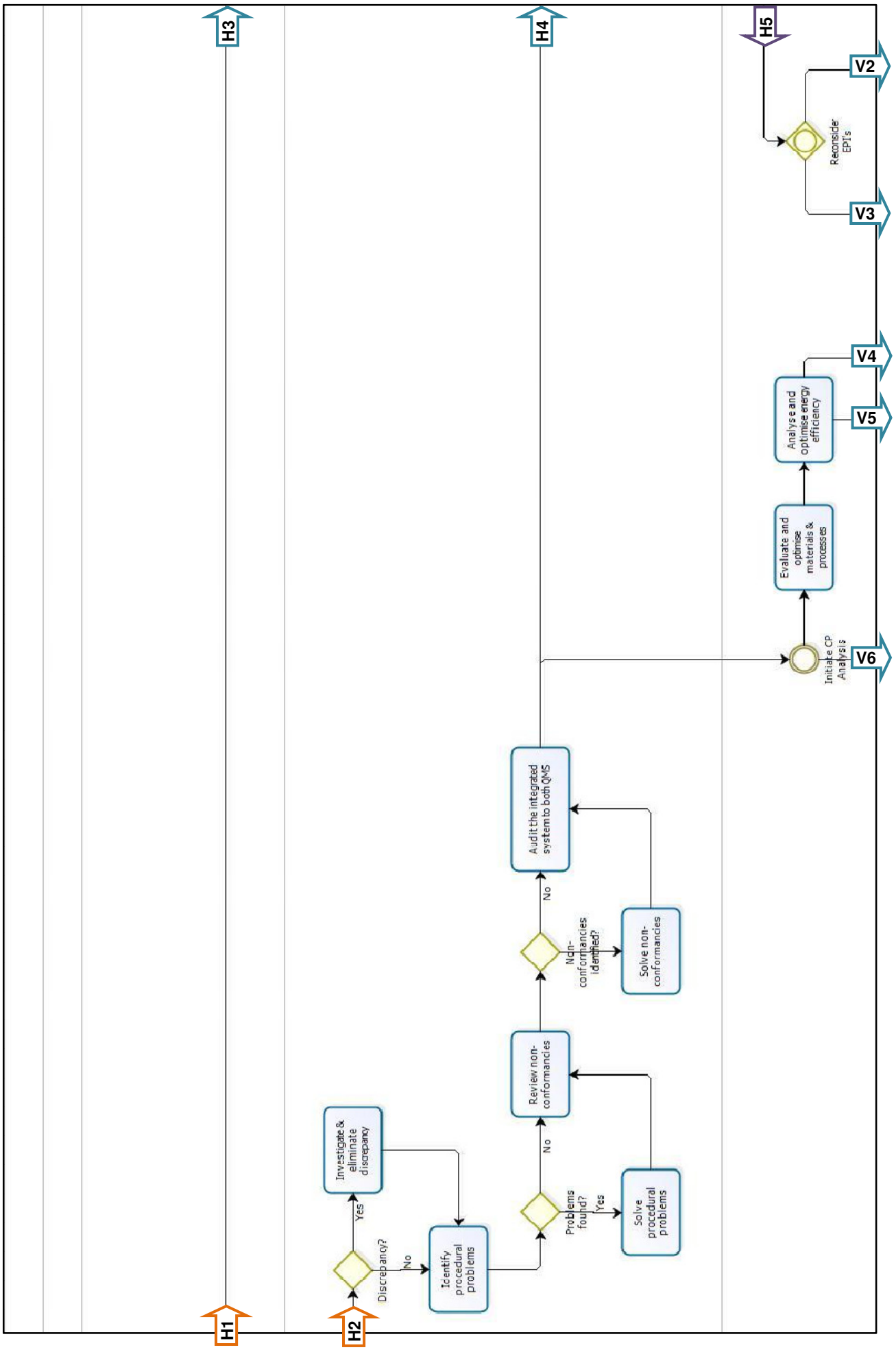
Average Score	38.59
Average Importance	3.3
Average PV	**11.69**

Units	Measured Value (after implementation)	Logic	Measured Value (before implementation)	Performance Value (Break-even = 10; Min = 0)	Score
Rands per year (R/year)	R 1 000 000.00	>	R 800 000.00	12.50	37.50
Average tonnes for Jan-Aug (kg * 10E3)	5	<	6	11.67	58.33
Decibels (dB)	64	<	65	10.15	20.31
Total number for Jan-Aug (#/8months)	5	<	3	3.33	13.33
Ranking on “most green companies”	3	<	4	12.50	62.50
Number per year (#/year)	20	<	15	6.67	20.00
Number per year (#/year)	10	<	12	11.67	11.67
Average hectares for Jan-Aug (m^2 * 10E4)	21.83	<	23.77	10.82	43.26
Average percentage of total waste (%)	20.00%	>	15.00%	13.33	26.67
Average litres for Jan-Aug (l)	161801.31	<	169640.19	10.46	41.85
Average mega watt hours for Jan-Aug (MWH)	9167.87	<	13882.81	13.40	53.58
Average tonnes for Jan-Aug (kg * 10E3)	52.58	<	99.91	14.74	44.21
Average tonnes for Jan-Aug (kg * 10E3)	50.29	<	73.34	13.14	52.57
Average percentage of non-conforming product for Jan-Aug	0.00	<	0.03	19.25	96.26
Average litres for Jan-Aug (l)	10146.50	<	15524.15	13.46	53.86
Average tonnes for Jan-Aug (kg * 10E3)	1009604.60	>	1627923.00	6.20	31.01
Average cubic metres for Jan-Aug (m^3)	111684.52	<	154012.71	12.75	25.50
Percentage of total budget (%)	5.00	>	4.50	11.11	11.11
Prospected number of employees trained per year (#/year)	100.00	>	75.00	13.33	53.33
Total number for Jan-Aug (#/8months)	12.00	>	8.00	15.00	15.00

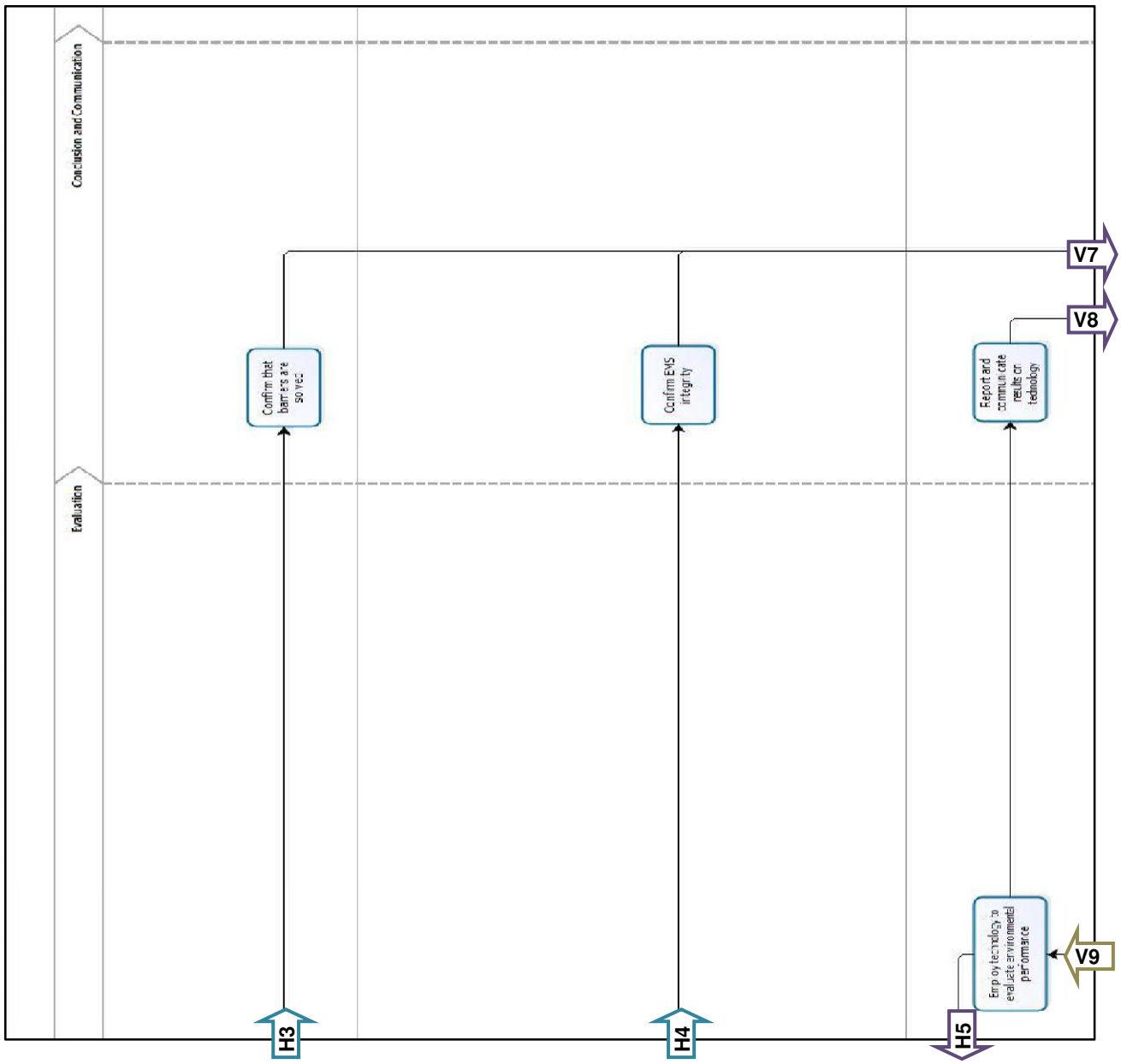
Process Model (Part 1)



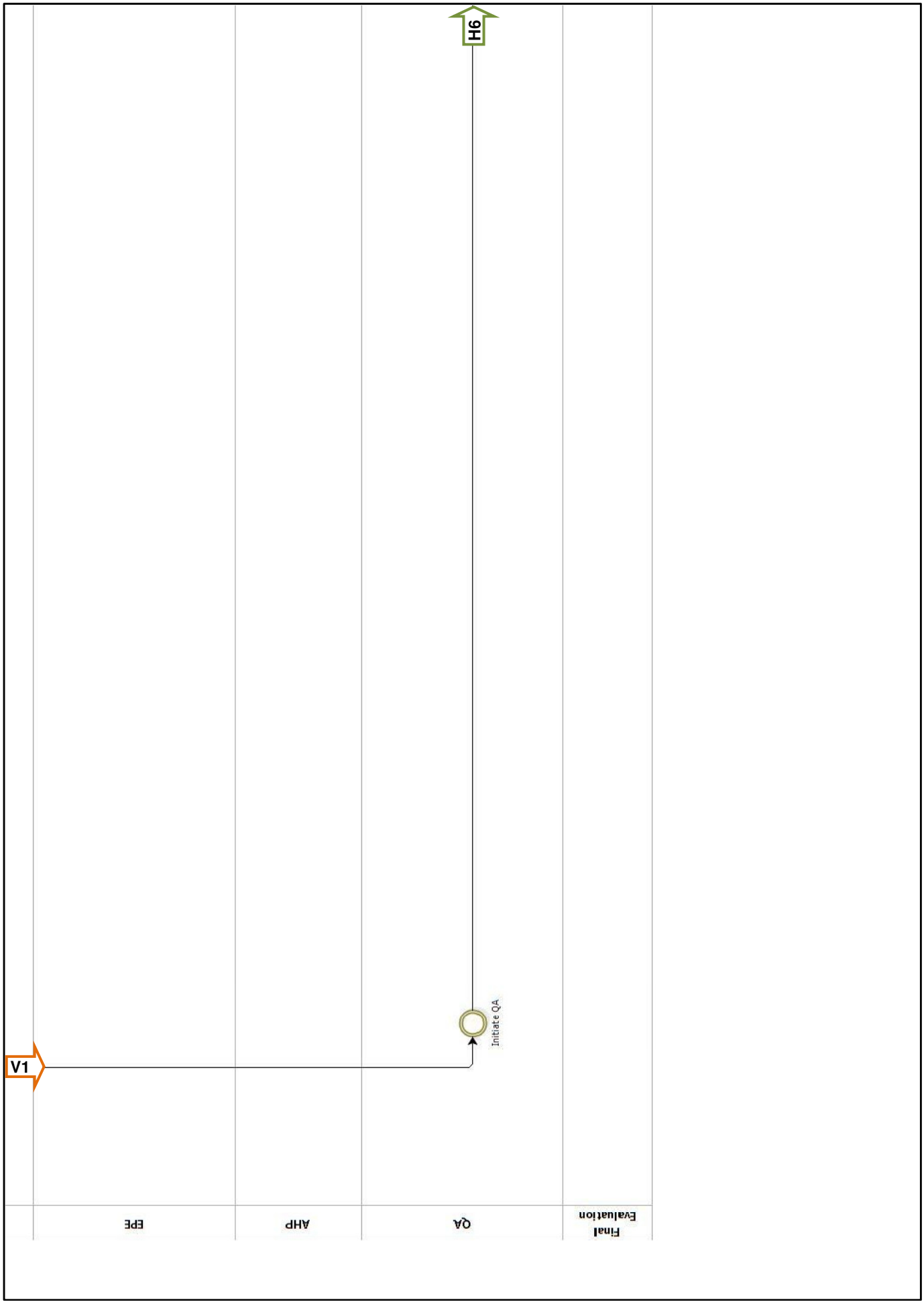
Process Model (Part 2)



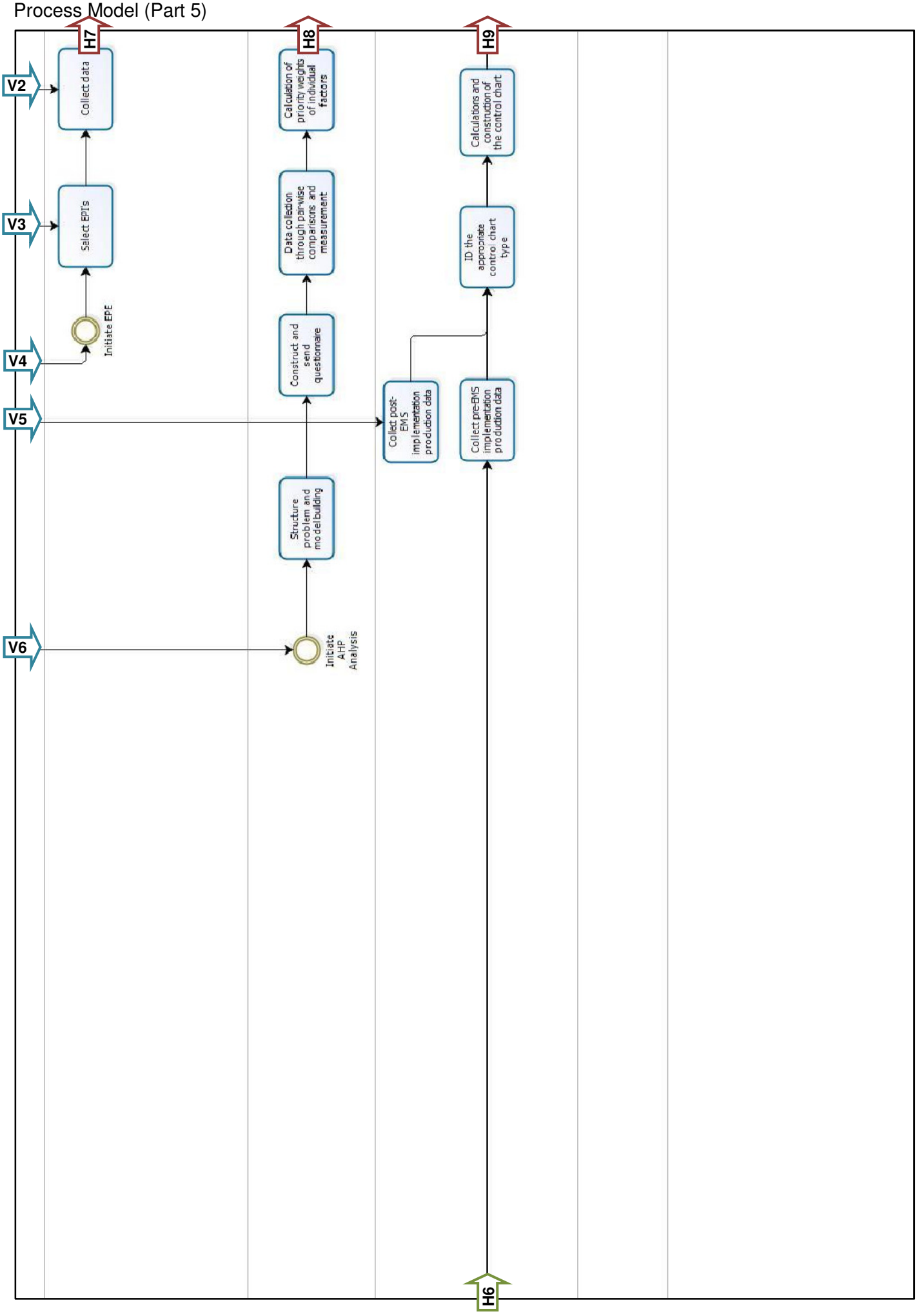
Process Model (Part 3)



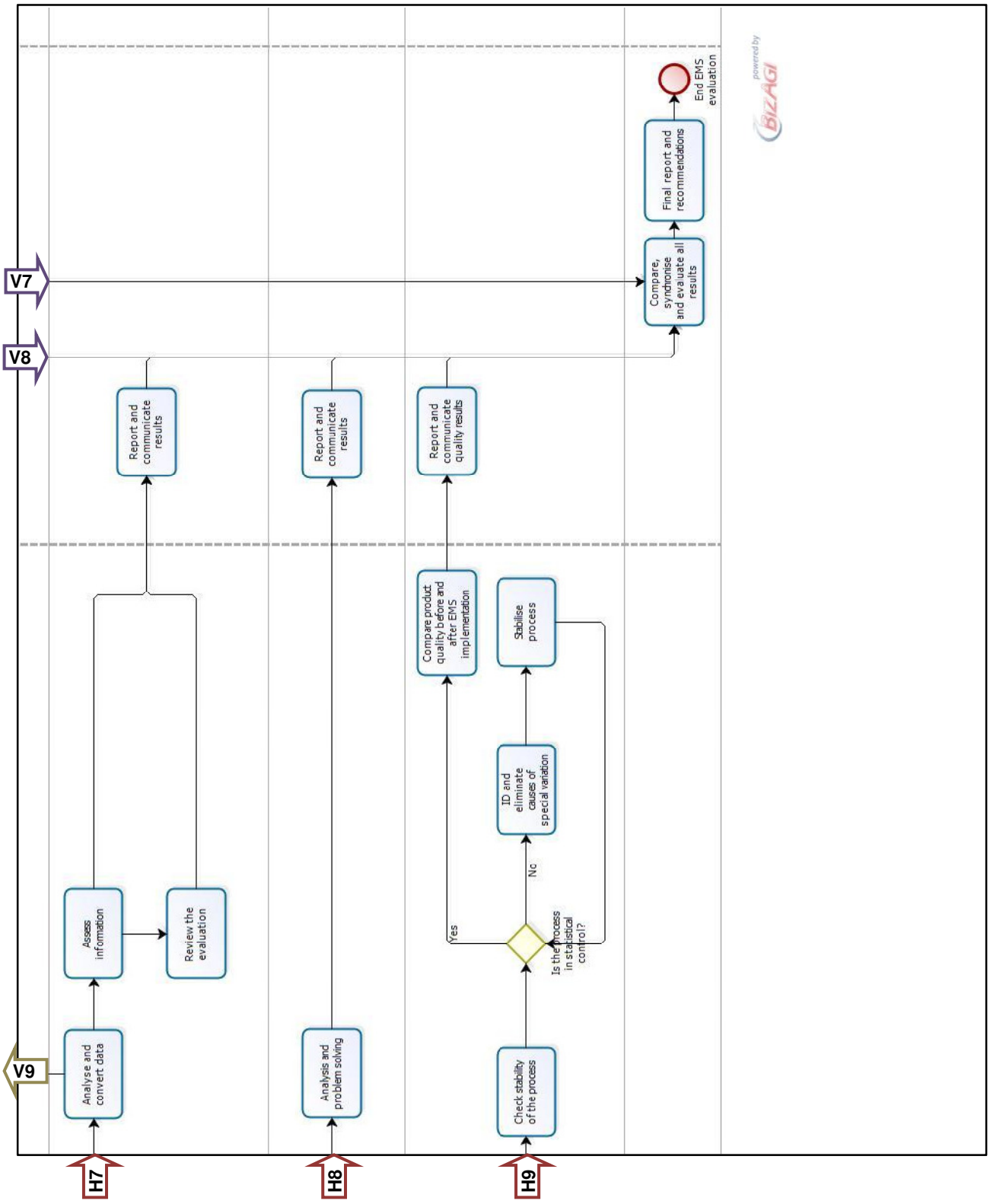
Process Model (Part 4)



Process Model (Part 5)



Process Model (Part 6)



QA (January 2008 - Desember 2009) Original Control Chart

Sub-group	Total coal produced	Saleable coal produced	Coal Rejected	Fraction (p)	Centre line (ṗ)	UCL	LCL	Boundry between lower zones A & B	Boundry between upper zones A & B	Boundry between lower zones B & C	Boundry between upper zones B & C
1	774897	774172	725	0.000936	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
2	978304	975862	2442	0.002496	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
3	888502	886083	2419	0.002723	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
4	1430410	1428212	2198	0.001537	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
5	1722937	1719395	3542	0.002056	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
6	1051198	1042288	8910	0.008476	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
7	1235522	1234004	1518	0.001229	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
8	1268584	1265987	2597	0.002047	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
9	956028	953872	2156	0.002255	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
10	737519	736309	1210	0.001641	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
11	947802	946262	1540	0.001625	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
12	1238169	1236145	2024	0.001635	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
13	1247721	1246753	968	0.000776	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
14	993585	990373	3212	0.003233	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
15	1050495	1047547	2948	0.002806	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
16	727834	726646	1188	0.001632	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
17	991378	989530	1848	0.001864	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
18	1033422	1031838	1584	0.001533	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
19	1126939	1125751	1188	0.001054	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
20	899885	898543	1342	0.001491	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
21	898459	896434	2025	0.002254	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
22	648838	648112	726	0.001119	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
23	652015	651465	550	0.000844	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
24	1002034	1001110	924	0.000922	0.002032	0.006614	0.00	0.00	0.005087	0.000504	0.003559
Totals	**24502477**	**24452693**	**49784**	**0.04818172**							

Standard deviation of p **0.00152738**

Process Capability **0.002008**

QA (January 2008 - Desember 2009) Stabilised Control Chart

Sub-group	Total coal produced	Saleable coal	Coal Rejected	Fraction (p)	Centre line (ṗ)	UCL	LCL	Boundry between lower	Boundry between	Boundry between	Boundry between
1	774897	774172	725	0.000936	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
2	978304	975862	2442	0.002496	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
3	888502	886083	2419	0.002723	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
4	1430410	1428212	2198	0.001537	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
5	1722937	1719395	3542	0.002056	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
7	1235522	1234004	1518	0.001229	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
8	1268584	1265987	2597	0.002047	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
9	956028	953872	2156	0.002255	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
10	737519	736309	1210	0.001641	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
11	947802	946262	1540	0.001625	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
12	1238169	1236145	2024	0.001635	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
13	1247721	1246753	968	0.000776	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
14	993585	990373	3212	0.003233	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
15	1050495	1047547	2948	0.002806	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
16	727834	726646	1188	0.001632	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
17	991378	989530	1848	0.001864	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
18	1033422	1031838	1584	0.001533	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
19	1126939	1125751	1188	0.001054	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
20	899885	898543	1342	0.001491	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
21	898459	896434	2025	0.002254	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
22	648838	648112	726	0.001119	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
23	652015	651465	550	0.000844	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
24	1002034	1001110	924	0.000922	0.001743	0.006325	0.00	0.00	0.004798	0.000216	0.003270
Totals	**23451279**	**23410405**	**40874**	**0.03970568**							

Standard deviation of p **0.00067406**

Process Capability **0.001726**

QA (January 2010 - August 2010) Original Control Chart

Subgroup	Total coal produced	Saleable coal produced	Coal Rejected	Fraction (p)	Center line (ṗ)	UCL	LCL	Boundry between lower zones A & B	Boundry between upper zones A & B	Boundry between lower zones B & C	Boundry between upper zones B & C
1	1076883	1076047	836	0.000776	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
2	1134663	1132441	2222	0.001958	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
3	1231591	1226971	4620	0.003751	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
4	865961	864289	1672	0.001931	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
5	738925	738375	550	0.000744	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
6	1176841	1174025	2816	0.002393	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
7	1216443	1216025	418	0.000344	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
8	1264623	1262598	2025	0.001601	0.001741	0.005032	0.000000	0.000000	0.003935	0.000644	0.002838
Totals	**8705930**	**8690771**	**15159**	**0.013499**							

Standard deviation of p **0.0010969**

Process Capability **0.001687**

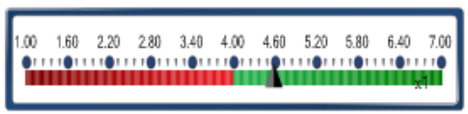
APPENDIX G – Sisense Prism Dashboard of Matla's EMS Performance

WELCOME TO
EXXARO MATLA COAL ENVIRONMENTAL MANAGMENT SYSTEM DASHBOARD

EMPLOYEE OPINION EMS PERFORMANCE

4.58

AHP PERFORMANCE SCALE



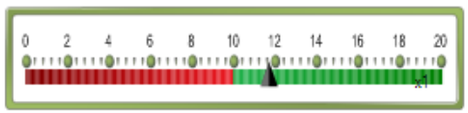
exxaro

POWERING POSSIBILITY

EPI FACTUAL EMS PERFORMANCE

11.69

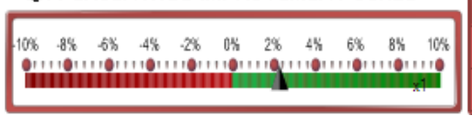
EPE PERFORMANCE SCALE



PRODUCT QUALITY EMS PERFORMANCE

2.26%

QA PERCENTAGE IMPROVEMENT SCALE



AHP Statistics

Criteria	Relative Weight	Question Average	Criteria Count
EC	0.08	4.29	0.35
EF	0.03	4	0.11
EI	0.14	3.67	0.51
EX	0.05	4.77	0.25
IR	0.31	4.60	1.41
LR	0.19	5.33	1.02
MA	0.10	4.71	0.47
RA	0.10	4.50	0.46

QA Statistics

Time Period	Process Capability
2008-2009 (Before)	0.001726
2010 >> (After)	0.001687

EPE Statistics

Perspective	EPI	Performance Value
Internal	Diesel consumption	10.46
	Electricity consumption	13.40
	General waste	14.74
	Hazardous waste	13.14
	Petrol consumption	13.46
	Production output	6.20
	Quality	19.25
	Water usage	12.75
Learning & Growth	Budget spent on R&D to improve environmental conditions	11.11
	Employees trained	13.33
	Number of contractors contacted about environmental management	15
Stakeholder	Incidents (Not reportable)	11.67
	Land disturbed	10.82
	Market Leadership	12.50
	Non-recyclable waste	13.33
	Number of complaints from public or employees	6.67
Triple bottom line	Air emissions	11.67
	Environmental Budget	11
	Noise	10.15
	Number of fines/violations per year	3.33