A Tool for Lubricant Management in the Mining Industry

by

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Executive Summary

The South African mining industry is vital to the country's economy because it provides hundreds of thousands of jobs to South Africans and contributes a large portion to the country's GDP, capital inflow and merchandise exports. However, the mining process relies heavily on industrial equipment and the energy, fuel, spares and lubricants needed to run this equipment, to function effectively. As a result of this, mining companies are beginning to implement commodity management and strategic sourcing (SS) programmes to effectively manage their supply and optimise the buying of these commodities.

One mining company (XYZ Mining) has recognised the importance of proper commodity management programs and the use of SS to add value to their commodity supply chains, and have begun the implementation of such a programme for their lubricants commodity supply chain. The SS cycle is a continuous process which includes four main steps: namely the building of knowledge and understanding for the commodity, identifying and developing improvement initiatives, implementing these initiatives and managing and monitoring the status of the commodity.

The aim of the project was therefore to develop a quantitative tool that could be used throughout the lubricant commodity SS cycle carried out at XYZ Mining. This tool was developed in the form of an information system separated into two main parts, namely a database for collecting all data about the lubricant commodity, and a set of analysis tools including:

- A total cost of ownership (TCO) analysis which is used to trace the use of lubricants to a per-equipment level and which may be used to trace the impact of improvement projects on specific fleets or lubricants;
- A dashboard comprising of trend analyses, summary TCO analyses and Pareto analyses to identify areas for improvement over the supply chain; and
- A project evaluator analysis which analyses a number of potential improvement projects and determines which projects should be implemented first.

The construction of the information system began with constructing a logical design of the database in the form of an entity relationship diagram; and a logical design of the analysis section in the form of a use-case diagram. Using these logical designs, a generic IS was designed and constructed for use at any mine, and an accompanying user manual was also developed.

The IS was developed to fit the requirements stated by XYZ Mining directly and it was developed using proven tools and techniques. User friendliness and ease of understanding were considered throughout the development of the IS and the user manual so that the ultimate implementation of the tool would be ensured.

Although the tool has not been implemented at XYZ Mining yet due to time constraints, the generic tool and the user manual have been delivered to the company for their use. The usefulness and importance of the IS was also demonstrated by positive feedback from XYZ Mining and by validating the model by means of a working example.

In the future, it is recommended to expand the information system so that it automatically pulls relevant data directly from XYZ Mining’s ERP systems. Also, this information system can be expanded to cover other commodities in the mining sector such as fuel or gearboxes; and it can even be extended beyond the mining sector to any industries that make use of commodity management.

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AHP	Analytical hierarchy process
BOY	Beginning of year
CC	Capitalised cost
ERD	Entity relationship diagram
ERP	Enterprise resource planning
EOY	End of year
IE	Industrial Engineering
IS	Information system
KPD	Key performance driver
NPV	Net present value
SS	Strategic sourcing
TCO	Total cost of ownership

1. Introduction and Background

1.1. Mining and Mining Equipment

South Africa has more than 2000 mining enterprises that provide over 500 000 jobs to locals and R435bn to the country's economy each year (Statistics South Africa, 2011). South Africa's mines also account for more than 50% of merchandise exports out of the country and 30% of capital inflows into the country (SouthAfrica.info, 2011). These statistics clearly indicate that the mining industry is a vital industry for the South African economy in more ways than one.

At the heart of the South African mining industry lie three main processes; namely the extraction of minerals via surface or underground mining; the sorting, washing and grading of the valuable minerals; and lastly the transportation of the minerals to be processed further within South Africa, or to be exported out of the country.

As a result of these processes, the mining industry relies heavily on mining equipment and vehicles to function effectively. Whether one considers draglines that are used in open cast coal mining operations; drills and continuous miners that are used to excavate underground; the earth moving machinery that is used on the mine site; or the crushing, screening and washing equipment used in the beneficiation process; it is evident that heavy industrial equipment and the energy, fuel, spares and lubricants needed to operate and maintain the equipment are vital inputs to the mining industry.

1.2. Commodity Management

In order to achieve the high availability and utilisation of equipment and vehicles that is needed to maintain adequate levels of production, mining companies rely on good commodity management programs. Commodities include any physical substances which are interchangeable with another product of the same type (InvestorWords.com, 2010); and in the context of the mining industry; commodities include the pumps, motors, fuel, electricity and lubricants used in the mining process. Commodity management strategies help businesses increase their competitive advantage by lowering the average procurement cost of their commodities and by reducing the impact of volatile commodity prices on the business' earnings (Deloitte Consulting LLP, 2007-2008). The key to proper commodity management lies in the effective management of the entire commodity supply chain, with particular emphasis being placed on supply management as it is the first, and most important, link in the chain.

One method being used by more and more businesses to effectively manage their supply and optimise the buying of commodities is called strategic sourcing (SS). SS can be defined as the process of evaluating, selecting and aligning with suppliers to achieve improvements in the supply chain that support a business' strategic objectives (UPS Supply Chain Solutions, 2005). SS can extract value in a commodity supply chain by improving a business' understanding of its current supply chain performance; by realising total cost savings over the lifetime of the commodity; by improving the business' competitive position; and by identifying opportunities for innovation over the supply chain (UPS Supply Chain Solutions, 2005). The method involves taking a strategic, as opposed to a tactical, approach to the management of the supply chain and it requires a continuous process to constantly monitor and track improvements and the performance of it. SS also requires a cross-functional approach that will incorporate the expertise of commodity specialists as well as suppliers and end users to ensure that the process becomes a sustainable effort (USAEC, 2010).

1.3. Strategic Sourcing Methodologies

With the increasing popularity of SS as a tool to extract value in commodity supply chains, a large number of methodologies which detail the use and implementation of SS in businesses are available. Three examples of these methodologies are shown in Appendix A to illustrate the differences, and similarities, between them. While most SS models vary widely in terms of the detail of the steps which are followed and the order in which tasks should be completed; they may all be summarised into a cycle consisting of four steps as illustrated in Figure 1.

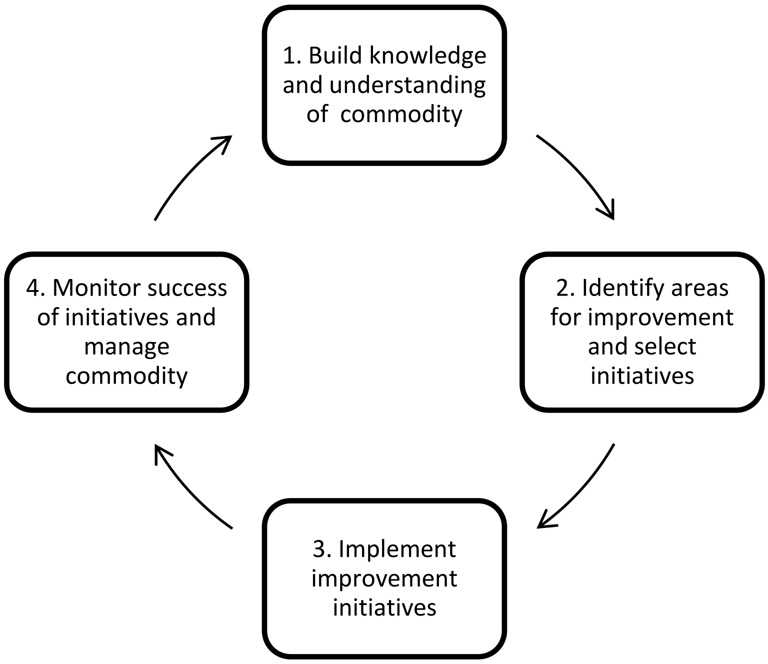


Figure 1: Summarised strategic sourcing cycle

The first step of the SS cycle, building a knowledge base and understanding of the commodity, is a critical step in the process. The knowledge base helps to build a full understanding of the current state of the commodity, and analyses of the data gathered will help to identify areas for improvement. The present knowledge base also serves as a baseline to measure the impact of improvement projects that are implemented in the future and to track savings to the bottom line of the business.

According to CIPS (2012), Efficio Consulting (2012) and Rendon (2005) the following analyses typically highlight opportunities for improvement over the supply chain and should be carried out while building the knowledge base and understanding for the commodity.

- Product analysis and segmentation,
- Spend analysis,
- Total cost analysis,
- Supply market analysis and profiling, and
- Identification of performance drivers.

The results gathered from these analyses may provide valuable insight into hidden areas for improvement over the supply chain and will be used in the idea generation phase (the next step in the cycle). Depending on the number of ideas that are generated for improving the performance of the supply chain in this phase, the ideas or initiatives may need to be compared to one another to choose the most profitable or beneficial initiatives to implement first.

The initiatives that are chosen will then be implemented and their progress monitored and managed to ensure that the benefits that were forecast are actually realised. Thereafter, the process is started again with the improved commodity supply chain being the basis on which the new knowledge and understanding is built.

2. Problem Statement

One mining company (hence forth referred to as XYZ Mining), has recognised the importance of proper commodity management programs and the use of SS to add value to their commodity supply chains, and have begun the implementation of such a programme for their lubricants commodity supply chain.

The management of the lubricants commodity is of particular importance in the mining industry as the equipment and vehicles used in the mining environment contain a large number of moving parts which need to be properly lubricated to function efficiently. Mining firms spend large amounts of money on lubrication for their vehicles and equipment, which means that a small improvement in this commodity supply chain could result in large savings for the company.

Because of the large amount of data that needs to be gathered and the number of analyses that need to be carried out during the SS cycle, XYZ Mining needs a tool to assist them in carrying out the data gathering and drawing up of the quantitative analyses needed for the SS cycle. The tool should also assist them in choosing between initiatives to implement and to monitor those initiatives that are implemented.

Owing to the nature of the tasks involved in developing a tool that can be used for these purposes, XYZ Mining identified the need for an Industrial Engineer or Industrial

Engineering student to assist them with the project, as it involves the application of many IE tools and techniques.

3. Aim

The aim of the project is to develop a tool that can be used throughout the lubricants commodity SS cycle carried out at XYZ Mining. The tool will be developed in the format of an Information System (IS) that consists of:

- A database where all of the raw data needed can be recorded and stored, and
- A set of analysis tools and a dashboard that measures the performance of the supply chain over time, identifies areas for improvement and compares the alternatives to choose the best initiatives to implement.

4. Scope

The scope of the project is defined by the set of activities that need to be completed through the duration of the project to achieve the stated aim. These activities include:

- Conducting a literature review of
    - The techniques that may be used for developing an IS, and selecting a methodology that will be followed for the duration of the project,
    - Each of the requirements of the IS,
    - Any other concepts that need further explanation,
- Translating the user requirements for the system into system functions,
- Gathering basic data that is necessary for the construction of the IS,
- Designing and constructing the IS based on the basic data collected,
- Reviewing the IS with relevant stakeholders,
- Emptying the IS to create a blank model that is ready to be implemented at XYZ Mining's mines,
- Deployment of the model to the mines,
- Development of a user manual, and
- A demonstration of the application of the IS.

A base line Gantt chart illustrating the activities to be completed; as well as when they will be completed is included in Appendix B

The budget associated with the project and the list of resources used throughout the duration of the project is also provided in Appendix B.

5. Literature Review and Selection of Techniques

5.1. Information Systems and Their Development

5.1.1. What is an Information System?

An IS is an arrangement of data, information technology and processes that capture and manage data and translate it into useful information that is used to support a business (Bentley & Whitten, 2007). Many businesses consider ISs to be vital in creating a competitive advantage because they improve the accuracy and productivity of the business and assist in acquiring and transferring knowledge quickly and effectively (Jessup & Valacich, 2006).

5.1.2. The Information System Development Process

An IS is developed through a process known as a software development life cycle and a number of models that may be used to guide the development process exist. The four main categories that software development models may be divided into are linear models, incremental models, evolutionary models and agile models (Kossiakoff, et al., 2011).

Linear development models consist of a sequence of steps that should be followed, and feedback loops between the steps that relay information and may be used for verification and validation of the model as it is built. Linear development models work best when the IS is well understood, has fixed requirements, has a reasonable schedule and documented practises that should be used to develop it (Kossiakoff, et al., 2011). Figure 2 illustrates a typical example of a linear model.

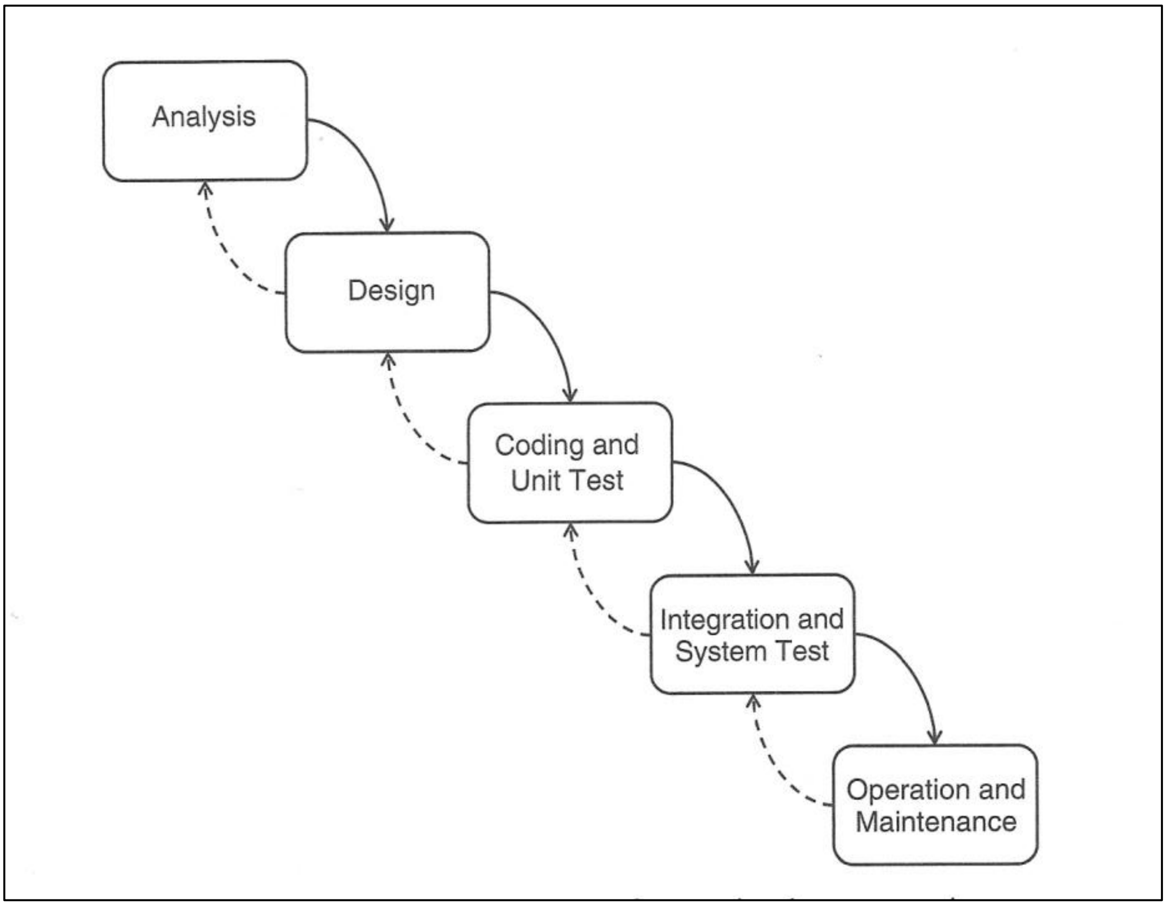


Figure 2: Linear development model (Kossiakoff, et al., 2011)

Incremental development models use the same basic steps as linear models with the exception that they repeat the process through multiple iterations with more detail being added in each one. Incremental models are most suitable for ISs that have fixed requirements and where a partially developed model is required before the IS is fully developed (Kossiakoff, et al., 2011). Figure 3 illustrates a typical example of an incremental model.

Evolutionary development models are built in a similar way to incremental models but are used in an environment where the characteristics of the final IS are not known at the start of the development process. The model is built in the form of a prototype that can be used for experimentation to determine what the ultimate need is (Kossiakoff, et al., 2011).

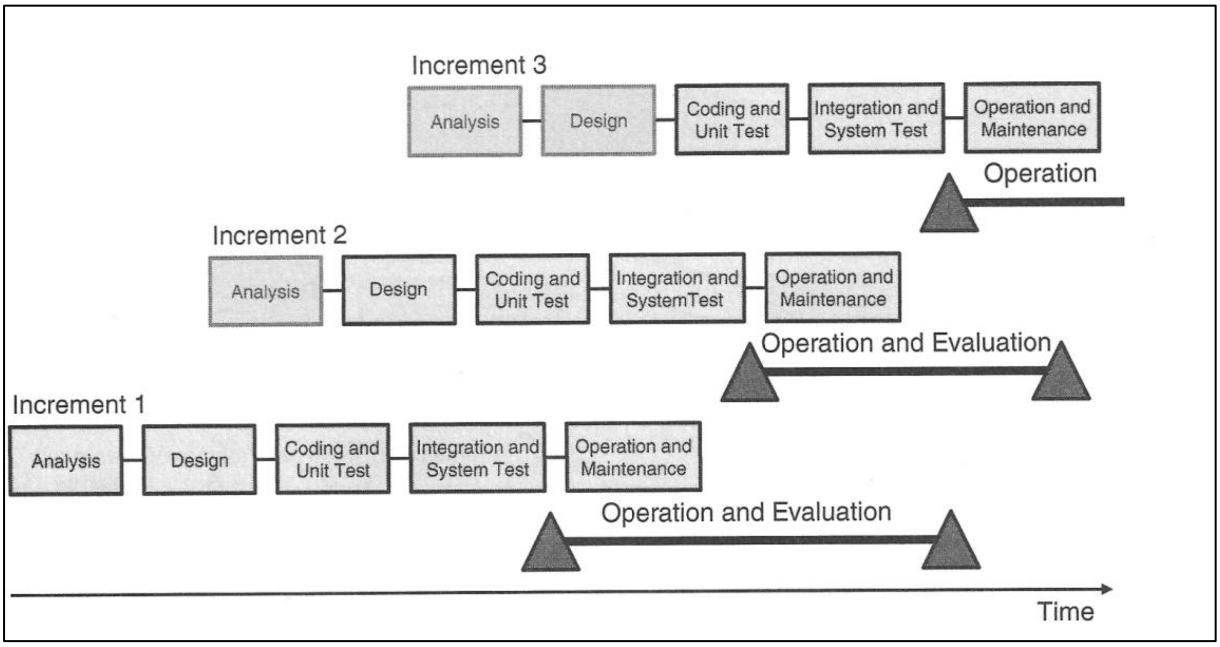


Figure 3: Incremental development model (Kossiakoff, et al., 2011)

Agile development models have no specific steps to follow as the traditional steps used in linear and incremental models may have to be combined to suit the particular use. Agile development models are most suited to projects where there is a lack of structure and constant change (Kossiakoff, et al., 2011).

Selection of Techniques

For the purpose of the IS that will be built for XYZ Mining, the linear software development model (also known as the waterfall model) would be the most suitable for use. The main reason for this is that the requirements for the IS are clear and well understood because the SS cycle is a well documented process. Time is also a limiting factor that would prevent the use of the iterative method, and only a final model is required, not partial models that need to be tested before the final model is developed.

The exact steps that should be followed when using the linear development model vary between sources as some provide more steps with smaller tasks to be completed while others combine these tasks into a few summarised steps. Appendix C provides three examples of the classic linear model to illustrate the differences and similarities between the models presented by Bentley & Whitten (2007), Kossiakoff et al. (2011) and OSQA (2009).

For the purpose of the project being undertaken, a combination of these three models will be used. The steps that were found to be common to all three models as well as any additional steps that are applicable to the project specifically were chosen for use. Figure 4 shows the process that will be followed when building the IS for XYZ Mining as well as a description of the basic activities to be completed for each step in the process so all of the activities described in the scope in Section 4 are covered.

The methodology presented in Figure 4 will be followed for the continuation of the project. The first activity that needs to be carried out in the development of the IS, namely gaining an understanding of the user requirements, will be carried out by conducting a literature review for each of the requirements. This will help to improve the understanding of what is actually required as well help to decide on the best techniques to use to fulfil the requirement. This review will be carried out in Section 5.2. The remaining activities will be carried out during the course of the project and their results documented in Section 6.

Three of the other activities listed in Figure 4 will also be reviewed in Sections 5.3 to 5.5 to identify the best techniques to use to carry them out. These activities are:

- Translating the requirements into system specifications,
- Developing the IS, and
- Developing a user manual.

5.2. Understanding User Requirements

In order to build a better understanding of the user requirements for the IS that is being developed, each of the requirements will have to be reviewed separately to understand what is expected of it. The user requirements that will be reviewed in this section include the generally accepted requirements for a SS system listed in Section 1.3 as well as any additional requirements as requested by XYZ Mining themselves.

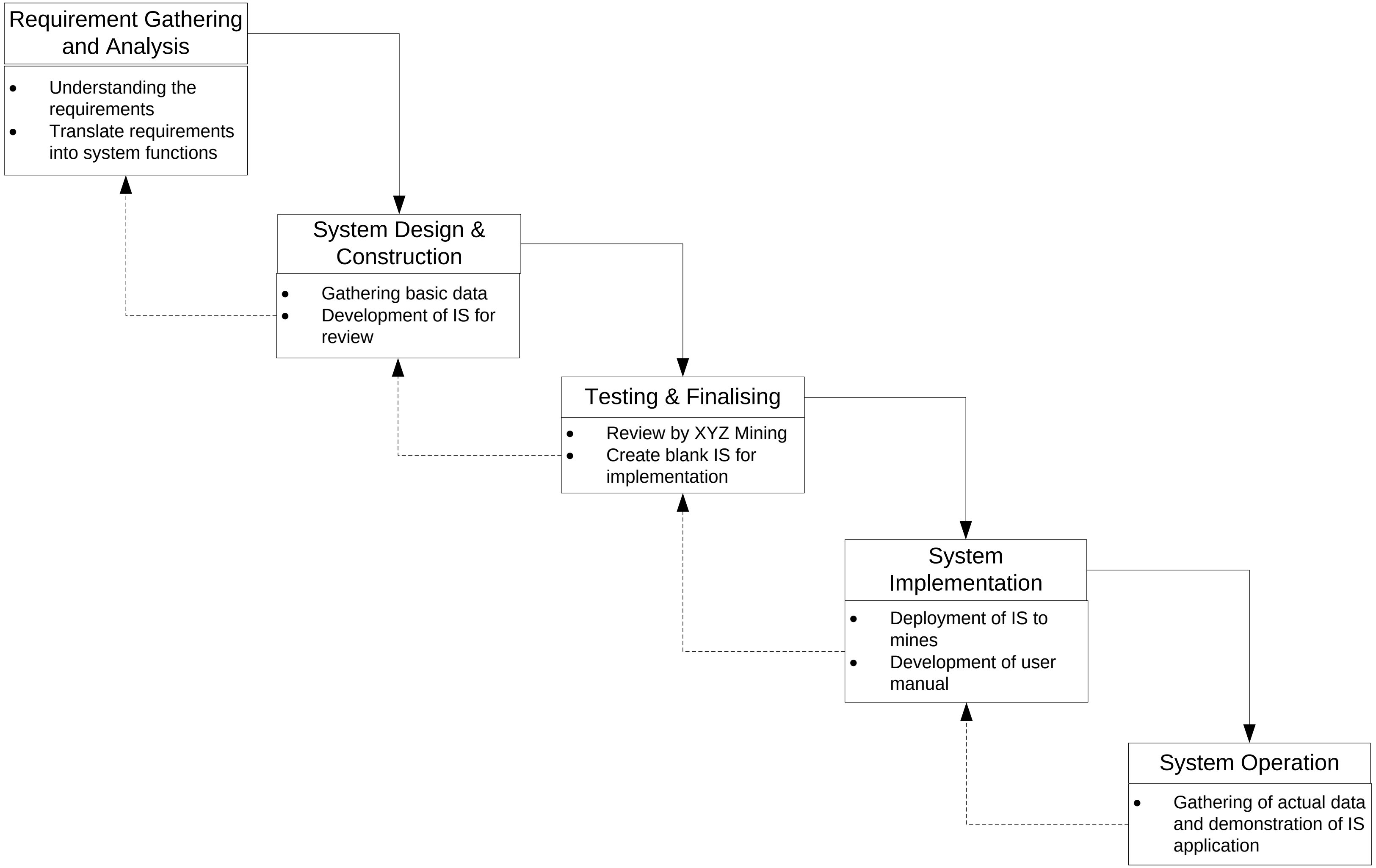


Figure 4: IS development process

5.2.1. Product Analysis: Lubricant Segmentation

A product analysis is an important part of building the knowledge and understanding of a commodity as well as an understanding the context in which the commodity is being used. Product analyses also gather information about whether a commodity is performing properly and fulfils all the functions that are required from it.

The first part of a product analysis focuses on product segmentation so that an overall picture of the different products used, as well as where and how they are used, can be gained.

Lubricant products may be segmented into six broad categories including automotive oils, hydraulic oils, industrial gear and machine oils, greases, compressor and turbine oils and speciality industrial oils (TOTAL South Africa, 2012).

More specifically, the lubricants used in mining equipment can be broadly divided into three categories as listed below:

- Heavy-duty lubricating oils, used for enclosed gear drives;
- Multipurpose engine, hydraulic and circulating oils used for engines, bearing lubrication and fluid power; and
- General purpose grease, used for specialised mining products and industrial bearing applications (Evans, 2002).

Selection of Techniques

The nature of the machinery used in mining is such that a single machine may have numerous parts that need to be lubricated including gears, bearings, hydraulics and an engine. Even with the recent drive towards the production of multipurpose lubricants to serve various parts of a machine (Evans, 2002), no single lubricant would prove sufficient to do the job of lubricating all these parts.

Therefore, the segmentation of lubricants for the purpose of building the IS would be more easily achieved if it were done according to the specific machinery or equipment using the lubricant, as opposed to the type of lubricant as categorised above. The large number of machines and vehicles that are used at each of XYZ Mining's mines means that segmentation according to fleets or machinery manufacturers may have to be done before the lubricants can be segmented according to the specific piece of equipment that they are used in. Figure 5 shows an example of how this segmentation may be carried out.

5.2.2. Product Analysis: Product Performance

The aim of the second section of the product analysis is to gain an understanding of the current performance and consumption of the commodity and compare this with industry standards or specifications to identify areas for improvement or value adding over the supply chain.

Oil Change Interval

Lubricant performance can be measured in terms of the oil change interval or the frequency of oil changes, where an increase in the length of the change interval or a lower frequency of changes will show an improvement of the performance of the lubricant. Usually, oil change intervals are determined by engine and machinery manufacturers (Filter Manufacturers Council, 2012) through extensive testing and historical data, but the intervals provided by manufacturers serve only as a guideline and may not take into account specific operating conditions of individual machines (Caterpillar Maintenance Services, 1998). The lubricant change interval is usually measured in terms of the service hours of the machine or vehicle and would be represented as a certain number of service hours that pass between lubricant changes or refills (Caterpillar, 2010). The performance of lubricants, in terms of the oil change interval, is affected by a large number of factors including the filters that are used, the application the lubricant is being used for, external contamination, operating practices and additives in the oil (Caterpillar Maintenance Services, 1998). All of these factors must be taken into account when generating ideas to improve the performance of lubricants.

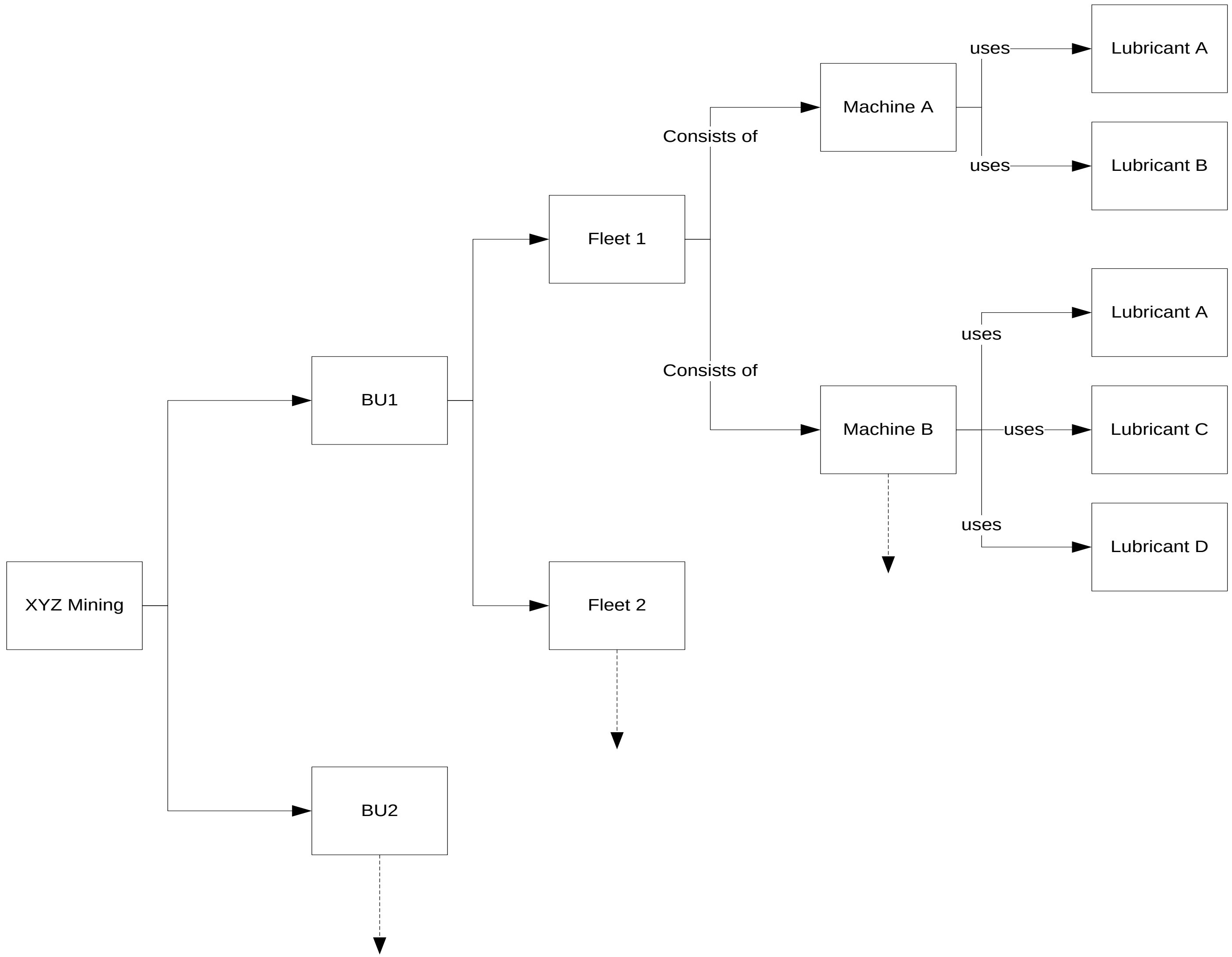


Figure 5: Lubricant segmentation

Lubricant Consumption

Measurement of the oil change frequency can be directly linked to lubricant consumption, where less frequent oil changes result in lower consumption (Lubrication Engineers International AG, 2012). The consumption of lubricants is measured in litres per period of time (e.g. litres per month etc.) which means the oil change frequency, as well as the amount of oil changed or refilled each time, would have to be known to accurately measure lubricant consumption.

Selection of Techniques

When analysing the performance of lubricants in terms of oil change intervals, the actual performance of the lubricant should be compared to the expected performance provided in the manufacturer's user manual. The analysis must therefore be done on a machine-by-machine basis as information regarding manufacturer standards may easily be gathered at this level.

The consumption of lubricants may be compared year-on-year for the same machine. Alternatively, the consumption of the same lubricant being used in the same machine in multiple departments or mines may be compared making the consumption a much more general measure to use for measuring lubricant performance than the oil change interval.

5.2.3. Spend Analysis

Introduction

A spend analysis is a study of the value and volume of purchasing transactions that an organisation makes. It helps organisations clarify what services and goods are being purchased, where they are purchased from and who purchases them (National eProcurement Project NePP, 2007). A spend analysis builds the foundation for strategic sourcing by providing factual insight into spend behaviour and giving a clear direction to aim sourcing and business strategies towards (Aberdeen Group, 2004).

A spend analysis also helps to create a picture of overall spend in an organisation and to determine the procurement function's performance (Deloitte, 2010). Spend analyses have also been proven to help increase procurement efficiency (Enporion Inc., 2008), and the benefits of the analyses may span as far as to reducing material and service costs and improving supplier management, contract compliance, product management, process cycles, inventory management and regulatory compliance (Aberdeen Group, 2004).

Spend Analysis Solutions

The ideal solution for a spend analysis is the implementation of a company-wide, fully automated system that extracts all of the information needed for the analysis from the business' enterprise resource planning (ERP) systems directly (Enporion Inc., 2008). This type of solution helps increase spend visibility and monitor it continuously, and is less time-consuming than a manual solution.

Many software and Information Technology companies, including SAS Institute Inc., Ariba Inc., Ketera Inc. and Verticalnet Inc. offer such solutions to organisations (Aberdeen Group, 2004). However, with a price tag of between R 800,000 and R 4,000,000 to implement the system and a project duration of at least six months (Enporion Inc., 2008), means many firms shy away from this option.

For the purpose of the project, these solutions are not applicable and instead, a spend analysis for the lubricants supply chain will be carried out manually using information extracted from XYZ Mining's ERP systems.

Selection of Techniques: Spend Analysis Methodology

A number of different methodologies that may be used to carry out a spend analysis have been presented in literature and three of these methodologies are shown in Appendix D for comparison. The methodology presented in Figure 6, which will be used for the actual spend analysis for the continuation of the project, combines the relevant and common steps from the methodologies presented by Deloitte (2010), Aberdeen Group (2004) and the National eProcurement Project NePP (2007) in Appendix D. An explanation of the work that is recommended to be completed for each step shown in Figure 6 is also provided.

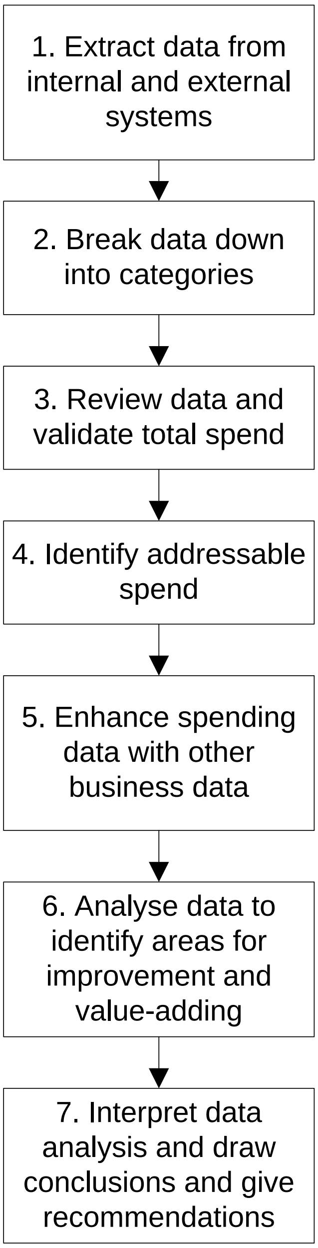


Figure 6: Spend analysis methodology

1. ***Extract data from internal and external systems***

All data relating to transactions with suppliers of lubricants must be gathered; either from XYZ Mining's ERP systems or from the suppliers themselves. This step will be carried out in the database section of the IS that is built.

2. ***Break data down into categories***

Spend data should be broken down and classified according to enterprise-specific taxonomies or according to industry-standard classification systems (Aberdeen Group, 2004). In the case of the spend analysis for lubricants used at XYZ Mining, the spend items will be classified using the same segmentation as the lubricants product segmentation for simplicity's sake. Figure 7 illustrates the structure of the spend analysis proposed for XYZ Mining.

3. ***Review data and validate total spend***

Individual data files and spend totals which were gathered in the previous steps must be checked and validated for accuracy and completion at this point (Aberdeen Group, 2004).

4. ***Identify addressable spend***

Addressable spend can be defined as "the proportion of expenditure that is eligible for spend savings" (National eProcurement Project NePP, 2007), and the data that is identified in this step will be focussed on during the idea generation phase as it holds potential for improvement and value-adding ideas. The addressable spend will be identified when the key performance drivers of the value of the supply chain are identified. This analysis is discussed further in Section 5.2.7.

5. ***Enhance spending data with other business data***

Additional information, which may improve the understanding of the context of the spend items should also be gathered. This may include contract terms, alternative product information, suppliers' performance records etc. (Aberdeen Group, 2004). This step may be carried out when carrying out the supply market analysis and supplier profiling as discussed in Sections 5.2.5 and 5.2.6.

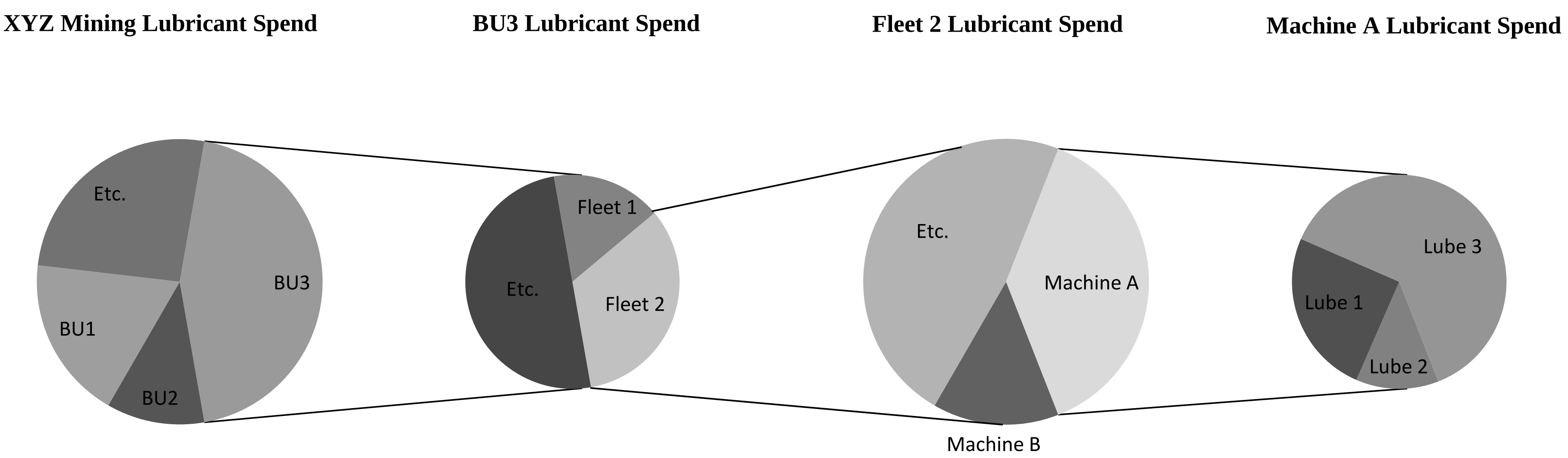


Figure 7: Proposed spend analysis layout

6. Analyse data to identify areas for improvement and value-adding

Steps 6 and 7 fall mainly under the scope of the idea generation phase of the project.

7. Interpret data analysis, draw conclusions and give recommendations

Steps 6 and 7 fall mainly under the scope of the idea generation phase of the project.

5.2.4. Total Cost of Ownership (TCO) Analysis

Introduction

TCO is a purchasing philosophy that is aimed at improving the understanding of the total cost of "buying a particular good or service from a particular supplier" (Ellram & Siferd, 1998). TCO analyses extend beyond considering only the price of purchasing goods or services to include all costs involved in the acquisition, use, maintenance and disposal of items (Ellram, 1993).

TCO analyses support strategic cost management and strategic sourcing by considering the broad effect of purchasing decisions on an organisation's costs and objectives, instead of focusing on internal cost elements alone (Ellram & Siferd, 1998). TCO analyses have also been proven to benefit organisations in the following ways:

- Provides a way to quantitatively measure the performance of suppliers,
- Aids decision making by forcing the quantification of trade-offs,
- Helps to raise awareness of the importance and significance of non price factors,
- Focuses improvement efforts on the right areas, and
- Reveals cost saving opportunities by highlighting significant cost elements (Ellram, 1993).

Selection of Techniques: TCO Analysis Process

The benefits associated with the calculation and analysis of the TCO of products has been recognised by organisations worldwide; and it is a tool now widely used at least to some extent by many companies (Ellram & Siferd, 1998). Although TCO analyses may be applied to a wide range of industries, the basic process used to implement a TCO analysis system is very generic. This process has been adapted from Ellram (1993) and Roodhoft et al. (2005) to suit the application of the project and is shown in Figure 8. The steps shown will be followed while developing the TCO analysis for XYZ Mining, as discussed below.

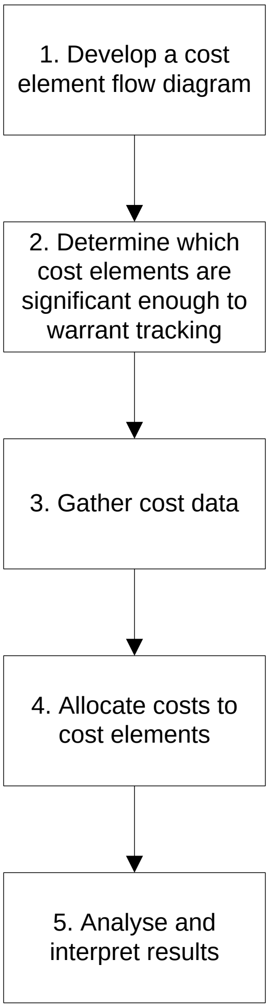


Figure 8: TCO analysis process

1. *Develop a cost element flow diagram*

As shown in the first step of Figure 8, in order to calculate the TCO of an item, all activities or time commitments that will incur costs within the item's life cycle must be considered. The cost associated with each one of these elements is added together to determine the TCO of the item. The cost elements typically included in a TCO analysis are the costs incurred during order placement, research and selection of suppliers, transportation, receiving, inspection, storage, disposal and the price of the product; but different products may have different cost elements depending on the nature of the product (Ellram & Siferd, 1998).

In the case of lubricants specifically, the typical cost-incurring elements that occur within its lifecycle are the following (Noria Corporation, 2010):

- Determining the lubricant specification needed for the application;
- The purchase of the lubricant (including the generation of purchase documents etc.),
- The cost of the lubricant itself,
- Receipt and storage of the lubricant,
- Invoice receipt, payment and approval,
- Transfer of the lubricant into machinery,
- Disposal cost of the lubricant,
- Cost of labour used to change the lubricant,
- Cost of machine downtime during oil change,
- Cost of any other materials used during the oil change,
- Cost of monitoring the performance of the lubricant over the length of the oil change interval, and
- Cost associated with the degradation of the lubricant over time (cost of loss of oil strength or corrosion).

2. *Choose significant cost elements*

Not all of the cost elements listed above need necessarily be included in the final TCO if one or more of them are found to be too insignificant to be tracked. The decision about which elements to include was made in conjunction with stakeholders at XYZ Mining and it was decided that the following cost elements would be recorded:

- The cost of purchasing the lubricant,
- The actual cost of the lubricant (also known as the spend),
- The cost of receiving the lubricant,
- The cost of holding the lubricant,
- The cost associated with changing the lubricant,

- The cost of monitoring the lubricant through its useful life, and
- The cost of disposing of the lubricant.

A cost element flow diagram for these costs is shown in Figure 9.

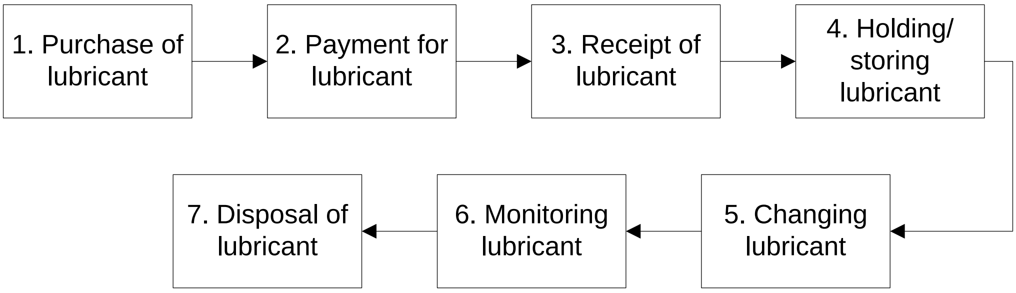


Figure 9: Cost element flow diagram

3. Gather cost data

The data that needs to be gathered for each of the cost elements shown in Figure 9 may be broken down according to how that specific cost element is calculated. It should be noted that where possible, the calculations for each cost element were kept as simple as possible so that no extra effort would be required to gather the data needed for the calculations. Where possible, measures that should already be in place at the mines were used in the calculations to simplify it even further. These calculations are explained below.

1. Purchasing Cost

The purchasing or ordering cost element includes all managerial and clerical costs involved in placing a single order for a product (Jacobs, et al., 2009), and is calculated using Equation 1 where the number of orders placed is measured over a given time period.

$$Purchasing\ cost = Number\ of\ orders\ placed \times Cost\ per\ order\ placed$$

Equation 1: Purchasing cost calculation

2. Spend

The spend cost element refers to the amount of money spent on the actual lubricant that is consumed and is calculated using Equation 2, where the price is the moving average price over the time period for which spend is being measured.

$$Spend = Consumption \times Price$$

Equation 2: Spend calculation

3. Receiving Cost

The cost of receiving an order includes the cost of transportation of the products as well as the cost associated with any activities at the receiving bay including counting, checking and packing the order. The total receiving cost over a given period of time may be calculated using Equation 3.

$$Receiving\ Cost = Number\ of\ orders\ placed \times Cost\ per\ order\ received$$

Equation 3: Receiving cost calculation

4. Holding Cost

The holding or carrying cost of an item includes all costs for storage facilities, handling, depreciation, insurance, taxes, pilferage, obsolescence, breakage and the opportunity cost of capital (Jacobs, et al., 2009). The holding cost may be calculated using Equation 4 where the average inventory is the average number of items being stored over a given period of time and the price is the moving average price over the same period. The holding cost per unit is a standard company-wide percentage used for calculating carrying costs.

$$Holding\ cost = Average\ inventory \times Holding\ cost\ per\ unit \times Price$$

Equation 4: Holding cost calculation

5. Changing Cost

The changing cost includes the cost associated with the labour and materials used each time the oil is changed as well as the cost of any lost machine time during the change. At XYZ Mining, lubricants are changed during scheduled machine downtime, which implies that there is no cost associated with it. In addition to this, the materials used to change lubricant at XYZ Mining are negligible and their cost may therefore be ignored. The cost of changing a lubricant may be calculated using Equation 5 while the total changing cost over a given period of time is calculated using Equation 6.

$$Cost\ of\ changing\ oil = Cost\ of\ labour\ per\ hour\ \times Time\ taken\ to\ change\ oil$$

Equation 5: Cost of changing oil

$$Changing\ cost = Cost\ of\ changing\ oil\ \times Number\ of\ changes$$

Equation 6: Total changing cost calculation

6. Monitoring Cost

The monitoring cost for a lubricant includes the costs involved in testing the lubricant for degradation and wear over its life cycle and may be calculated using Equation 7, where the cost per oil analysis includes the cost of laboratory tests and the labour used for carrying out the testing. Similarly to the previous equations, the total monitoring cost is also measured over a given period of time.

$$Monitoring\ cost = Number\ of\ analyses\ \times Cost\ per\ oil\ analysis$$

Equation 7: Monitoring cost calculation

7. *Disposal Cost*

The costs involved in disposing of lubricants include both the cost of disposing of the lubricant itself and the cost of disposing the drums that the lubricant was transported and stored in. The total disposal cost may therefore be calculated using Equation 8.

$$Disposal\ cost = Cost\ of\ disposing\ oil\ + Cost\ of\ disposing\ drums$$

Equation 8: Total disposal cost calculation

When oil is disposed, it is all poured together and a single rebate for the mixture is received. The cost of disposing the oil alone may therefore be calculated using Equation 9 where the litres of oil disposed includes all lubricants used at the mine over a given period of time, and the rebate is assigned a negative value because it is an income as opposed to a cost.

$$Cost\ of\ disposing\ oil = -Rebate\ per\ liter\ of\ oil\ \times Liters\ of\ oil\ disposed$$

Equation 9: Cost of disposing oil

Finally, the cost associated with disposing the drums may be calculated using Equation 10 where a certain rebate may be given for being able to recycle a used metal drum.

$$\begin{aligned} &Cost\ of\ disposing\ drums \\ &\qquad = Number\ of\ drums\ disposed\ (Cost\ of\ disposing\ drum \\ &\qquad - Rebate\ per\ drum) \end{aligned}$$

Equation 10: Cost of disposing drums

All of the cost data that needs to be gathered to calculate the selected cost elements will be gathered and stored in the database section of the IS that is developed.

4. *Allocate costs to cost elements*

The allocation of relevant data to each cost element will be done in the analysis portion of the IS that is developed.

5. Analyse and interpret results

Figure 10 illustrates the typical layout of a TCO analysis that would be included in the final IS for XYZ Mining. The results of the analysis will be used for the idea generation step of the SS cycle.

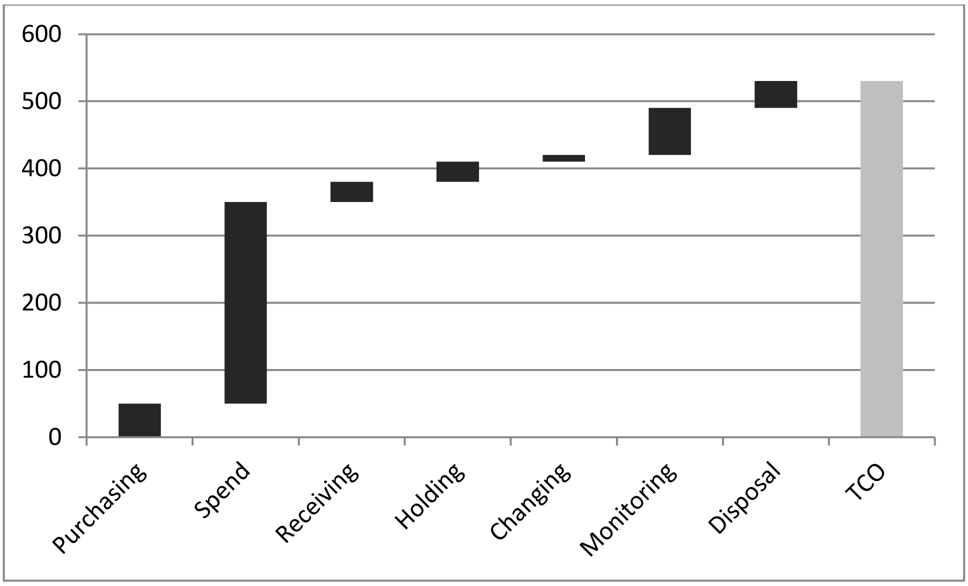


Figure 10: TCO analysis for lubricants

5.2.5. Supply Market Analysis

Why Supply Analysis?

A supply market analysis is a technique used by organisations to improve their understanding of the environment in which their purchases are made. It focuses specifically on understanding how the market works, the competitiveness of the market, the direction that the market is heading in, the key suppliers in the market and the balance of power between the supplier and the consumer (National Public Procurement Policy Unit, 2007). Supply market analyses form an essential part of any strategic sourcing program, and are needed to properly manage any category of products that are procured for an organisation (Hargraves, 2010). The development of a supply analysis also improves an organisation's knowledge of suppliers' strategies which will help them manage risks better, make more informed choices between suppliers and identify opportunities for improvement in supply management (National Public Procurement Policy Unit, 2007).

Selection of Techniques: Supply Market Analysis Framework

Although carrying out a supply market analysis does form an important part of the SS process, it is a very qualitative analysis to carry out and will thus not be included in the IS being developed for XYZ Mining. The tool that is being developed is mainly focused on quantitative analyses.

5.2.6. Supplier Profiling

Why Supplier Profiling?

Part of strategic sourcing involves the continuous managing of suppliers to improve performance and enhance the supply chain. Obviously, not all suppliers should be dealt with in the same way as they are not supplying equally important or valuable goods or services (Gelderman & van Weele, 2005). This brings about the need for some sort of supplier classification system, like supplier profiling or creating a purchasing portfolio for the organisation.

Selection of Techniques

Although carrying out a supplier profiling analysis does form an important part of the SS process; it is also a very qualitative analysis to carry out and will thus not either be included in the IS being developed for XYZ Mining.

5.2.7. Identifying Performance Drivers

Another analysis that must be carried out when building the knowledge and understanding for the lubricant commodity involves identifying which items drive the performance of all the areas that are being measured in the various analyses. The performance drivers of each of the following aspects need to be found:

- Lubricant consumption (discussed in Section 5.2.2)
- Lubricant spend (discussed in Section 5.2.3)
- TCO of lubricants (discussed in Section 5.2.4)

Key performance drivers (KPDs) capture information about which processes, assets and resources are truly driving a business or an area in a business. They also provide a measure of the extent of the impact of these processes or assets on the business, and are crucial to understand if a competitive advantage is to be created. KPDs are also very important to identify for idea generation as they give a good indication of which processes or assets are at risk and which are in line with the organisation's strategy (Laurent, 2010).

The KPDs of the TCO, consumption and spend of lubricants can all be identified based on quantitative measurements because these aspects will be measured through the development of the various analyses discussed before.

Many decision-making tools for choosing the best option between alternatives exist; including grid analyses, paired comparison analyses, the Analytical Hierarchy Process, Pareto analyses and decision trees (Mind Tools, 2012). Grid analyses, paired comparison analyses and the Analytical Hierarchy Process are most suited to making decisions that involve comparing alternatives to each other and choosing the most valuable or advantageous alternative. Decision trees are also best suited to choosing between a set of alternatives and are based on the expected outcome of each alternative. A Pareto analysis however, is used best when a number of different options exist and they must be prioritised to find the options that will most improve the current situation (Mind Tools, 2012). A Pareto analysis is a statistical technique that makes use of the Pareto Principle; which states that 20% of the work can be done to generate 80% of the benefits desired (Haughey, 2009).

Selection of Techniques

In the context of identifying KPD's, the Pareto analysis tool is the most suitable technique to use as it helps to identify where effort should be focused to produce a significant effect and drive the performance of the measure (Chaneski, 2008). The use of Pareto analyses is suited to both qualitative and quantitative measures, provided the categories affecting the quantitative measures can be allocated some sort of score to use for comparison. Pareto analyses are also ideal to use when the item you are investigating contains data that are broken down into different categories (Florida Department of Health, 2010) as is the case for the spend analysis, TCO and lubricant consumption.

Figure 11 illustrates a typical Pareto analysis that could be drawn up to identify the KPD's for the TCO of a lubricant (based on Figure 10).

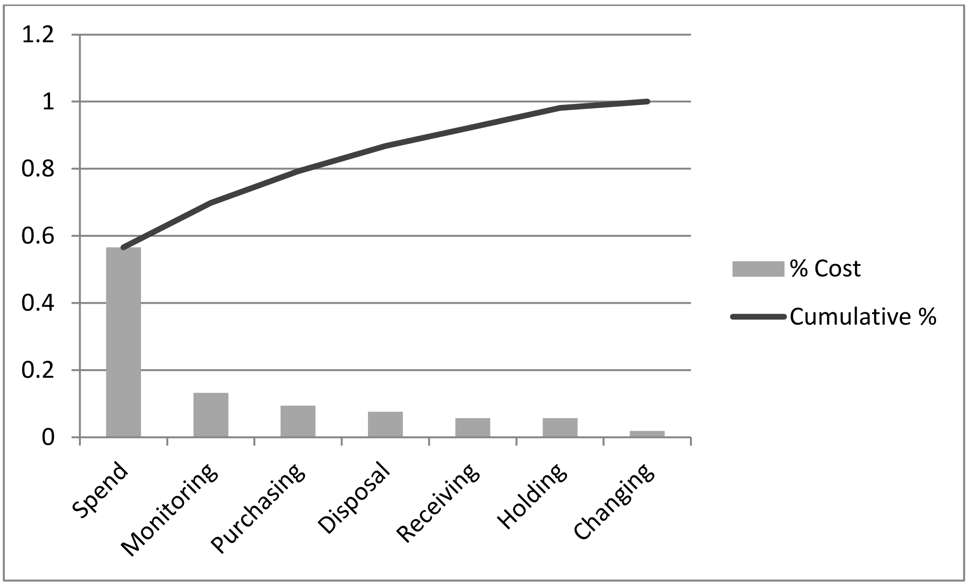


Figure 11: TCO Pareto analysis

5.2.8. Other User Requirements

Sections 5.2.1 to 5.2.7 dealt with gaining a better understanding of each of the IS requirements that were recommended by literature relating to strategic sourcing. Apart from these requirements, XYZ Mining also has requirements for the IS that is to be built:

- The first requirement is that the system includes a section of analyses that may be used to choose between potential improvement projects that could be implemented in the supply chain. This section must include at least an analysis of what impact the potential projects would have on the overall TCO of lubricants, but more than one analysis may be used. The review and selection of techniques that may be used for this purpose will be carried out in Section 5.2.9.

- The second requirement is that the model that is built must be generic enough to be used at any of XYZ Mining's mines. It should also be robust enough to withstand changes in the data (for example a new lubricant that is purchased that was never purchased before) and the addition of new data for at least the next five years. This requirement will have to be considered during the design and construction of the model as it is dependent on the data in the IS and there is no literature available to recommend ways to make specific ISs generic and robust.
- The IS should be able to trace the progress of improvement initiatives that are implemented to determine whether they are in fact realising the benefits that were expected of them. This requirement will be satisfied by adding a capability to the analysis section of the IS that allows the user to compare year-on-year data so that any changes may be traced.
- Lastly, the model should be user-friendly and easy to manage and understand. This is also a requirement that will have to be considered throughout the design and construction on the model.

5.2.9. Choosing Between Potential Improvement Projects

The process of choosing between alternatives can be made much easier by making use of decision-making tools. Numerous tools exist for choosing between a number of different alternatives and these tools vary in their application as discussed below:

- *Grid Analyses* may be used to make a decision by weighing different factors against each other and deciding on the most beneficial option.
- *Paired Comparison Analyses* help work out the importance of a number of options relative to one another.
- The *Analytical Hierarchy Process (AHP)* helps to make a decision by weighing up subjective factors against each other. (Mind Tools, 2012)

A common theme through these three tools is that a number of factors which may affect the ultimate decision of which alternative to choose must be considered. The decision-making tool that would be most applicable to any given situation would therefore depend on the nature of the factors which need to be considered. This point will be discussed further before a final decision about the type of decision-making tool to use will be made.

Factors to consider when choosing between projects

For the application of choosing between projects, there are numerous factors to take into account before a proper decision about which project would really benefit a company can be made. The list provided in Figure 12 (Meredith & Mantel, 2008) shows that these factors may be broken down into five main categories, namely production, marketing, financial, personnel and admin and miscellaneous factors.

The most effective way to choose the factors that should be included in the analysis that will be drawn up for the project specifically was to get direct input from the stakeholders at XYZ Mining. After careful consideration by the stakeholders of all of the factors listed in Figure 12 as well as other factors that they are aware of, the following factors were deemed the most important to consider when choosing between potential improvement projects:

- Profitability or net present value of the project,
- Payback period of the project,
- Impact of project on TCO (part of profitability calculation),
- The time taken to implement the project, and
- The difficulty of implementation in terms of
    - Operational changes that may need to be made,
    - Changes in business systems,
    - Changes in commercial strategies, and
    - Changes in technical specifications and design.

Production Factors

1. Time until ready to install
2. Length of disruption during installation
3. Learning curve—time until operating as desired
4. Effects on waste and rejects
5. Energy requirements
6. Facility and other equipment requirements
7. Safety of process
8. Other applications of technology
9. Change in cost to produce a unit output
10. Change in raw material usage
11. Availability of raw materials
12. Required development time and cost
13. Impact on current suppliers
14. Change in quality of output

Marketing Factors

1. Size of potential market for output
2. Probable market share of output
3. Time until market share is acquired
4. Impact on current product line
5. Consumer acceptance
6. Impact on consumer safety
7. Estimated life of output
8. Spin-off project possibilities

Financial Factors

1. Profitability, net present value of the investment
2. Impact on cash flows
3. Payout period
4. Cash requirements
5. Time until break-even
6. Size of investment required
7. Impact on seasonal and cyclical fluctuations

Personnel Factors

1. Training requirements
2. Labor skill requirements
3. Availability of required labor skills
4. Level of resistance from current work force
5. Change in size of labor force
6. Inter- and intra-group communication requirements
7. Impact on working conditions

Administrative and Miscellaneous Factors

1. Meet government safety standards
2. Meet government environmental standards
3. Impact on information system
4. Reaction of stockholders and securities markets
5. Patent and trade secret protection
6. Impact on image with customers, suppliers, and competitors
7. Degree to which we understand new technology
8. Managerial capacity to direct and control new process

Figure 12: Factors to consider for project selection (Meredith & Mantel, 2008)

The time taken to implement the project is a factor that may simply be added to the analysis as a numerical value; and the difficulty in terms of each of the four factors mentioned above may be measured on a scale from high to low. The payback period of the project and profitability of the project however are factors that must be reviewed further to determine the best techniques to measure them.

Profitability of a project

Carrying out a profitability or net present value (NPV) analysis involves comparing the present value of all future money receipts to the present value of all future disbursements that are associated with the project (Newnan, et al., 2009). The difference between the two is known as the NPV of the project and it is used to determine if the project is profitable or an acceptable investment (Seal, et al., 2009).

The typical future money receipts that should be included in the analysis are all incremental revenues, salvage values, reductions in costs and any release in working capital. The future disbursements that should be included are any initial investments, repairs and maintenance, increased working capital needs and incremental operating costs (Seal, et al., 2009).

When profitability analyses are drawn up specifically for the purpose of comparing alternatives, the length of the projects being compared play a vital role in choosing the method that will be used for the analysis. Four basic possibilities for the length of the projects being compared exist:

- The projects involve a once-off disbursement or money receipt,
- The projects' lives are of equal length,
- The projects' lives have different lengths, or
- The projects have an infinite life span.

In the case of the projects that will be compared by XYZ Mining in the SS cycle, all of the projects are improvement projects and will thus either be once-off money receipt projects or sustainable cost-reduction projects with an infinite life span.

Capitalised Cost

A profitability analysis of a project with an infinite life span is known as the capitalised cost (CC) of the project. The capitalised cost may be defined for the purpose of the project as the present value of all money receipts and disbursements, for an improvement project whose benefits or savings will be realised for an infinite period of time in the future. In very simple terms, the CC of a project may be calculated using Equation 11 where the annual cash flow is the net cash flow for each year that the project is implemented and the interest rate is the minimum required rate of return for projects that are implemented.

$$Capitalised\ Cost\ (CC) = \frac{Annual\ Cash\ Flow\ (A)}{Interest\ Rate\ (i)}$$

Equation 11: Capitalised cost calculation

However, in order to correctly evaluate the CC of a project, two types of cash flows need to be differentiated:

- *Recurring cash flows* are those cash flows that occur at regular intervals and are known and anticipated. If these cash flows occur annually, they may be used directly in Equation 11 to calculate the CC. However, if they occur regularly over any other time period than 1 year, they must be resolved into equivalent annual cash flow to be used for calculating the CC. This may be done by making use of Equation 12 where *F* is the amount of the recurring cash flow, *i* is the interest rate or minimum required rate of return and *n* is the length of time (in years) that passes between each recurring cash flow. The annual cash flow as calculated with Equation 12 may then be used directly in the CC calculation.

$$Equivalent\ Annual\ Cash\ Flow\ (A) = F\left[\frac{i}{(1+i)^n - 1}\right]$$

Equation 12: Resolving recurring cash flow to equivalent annual cash flow

- *Nonrecurring cash flows* are once-off cash flows that occur at irregular intervals and may thus be difficult to anticipate and plan for (Newnan, et al., 2009). The CC of nonrecurring cash flows is simply the present worth of the cash flow and may be calculated using Equation 13; where *F* is the amount of the nonrecurring cash flow, *i* is the interest rate or minimum required rate of return and *n* is the length of time (in years) that passes from present until the nonrecurring cash flow occurs.

$$Present\ worth\ (P) = \frac{F}{(1+i)^n}$$

Equation 13: Present worth of a nonrecurring cash flow

The CC of all recurring and nonrecurring cash flows must be summed together to find the total CC of the project under consideration.

Payback Period

The payback period of a project may be defined as the length of time that it takes for the profit or benefits of the project to equal the cost of the initial investment required (Newnan, et al., 2009). The payback period is a criterion that should be minimised because the shorter the payback period, the more desirable the project or investment becomes (Seal, et al., 2009).

When the net annual cash inflow is constant each year throughout the life of the project, the payback period may be calculated using Equation 14 (Seal, et al., 2009).

$$Payback\ period = \frac{Investment\ required}{Net\ annual\ cash\ flow}$$

Equation 14: Payback period of a project

If the net annual cash inflows are not constant however, the payback period computation is slightly more complex as the unrecovered investment has to be tracked year by year until the remaining unrecovered investment is equal to zero (Seal, et al., 2009).

In the case of the payback period that will be calculated for XYZ Mining when choosing between improvement projects, once off costs or savings could be incurred at different times during the life cycle of the project which implies that Equation 14 cannot be used as it does not take into account once-off cash flows later in the project. Therefore, the method described in the paragraph above will be used instead.

Selection of Decision-Making Tool

In choosing between the three decision-making tools listed in the beginning of this section, the main consideration was the nature of the factors which need to be weighed against one another. The profitability of the project, the project payback period and the time taken to implement the project are all quantitative factors that may be measured or calculated. However, the difficulty of implementation is a qualitative and subjective factor measured on a scale of high to low, and dependent on the person who is rating it. The inclusion of this subjective factor makes the use of the Analytical Hierarchy Process the most suitable decision-making tool to use for the project.

The principles of AHP are applicable to the selection of improvement projects and the prioritisation of projects because the technique helps to identify projects that are most closely aligned with a business' organisational strategy and project selection criteria. The AHP technique is also a very intuitive and simple technique to execute and it may be used by an organisation of any size for any type of decision-making. The reason for its simplicity and wide application lies in the fact that it makes use of qualitative data that does not require specific metrics to be measured (Kendrick & Saaty, 2007).

The steps that must be followed to carry out an AHP analysis for choosing between projects have been adapted from Kendrick & Saaty (2007) and are shown in Figure 13. An explanation of how each of the steps is applied in practice is also provided.

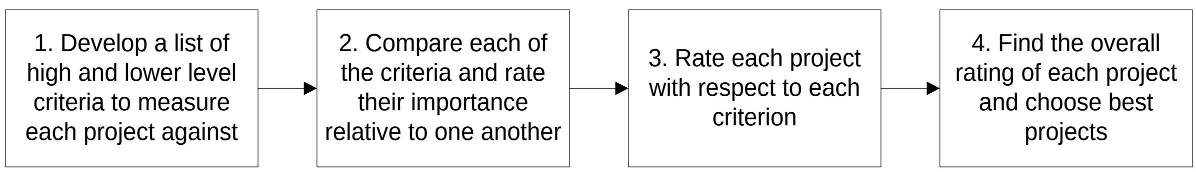


Figure 13: AHP analysis steps

1. The criteria that will be used for the AHP analysis are the factors provided by XYZ Mining that were listed earlier in the section.

2. Each of the criteria will be compared to one another using the pair-wise comparison technique in the format of a matrix. Using this technique, the relative importance of one criterion to another is rated on a scale of 1 to 9; where 1 means that criteria *i* and *j* are equally important, and 9 means that criterion *i* is absolutely more important than criterion *j*. An example of such a pair-wise comparison for three arbitrary criteria is shown in Table 1. In order to find the overall importance of each criterion, expressed as a percentage, an intermediate matrix is developed (see Table 2) where each value in the initial matrix is divided by the sum of its column as shown in the last row of Table 1. These values are then averaged across each row to determine the overall importance of each criterion. This may also be seen in Table 2 where it is clear that criterion 1 is the most important criterion and criterion 3 is the least important.

Table 1: Pair-wise comparison of project criteria

	Criterion 1	Criterion 2	Criterion 3
Criterion 1	1.00	3.00	4.00
Criterion 2	0.33	1.00	2.00
Criterion 3	0.25	0.50	1.00
Sum	**1.58**	**4.50**	**7.00**

Table 2: Intermediate matrix, importance of criteria

0.63	0.67	0.57	**0.62**
0.21	0.22	0.29	**0.24**
0.16	0.11	0.14	**0.14**

3. Each of the projects will also be rated according to each of the criteria using a pair-wise comparison, and on a scale of 1 to 9 where a rating of 1 means that project *i* and project *j* meet the criterion equally well, and a rating of 9 means that project *i* meets the criterion absolutely better than project *j*. An example of three arbitrary projects that have been rated according to an arbitrary criterion is shown in Table 3. In order to find how well each of the projects meets the criterion, in terms of a percentage, an intermediate matrix similar to Table 2 is developed. This may be seen in Table 4 where it is clear that project A meets the criterion the best of the three projects, and project C meets it the worst. Matrices similar to Table 3 and Table 4 are developed for each criterion to find the performance of each project with respect to each criterion separately.

Table 3: Project rating according to criterion

Rating with respect to Criterion 1	Project A	Project B	Project C
Project A	1.00	2.00	3.00
Project B	0.50	1.00	4.00
Project C	0.33	0.25	1.00
Sum	**1.83**	**3.25**	**8.00**

Table 4: Intermediate matrix, rating of projects

0.55	0.61	0.38	**0.51**
0.27	0.31	0.5	**0.36**
0.18	0.08	0.12	**0.13**

4. Finally, the overall rating of each project is calculated. This is done for a single project by multiplying the importance of each criterion by the rating of the specific project for that criterion and adding these figures together. An example of the calculation of the overall rating for a single arbitrary project is illustrated in Table 5. The final rating figure generated by this calculation will be compared to the same figure as calculated for the remaining projects and the project with the highest rating will be given the highest priority, or chosen, for implementation.

Table 5: Rating a project

Criterion	Importance of Criterion (from Table 2)	Rating of how well Project A meets criterion	Product
Criterion 1	0.62	0.51	0.32
Criterion 2	0.24	0.16	0.04
Criterion 3	0.14	0.44	0.06
	Total Rating, Project A		0.42

An AHP Analysis that will make provision for the eight criteria listed earlier in the section will be developed in the IS. This analysis will make provision for five projects to be compared at a time, in order to choose between them, or to choose which projects to implement first.

5.2.10. Conclusion: User Requirements

From the reviews carried out in Sections 5.2.1 to 5.2.9 it is obvious that a large number of analyses using similar and sometimes the same data need to be built into the IS. Considering this fact, a number of the analyses may be combined to form a single, more concise analysis. This is done as described below:

- The lubricant segmentation format will be used for the spend analysis because spend must be traced all the way down to the lowest level of segmentation. This means that these two analyses may be combined into a single analysis.
- The consumption of lubricants may be directly linked to the lubricant spend as seen in Equation 2. The same layout may therefore also be used for the consumption analysis as it allows consumption to be traced down to the lowest level as well.
- The spend analysis forms part of the broader TCO analysis as spend is one of the cost elements that must be included in the TCO calculation. A similar layout as is used for the spend analysis will therefore be used for the entire TCO analysis with the exception that some of the other cost elements may not be able to be traced down to as low a level as the spend is. An outline of this layout is provided in Figure 14.

KPD's may be gathered from this single analysis and broken down to analyse the key drivers of the TCO, the spend and the consumption of lubricants. All of the data that will be used in the analysis (this data constitutes all of the measures that need to be gathered for the calculation of each of the TCO cost elements) will be gathered in a separate database section of the IS and linked to the analysis portion. The analysis that will assist in choosing between potential improvement projects will be built separately as it uses separate data and techniques to the rest of the analyses.

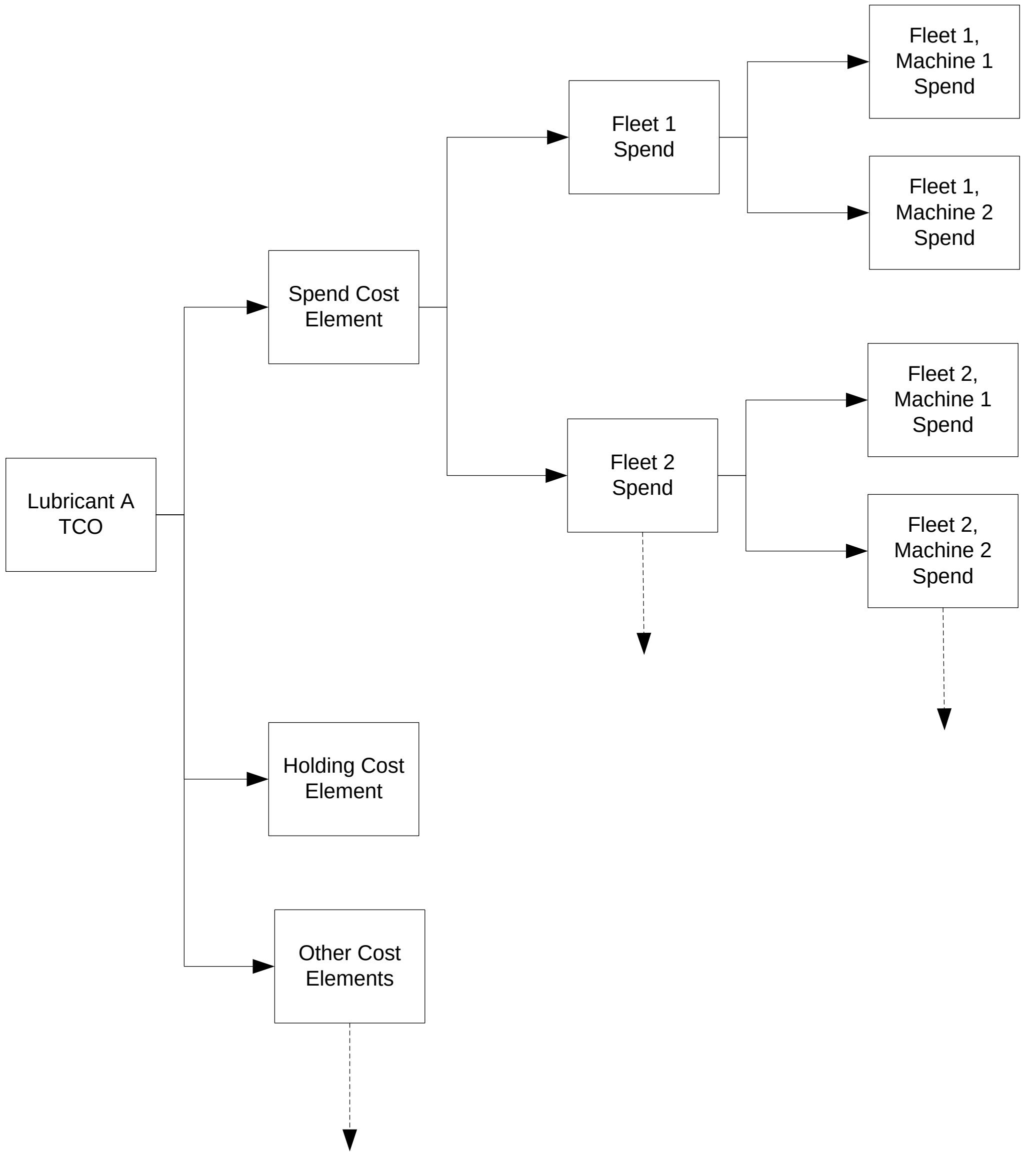


Figure 14: Outline of analysis section of IS

5.3. Translating Requirements to System Specifications

In the process of developing an IS, the first step is gathering and understanding each of the user requirements. Once this information has been gathered the development of the IS may begin. It is however important that the IS be developed based on the user requirements and only the user requirements so that it does not fail to achieve the purpose for which it was intended, and at the same time it does not offer unnecessary functions.

One method for getting around this issue is to use a development technique called user-centred development. This technique is based on building an understanding of the stakeholders' needs and the reasons why the IS should be developed. It helps the system designer focus on how the system will be used instead of how it should be constructed (Bentley & Whitten, 2007). This method will be of particular relevance in the development of the IS for XYZ Mining as the primary purpose for it is to be used.

Use-case Modelling

Use-case modelling is a technique based on user-centred development that helps to translate user requirements into system functions. Use-case modelling involves modelling an IS's functions in terms of events that occur within the system, and each of the events that need to occur may be seen as a user requirement that has been carried out.

In addition to being a technique to translate user requirements into functions, use-case modelling also provides the following benefits:

- It helps to break the system scope up into smaller pieces,
- It acts as a tool for tracing user requirements,
- It helps to identify, control and manage development activities,
- It captures the system's functional requirements, and
- It provides a baseline for developing user manuals (Bentley & Whitten, 2007).

Use-case Diagram

A use-case diagram is a tool used when carrying out use-case modelling. It is a diagram that shows the interactions between external systems and users of the IS and the IS itself. It shows each of the ways that the user should be able to interact with the system and thus all of the system's functional requirements (Bentley & Whitten, 2007).

The diagram is made up of three main elements, namely use cases, actors and relationships (Bentley & Whitten, 2007):

- *Use cases* are sets of steps grouped together for the purpose of completing a single business task. They describe the IS's functions from the user's perspective and in terminology that it easy for them to understand. Use cases are depicted in a use-case diagram using horizontal ellipses.
- *Actors* may be humans, external ISs etc. that interact with the IS and exchange information with it. Actors are responsible for triggering or initiating all use cases and are depicted using stick figures.
- *Relationships* are simply directional lines connecting specific actors to use cases to show their interaction with the system and the nature of the interaction. A use-case diagram may make use of association, extension, inheritance or dependent relationships.

Figure 15 shows a generic example of a use case diagram (Bentley & Whitten, 2007).

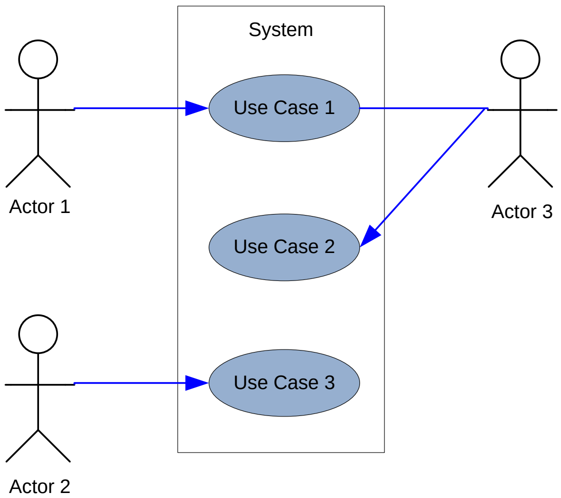


Figure 15: Generic use-case diagram

Selection of Techniques

A use-case diagram will be developed for the IS that is being developed for XYZ Mining. The process of drawing up the diagram will assist in translating user requirements into system functions and the diagram itself will help to gain a better understanding of the scope of the system and the approach to use when developing it.

5.4. Developing the Information System

According to Bentley & Whitten (2007), the development of an IS, once a requirements analysis has been completed, consists of three main steps to be carried out:

1. *Logical or conceptual design*, where the user requirements are further developed into a proposed system model using data modelling.
2. *Decision analysis*, where decisions pertaining to the automation of the system, the software to use for the system and the information technology required for the system are made.
3. *Physical design, construction and integration*, where the actual IS is built based on the use-case diagram and the conceptual system design, and then implemented.

The first two steps will be reviewed further in Section 5.4.1 and 5.4.2.

5.4.1. Logical Design

The logical design of an IS, and more specifically a database, is developed using data modelling, as the layout of the database would ultimately be determined by the data that it is capturing, storing and analysing.

The actual model used to develop a high-level logical design for the database is called an entity relationship model which is depicted graphically using an entity relationship diagram (ERD). An ERD is a data model that depicts data in terms of entities and the relationships that exist between the entities (Bentley & Whitten, 2007). It shows how the data will be organised in the final database, without specifying the actual data or any finer details (Riccardi, 2003).

The concept of an ERD was first developed by Peter Chen in 1976 and since then slight changes and improvements have been added to the basic design by numerous authors (SmartDraw, 2012). Although many notations for drawing up ERDs exist, most of them generally use the same concepts and constructs. A basic ERD consists of three building blocks, namely entities, attributes and relationships.

- An *entity* is a class of objects, persons, places or concepts that have data relating to them which needs to be captured and stored (Bentley & Whitten, 2007). They are depicted in the ERD as a rectangle.
- An *attribute* (also called a property or field) is a descriptive characteristic of an entity. Each attribute describes a piece of data about the entity that needs to be stored (Bentley & Whitten, 2007). Attributes are simply listed underneath the name of the entity to which they relate.
- *Relationships* show the associations between entities and are represented using rules of cardinality. Cardinality in turn describes the maximum and minimum number of times that one entity may be related to a single occurrence of another entity (Bentley & Whitten, 2007) and the basic cardinality rules that may be used in an ERD drawn in an Information Engineering format are shown in Figure 16 (SmartDraw, 2012).

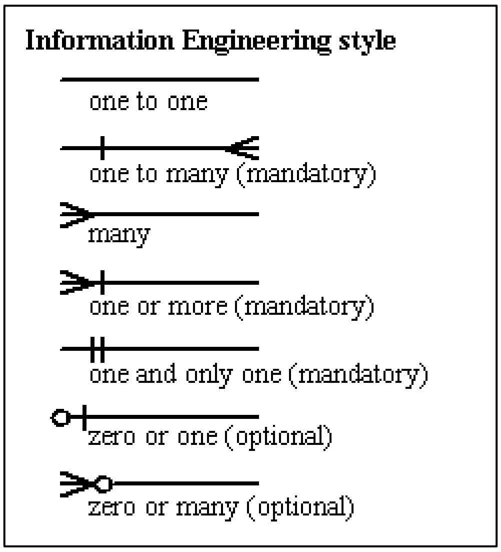


Figure 16: Cardinality rules for ERDs (SmartDraw, 2012)

Selection of Techniques

An ERD will be drawn up for the IS that is being developed for XYZ Mining. This diagram will serve as a conceptual model of the database section of the IS being developed. An ERD will not be drawn up for the analysis section of the IS because this section of the model does not store data as much as analyse the data that is already stored in the database. The analysis section of the IS will be developed following the broad outline provided in Figure 14.

5.4.2. Decision Analysis

Software and automation of IS

Strategic sourcing software supports the process used to gather data that is needed to make smart and informed purchasing decisions (Software Advice Inc., 2012). SS software is developed by many companies and usually includes a spend analysis, TCO analysis and supplier management system in the package among other features. These software solutions are also completely automated and draw all relevant data needed for the analyses from the respective information systems or ERP systems installed in the business. While these software packages offer complete solutions for the SS process, they are often specialised and require staff from the developers to implement the system in the organisation. The software may also require trained staff members to operate it which means that it will incur high installation and operational costs, and may take long to implement fully.

Selection of techniques

Due to the limited budget and time frame associated with the project, an alternative solution that may be easily implemented in the business was needed. Based on the nature of the IS; and the software that XYZ Mining already has installed on their premises, it was decided that Microsoft Excel and Microsoft Access would be the most suitable software packages to use for the development of the IS. More specifically, MS Access would be suitable for the development of the database and MS Excel would be suitable for the development of the analysis section.

Although both MS Access and MS Excel are already installed at XYZ Mining, the staff members, and most importantly those staff members working at the mines themselves (who will be responsible for gathering the data), are most familiar with MS Excel. Therefore it was decided that MS Excel would be used for both the development of the database and the analysis section of the IS. MS Excel has features that may be used to build both the database and the analyses that are required so that they are easy to use and intuitive to understand. Lastly, the author and supervisors of the project are familiar with MS Excel which will make the development of the IS a much more efficient process. The IS that is developed will not be automated mainly due to the highly complicated nature of automating the extraction of data and the limited time frame associated with the project.

5.5. Developing a User Manual

The development of a user manual involves the following six main steps according to Deepa (2007) and Miller (1987):

- *Planning*, including gaining a better understanding of the audience and gathering information;
- *Style sheet creation*, which includes decisions about the formatting and typography of the document;
- *Development*, the actual creation of the user manual;
- *Review* by all relevant stakeholders;
- *Version Management*; and
- *Delivery.*

These steps will be followed when developing the user manual for XYZX Mining. Deepa (2007) also suggests a generic user manual structure which may be edited for different applications. The complete suggested structure is shown in Appendix E, and this structure was used as a basis for the final development of the user manual.

6. Development of the Information System

The development of the IS for XYZ Mining will be carried out following the steps presented in Figure 4 (page 10). For simplicity and continuity's sake, the layout of Section 6 will follow the structure of the diagram as well.

6.1. Requirements Gathering and Analysis

6.1.1. Understanding User Requirements

Gathering and understanding each of the requirements for the IS was the first activity to be completed in the process of developing the IS. This activity was completed in Sections 1.3 and 5.2 by carrying out a study of literature that suggests requirements for strategic sourcing information systems, and gathering any extra requirement from XYZ Mining themselves. Thereafter, a literature review of each of the requirements was carried out to help build a full understanding of them and choose techniques to use when fulfilling them.

6.1.2. Translating User Requirements to System Functions

In order to translate each of the user requirements for the IS into system functions, a use-case diagram illustrating each of the system's functions as well as the actor who triggers each of the functions was drawn. This diagram may be seen in Figure 17.

As discussed in Section 3, the IS will be developed in such a way that it is split into a database section and an analysis section. The system functions in the use-case diagram have also been split according to this division as the functionalities of the two sections vary widely:

- The functions of the database revolve mainly around adding new data and editing existing data (referred to as 'maintaining' the data in Figure 17) that relates to lubricants, equipment, spend, performance and TCO cost elements.
- The functions of the analysis section however are focused on drawing up the actual analyses required, identifying KPDs and evaluating potential improvement projects.

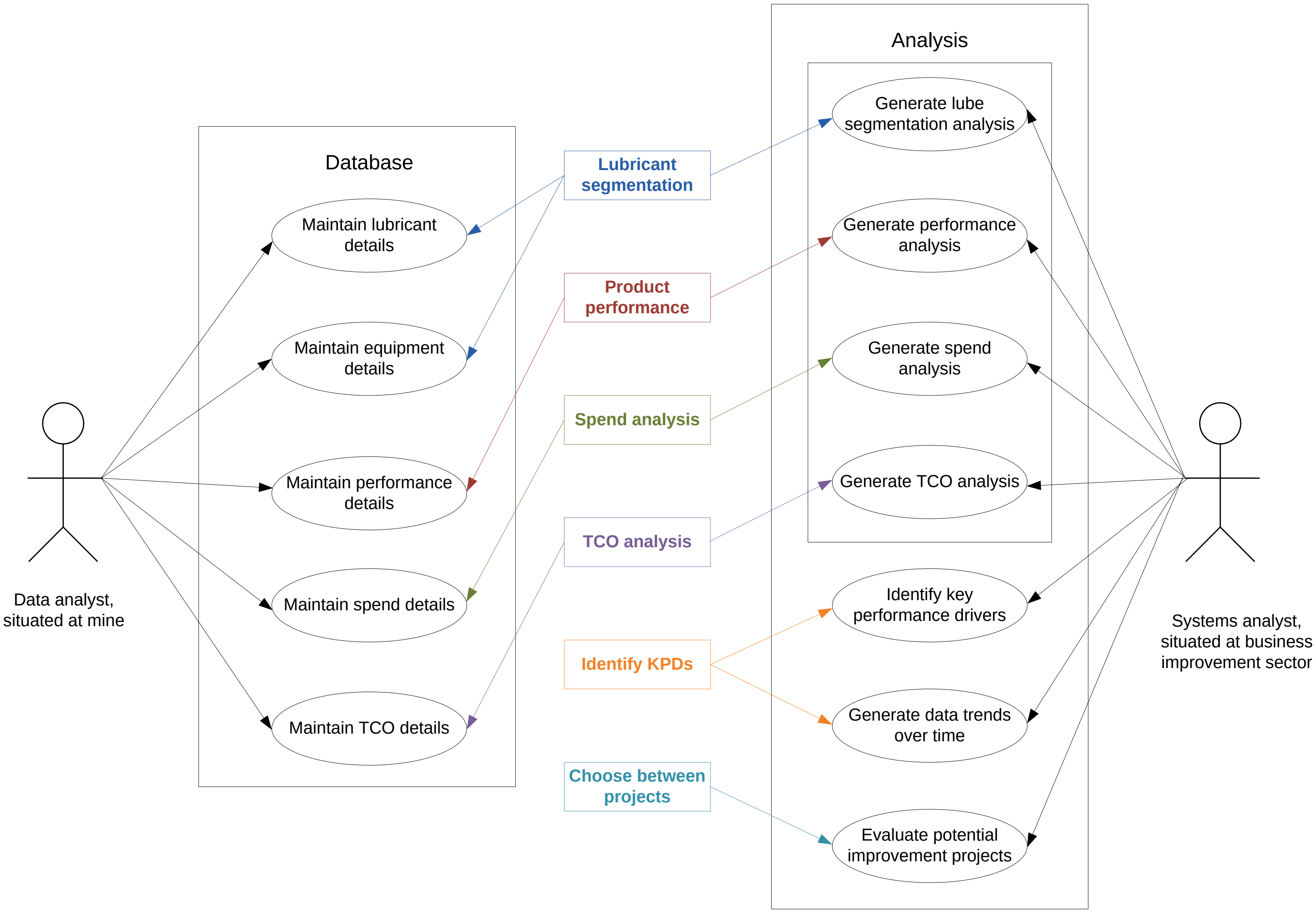


Figure 17: Use-case diagram

To illustrate how each of the user requirements has been met by one or more system functions, each of the requirements has been listed and coloured arrows used to indicate which system functions fulfil the requirement. In addition to this, four of the analyses that form part of the analysis section have been loosely grouped together to illustrate that they will all be carried out within one larger analysis as described in Section 5.2.10.

6.2. System Design and Construction

6.2.1. Data Gathering

In order to begin the development of the IS, some basic data needed to be gathered to gain a better understanding of the extent of the IS. The data gathered was used to provide guidelines about how many pieces of equipment to make provision for in the model, how many lubricants to make provision for and how much space to allow for the addition of data. This basic data, as well as fictitious figures, were used to build the basic IS that was used in the review step of the development. This data was intended mainly for demonstration purposes and to illustrate the concept behind the IS rather than actual results, so the accuracy of the data was not of absolute importance.

6.2.2. Design and Construction of IS

The design and construction of the IS started with the construction of an entity relationship diagram that would serve as a conceptual model for the database section of the IS. Figure 14, the outline for the analysis section of the IS, will serve as the conceptual model for that portion.

Entity Relationship Diagram

An ERD shows all of the data that needs to be gathered and stored in the database and may thus be explained according to the nature of the data that is collected.

All of the data in the database is collected solely for the purpose of being used in the analyses that will be drawn up in the analysis portion of the IS. The data will thus relate to the cost items which are included in the TCO analysis, as explained in Section 5.2.4. Some of this data may only be measured on a per-mine basis (e.g. the cost of the labour used to change lubricants is measured per mine) while other data may be measured on a per-lubricant basis (e.g. the price of the lubricant) or even a per-equipment basis (e.g. the consumption per machine.)

Each of these measurement bases (mines, lubricants, equipment etc.) will be defined as a separate entity in the ERD. Understanding that data is collected according to the entity that it is measured by will help the reader in understanding the relationships between the entities shown in the ERD in Figure 18.

After completing the conceptual designs for both the database and the analysis sections of the IS, the construction of the IS could begin. For ease of explanation, the construction of the IS will be split into four main sections that will be explained separately:

- The construction of the database using the design from the ERD,
- The construction of the larger TCO analysis which contains the lubricant segmentation, performance analysis and spend analysis within it,
- The construction of the portion of the analysis section that identifies KPD's, and
- The construction of the portion of the analysis that evaluates potential improvement projects.

6.2.2.1 Construction of Database Portion of IS

The database portion of the information system was constructed based on the ERD shown in Figure 18.

Lubricant and Lubricant per Year data

An important distinction should be made at this point to improve the understanding of the IS: that is the difference between traceable and non-traceable lubricants as defined below for the purpose of the project:

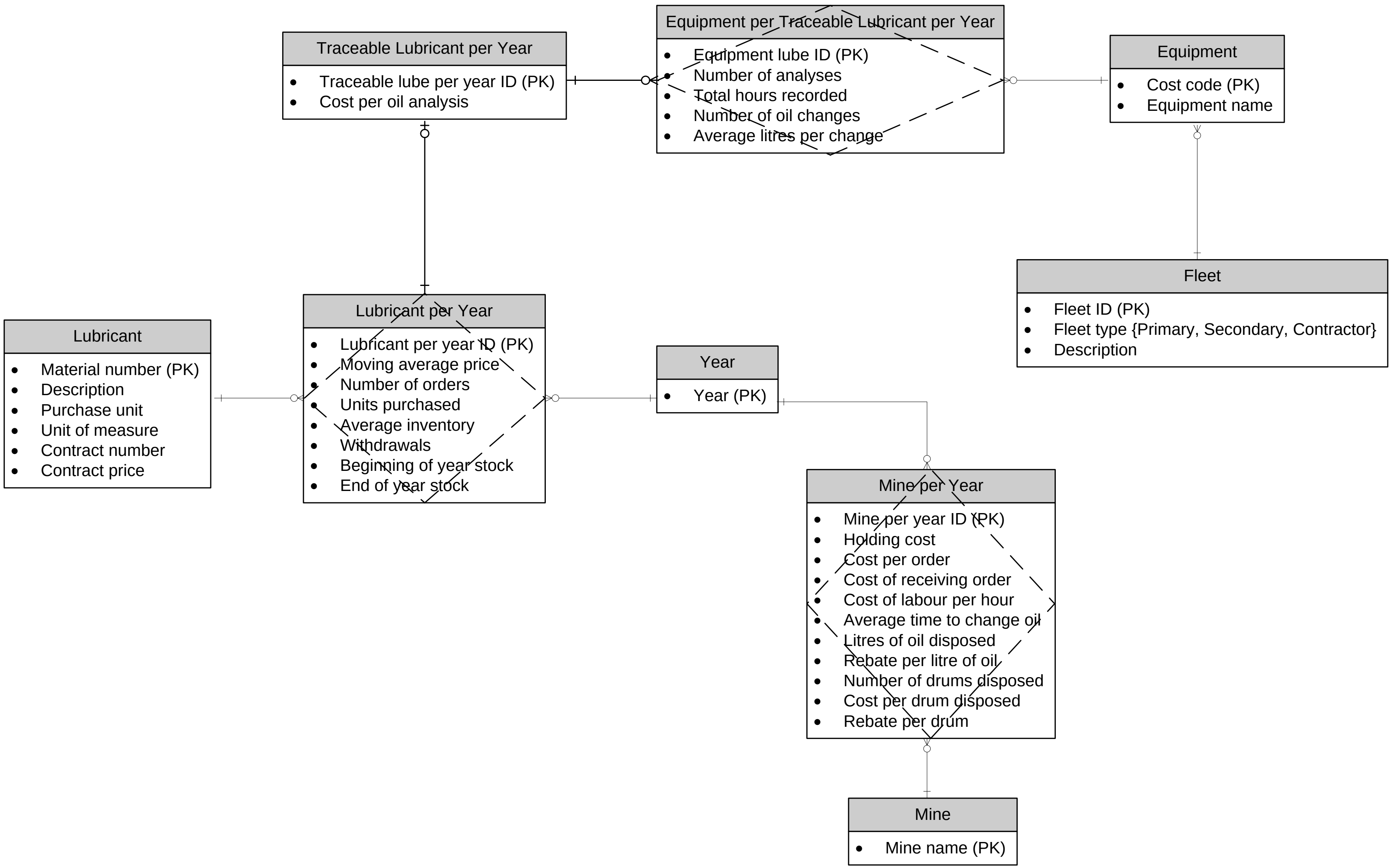


Figure 18: Entity relationship diagram

- A *traceable lubricant* is one whose consumption may be traced down to a per-equipment level easily and conveniently. For example when engine oil is refilled one can measure exactly how much oil is being refilled (because it is generally a large quantity of oil) and which equipment it is being refilled in.
- A *non-traceable lubricant* is one whose consumption may not be traced down to a per-equipment level easily or conveniently. For example a bearing may be lubricated using only a few millilitres of oil, and any piece of equipment may have many identical bearings which make it very difficult to trace the exact consumption of the oil.

For each traceable and non-traceable lubricant, basic information such as the material number, a description of the lubricant, the units that it is purchased and measured in, as well as any information about contracts that have been set up for the purchasing of the lubricant, is recorded. In order to make the database more robust, provision for the addition of extra lubricants that are not currently purchased has also been made and a total of 20 traceable and 24 non-traceable lubricants may be measured for each mine.

The database has been developed to be used for the years 2011 to 2017, and for each year in the system, the moving average price, the number of orders, the number of units that were purchased, the average inventory, the withdrawals, and beginning and end of year stock have to be recorded for each traceable and non-traceable lubricant. In addition to this, the number of oil analyses that were carried out on traceable lubricants for the year should also be recorded. To make the gathering of information a more intuitive process, each category of data that needs to be gathered has been linked to the specific departments who would be responsible for recording it.

The layout of the lubricant section of the database as it was developed with fictitious figures is shown in Figure 19, while Figure 20 shows a zoomed-in view of the basic data that is collected for each lubricant and Figure 21 shows a zoomed-in view of the data that must be collected each year for each lubricant. The areas of the database highlighted in green should only be changed or filled in if a new lubricant is purchased or there is change to the current data about a lubricant. The areas highlighted in yellow however should be filled in at the end of each year and the layout shown in Figure 21 is repeated for the years 2011 to 2017.

Fleet, Equipment and Equipment per Traceable Lubricant per Year data

A tab for each fleet of equipment has been added to the main database to make navigation through the database easier. Each tab makes provision for the addition of data about the equipment included in the fleet, as well as information about the equipment itself, including its cost code and equipment name. In order to make the database robust, provision has been made for the addition of new equipment within the fleet (e.g. provision has been made for each mine to have a maximum of 56 dump trucks); and the basic layout of each tab may be seen in Figure 22.

Each tab makes provision for data to be added about which traceable lubricants are used in each piece of equipment. To make the database more robust, provision has been made for every traceable lubricant to be used in every piece of equipment. If a traceable lubricant is actually used in the piece of equipment, the compartment where it is used should be added to differentiate it from lubricants that are not used. Also, if a traceable lubricant is used, the following data should be recorded for it each year (provision made for 2011 to 2017):

- The number of oil analyses that were carried out on the lubricant during the year;
- How much oil was added each time the oil was changed, and
- The amount of time that passed between oil changes.

Provision has been made for the oil in equipment to be changed at most 52 times in a year (i.e. once a week) and the data relating to each change is gathered as shown in Figure 23. The section of the database shown in this figure is hidden from view in Figure 22 for ease of navigation but it may be expanded to fill out.

Once the data listed above has been gathered; the number of oil changes, the number of working hours recorded and the average number of litres added per oil change are calculated for each lubricant for the year. Once again, the areas highlighted in yellow in the database should be filled in at the end of each year and the data for the areas highlighted in blue will be automatically calculated.

Traceable Lubricants						2011							
						Purchasing Department			Stores Department		Maintenance Department		
Material Number	Description	Purchase Unit	Unit of Measure	Contract	Contract price	Moving Avg Price	No.of Orders	Units Purchased	Avg Inventory	Withdrawals	BOY Stock	EOY Stock	Cost per Oil Analysis
1700001	Traceable Lubricant 1	210 Litre drum	Litre			10.00	10	2300	625	2100	11	24	320
1700004	Traceable Lubricant 2	210 Litre drum	Litre			11.00	23	30000	325	28000	10	15	320
2548052	Traceable Lubricant 3	210 Litre drum	Litre			12.00	40	3500	850	3000	90	67	120
20433094	Traceable Lubricant 4	Litre	Litre			10.00	25	4200	759	4000	34	20	450
25480015	Traceable Lubricant 5	180kg drum	Kg			11.00	13	1500	450	1400	56	21	70
25480084	Traceable Lubricant 6	Litre	Litre			12.00	2	2000	678	1900	43	22	600
25480327	Traceable Lubricant 7	Litre	Litre			3.00	34	4500	453	4300	21	23	300
25480406	Traceable Lubricant 8	Litre	Litre			3.00	21	3578	654	2500	20	21	150
25486356	Traceable Lubricant 9	Litre	Litre			5.00	22	3490	345	3500	12	11	220
100000009	Traceable Lubricant 10	210 Litre drum	Litre	608547	5.50	6.00	3	2300	657	2000	34	43	220
100000013	Traceable Lubricant 11	20 Litre drum	Litre	608547	8.90	9.00	13	3400	890	3000	12	23	220
100000021	Traceable Lubricant 12	20 Litre drum	Litre	608547	8.85	9.00	14	1700	786	1200	12	10	320
	Extra Traceable Lubricant 1												
	Extra Traceable Lubricant 2												
	Extra Traceable Lubricant 3												
	Extra Traceable Lubricant 4												
	Extra Traceable Lubricant 5												
	Extra Traceable Lubricant 6												
	Extra Traceable Lubricant 7												
	Extra Traceable Lubricant 8												

Non-Traceable Lubricants						2011							
						Purchasing Department			Stores Department		Maintenance Department		
Material Number	Description	Purchase Unit	Unit of Measure	Contract	Contract price	Moving Avg Price	No.of Orders	Units Purchased	Avg Inventory	Withdrawals	BOY Stock	EOY Stock	Cost per Oil Analysis
1800030	Non-Traceable Lubricant 1	500ml bottle	Each			24.00	12	84	15	78	1	1	
1800093	Non-Traceable Lubricant 2		Each			12.00	8	24	2	20	1	1	
25480023	Non-Traceable Lubricant 3	210 Litre drum	Litre			14.00	16						
100000016	Non-Traceable Lubricant 4	210 Litre drum	Litre	608547	11.67	12.00	5						
100009034	Non-Traceable Lubricant 5	15kg pail	Each			17.00	4						
100009083	Non-Traceable Lubricant 6	20 Litre drum	Each			32.00	4						
100012454	Non-Traceable Lubricant 7		Each			12.00	12						
100012455	Non-Traceable Lubricant 8		Each			23.00	11						
100012456	Non-Traceable Lubricant 9		Each			14.00	7						
100012459	Non-Traceable Lubricant 10	12mm	Each			22.00	4						
100020528	Non-Traceable Lubricant 11		Litre			21.00	2						

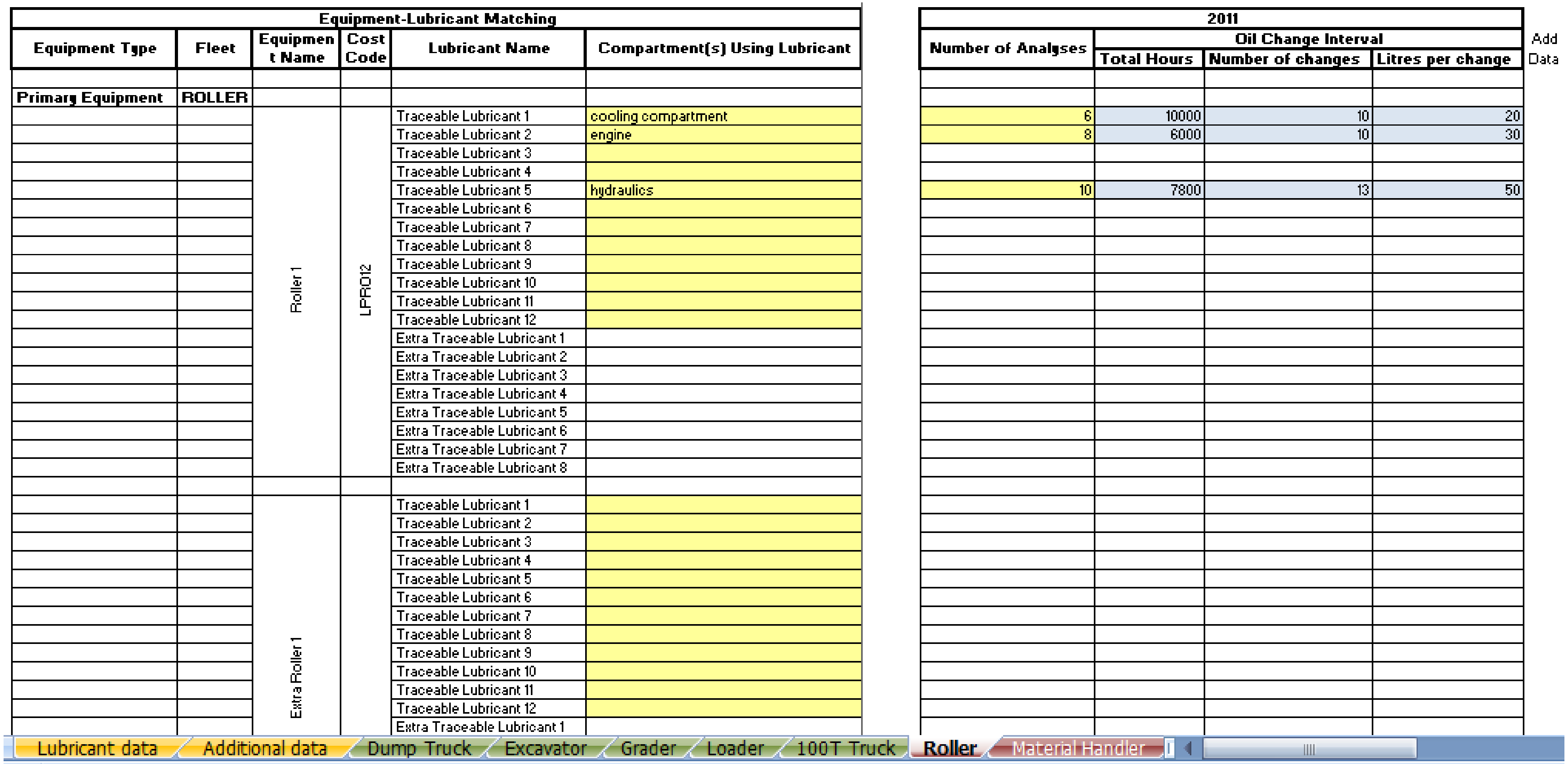
Figure 19: Lubricant section of database, layout

Traceable Lubricants					
Material Number	Description	Purchase Unit	Unit of Measure	Contract	Contract price
1700001	Traceable Lubricant 1	210 Litre drum	Litre		
1700004	Traceable Lubricant 2	210 Litre drum	Litre		
2548052	Traceable Lubricant 3	210 Litre drum	Litre		
20433094	Traceable Lubricant 4	Litre	Litre		
25480015	Traceable Lubricant 5	180kg drum	Kg		
25480084	Traceable Lubricant 6	Litre	Litre		
25480327	Traceable Lubricant 7	Litre	Litre		
25480406	Traceable Lubricant 8	Litre	Litre		
25486356	Traceable Lubricant 9	Litre	Litre		
100000009	Traceable Lubricant 10	210 Litre drum	Litre	608547	5.50
100000013	Traceable Lubricant 11	20 Litre drum	Litre	608547	8.90
100000021	Traceable Lubricant 12	20 Litre drum	Litre	608547	8.85
	Extra Traceable Lubricant 1				
	Extra Traceable Lubricant 2				
	Extra Traceable Lubricant 3				
	Extra Traceable Lubricant 4				
	Extra Traceable Lubricant 5				
	Extra Traceable Lubricant 6				
	Extra Traceable Lubricant 7				
	Extra Traceable Lubricant 8				

Figure 20: Lubricant data

2011							
Purchasing Department			Stores Department		Maintenance Department		
Moving Avg Price	No.of Orders	Units Purchased	Avg Inventory	Withdrawals	BOY Stock	EOY Stock	Cost per Oil Analysis
10.00	10	2300	625	2100	11	24	320
11.00	23	30000	325	28000	10	15	320
12.00	40	3500	850	3000	90	67	120
10.00	25	4200	759	4000	34	20	450
11.00	13	1500	450	1400	56	21	70
12.00	2	2000	678	1900	43	22	600
3.00	34	4500	453	4300	21	23	300
3.00	21	3578	654	2500	20	21	150
5.00	22	3490	345	3500	12	11	220
6.00	3	2300	657	2000	34	43	220
9.00	13	3400	890	3000	12	23	220
9.00	14	1700	786	1200	12	10	320

Figure 21: Lubricant per year data



Equipment-Lubricant Matching						2011			
							Oil Change Interval		
Equipment Type	Fleet	Equipment Name	Cost Code	Lubricant Name	Compartment(s) Using Lubricant	Number of Analyses	Total Hours	Number of changes	Litres per change
Primary Equipment	ROLLER								
		Roller 1	LPRO12	Traceable Lubricant 1	cooling compartment	6	10000	10	20
				Traceable Lubricant 2	engine	8	6000	10	30
				Traceable Lubricant 3					
				Traceable Lubricant 4					
				Traceable Lubricant 5	hydraulics	10	7800	13	50
				Traceable Lubricant 6					
				Traceable Lubricant 7					
				Traceable Lubricant 8					
				Traceable Lubricant 9					
				Traceable Lubricant 10					
				Traceable Lubricant 11					
				Traceable Lubricant 12					
				Extra Traceable Lubricant 1					
				Extra Traceable Lubricant 2					
				Extra Traceable Lubricant 3					
				Extra Traceable Lubricant 4					
				Extra Traceable Lubricant 5					
				Extra Traceable Lubricant 6					
				Extra Traceable Lubricant 7					
				Extra Traceable Lubricant 8					
		Extra Roller 1		Traceable Lubricant 1					
				Traceable Lubricant 2					
				Traceable Lubricant 3					
				Traceable Lubricant 4					
				Traceable Lubricant 5					
				Traceable Lubricant 6					
				Traceable Lubricant 7					
				Traceable Lubricant 8					
				Traceable Lubricant 9					
				Traceable Lubricant 10					
				Traceable Lubricant 11					
				Traceable Lubricant 12					
				Extra Traceable Lubricant 1					

Figure 22: Equipment section of database, layout

Equipment-Lubricant Matching						Oil Change Interval											
Equipment Type	Fleet	Equipment Name	Cost Code	Lubricant Name	Compartment(s) Using Lubricant	1		2		3		4		5		6	
						Litres	Hours	Litres	Hours	Litres	Hours	Litres	Hours	Litres	Hours	Litres	Hours
Primary Equipment	DUMP TRUCK																
		DT50 CAT Dump Truck	LPDT50	Traceable Lubricant 1	Cooling System	30	3000	30	3000	30	3000	30	3000	30	3000	30	3000
				Traceable Lubricant 2	Hydraulics	500	500	500	500	500	500	500	500	500	500	500	500
				Traceable Lubricant 3													
				Traceable Lubricant 4	Engine	30	500	30	500	30	500	30	500	30	500	30	500
				Traceable Lubricant 5													
				Traceable Lubricant 6	Final Drives	2	2000	2	2000	2	2000	2	2000	2	2000	2	2000
				Traceable Lubricant 7													
				Traceable Lubricant 8													
				Traceable Lubricant 9													
				Traceable Lubricant 10													
				Traceable Lubricant 11													
				Traceable Lubricant 12	Transmission	20	1000	20	1000	20	1000	20	1000	20	1000	20	1000
				Extra Traceable Lubricant 1													
				Extra Traceable Lubricant 2													
				Extra Traceable Lubricant 3													
				Extra Traceable Lubricant 4													
				Extra Traceable Lubricant 5													
				Extra Traceable Lubricant 6													
				Extra Traceable Lubricant 7													
				Extra Traceable Lubricant 8													

Figure 23: Equipment per traceable lubricant per year data

Mine and Mine per Year data

As discussed in Section 6.2.2, some of the data that needs to be gathered and stored in the database may only be gathered on a per-mine basis. This data includes the standard holding cost, the cost of placing an order, the cost of receiving an order, the cost of labour per hour, the average time taken to change a lubricant, the litres of oil disposed, the rebate per litre of oil, the number of drums disposed, the cost per drum disposed and the rebate earned per drum. Each of these measures may be recorded in a separate tab in the database as shown in

Figure 24, and provision has been made for data to be added at the end of each year from 2011 to 2017. As with the lubricant per year data, the data has been sorted according to the department responsible for recording the data to make the data gathering process easier.

2011	
Stores Department	
Holding Cost per Unit	0.1
Supply Chain Department	
Cost per Order by Purchasing Department	169
Cost of Receiving Order	243
Maintenance Department	
Cost of Labour per Hour	25
Average Time to Change Oil	0.5
Disposal Costs	
Litres of Oil Disposed	8000
Rebate per Litre of Oil	0.5
Number of Drums Disposed	400
Cost per Drum Disposed	12
Rebate per Drum	8

Figure 24: Mine per year data

Data Protection

To protect the database integrity, all of the sheets in the database have been locked with a password that will only be provided to the administrators of the system at XYZ Mining. This protection will prevent users from deleting formulas, making changes to the formatting of the database and adding information to the wrong areas of the database. The addition of error messages to warn users of figures that may be wrong is a feature that will be built into the database at a later stage.

6.2.2.2 Construction of TCO Analysis Portion of IS

The analysis portion of the IS encompasses the larger TCO analysis which will include the spend analysis, lubricant segmentation and product performance analysis within it. The layout of the TCO analysis will follow the outline provided in Figure 14 (page 41) and will also be explained accordingly.

Figure 25, Figure 26 and Figure 27 show a broad view of how the total TCO is calculated for non-traceable lubricants, traceable lubricants and the mine as a whole. The TCO is calculated by adding together each of the cost elements listed in Section 5.2.4. An important observation to make however is the fact that not all of the cost elements are relevant to both traceable and non-traceable lubricants. Most importantly, the changing and monitoring cost elements may be excluded from the TCO of non-traceable lubricants as they are negligible (see Figure 25). Secondly, the disposal cost element may only be measured for the mine as a whole because all of the lubricants are mixed and disposed of together, thus this cost element is ignored for both the traceable and non-traceable lubricant TCO calculations and only included in the total TCO for the mine (see Figure 27).

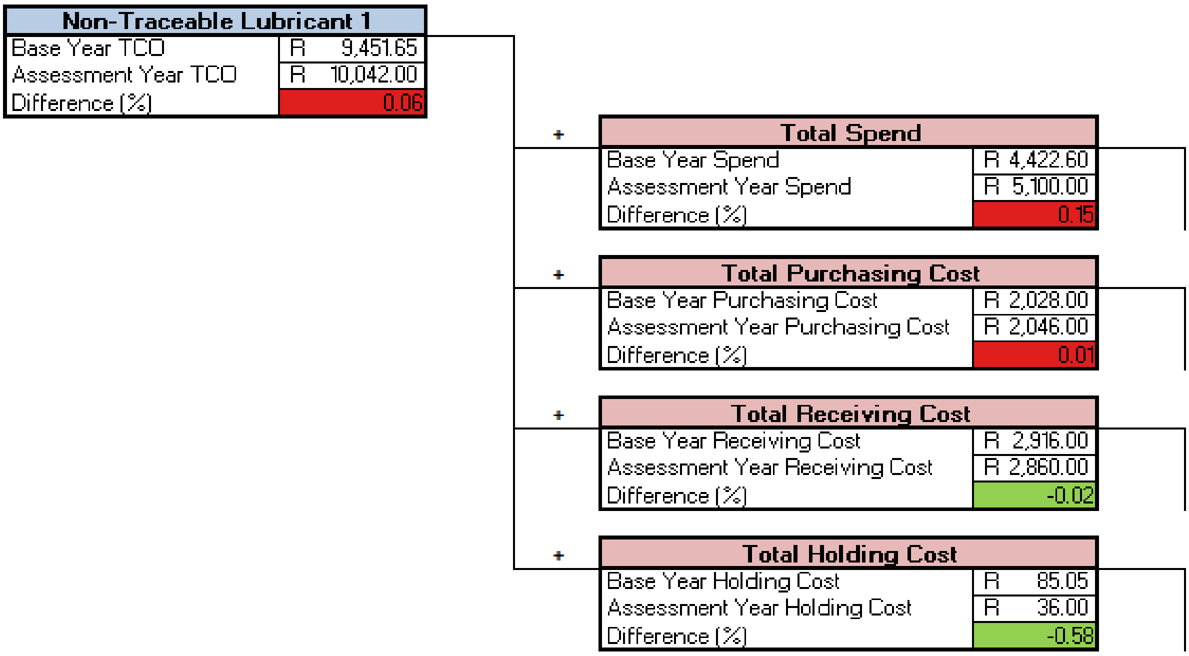


Figure 25: Non-traceable lubricant TCO calculation

Traceable Lubricant 1		
Base Year TCO	R	42,373.10
Assessment Year TCO	R	49,337.00
Difference (%)		0.16

+ Total Spend		
Base Year Spend	R	35,082.47
Assessment Year Spend	R	39,600.00
Difference (%)		0.13

+ Total Purchasing Cost		
Base Year Purchasing Cost	R	1,690.00
Assessment Year Purchasing Cost	R	2,418.00
Difference (%)		0.43

+ Total Receiving Cost		
Base Year Receiving Cost	R	2,430.00
Assessment Year Receiving Cost	R	3,380.00
Difference (%)		0.39

+ Total Holding Cost		
Base Year Holding Cost	R	1,050.63
Assessment Year Holding Cost	R	828.00
Difference (%)		-0.21

+ Total Monitoring Cost		
Base Year Monitoring Cost	R	1,920.00
Assessment Year Monitoring Cost	R	2,880.00
Difference (%)		0.50

+ Total Changing Cost		
Base Year Changing Cost	R	200.00
Assessment Year Changing Cost	R	231.00
Difference (%)		0.16

Figure 26: Traceable lubricant TCO calculation

Mine 1 TCO All Lubricants	
Base Year TCO	R 776,366.83
Assessment Year TCO	R 880,527.20
Difference (%)	0.13

Total Spend All Lubricants	
Base Year Spend	R 610,108.28
Assessment Year Spend	R 722,751.00
Difference (%)	0.18

Total Purchasing Cost All Lubricants	
Base Year Purchasing Cost	R 52,052.00
Assessment Year Purchasing Cost	R 40,734.00
Difference (%)	-0.22

Total Receiving Cost All Lubricants	
Base Year Receiving Cost	R 74,844.00
Assessment Year Receiving Cost	R 56,940.00
Difference (%)	-0.24

Total Holding Cost All Lubricants	
Base Year Holding Cost	R 9,182.55
Assessment Year Holding Cost	R 9,177.20
Difference (%)	0.00

Total Monitoring Cost All Lubricants	
Base Year Monitoring Cost	R 27,930.00
Assessment Year Monitoring Cost	R 48,510.00
Difference (%)	0.74

Total Changing Cost All Lubricants	
Base Year Changing Cost	R 4,650.00
Assessment Year Changing Cost	R 5,115.00
Difference (%)	0.10

Total Disposal Cost All Lubricants	
Base Year Disposal Cost	R -2,400.00
Assessment Year Disposal Cost	R -2,700.00
Difference (%)	0.13

Figure 27: Mine total TCO calculation

Each of the TCO cost elements included in the analyses shown above is calculated as described by Equation 1 to Equation 10 in Section 5.2.4. Examples of the holding, purchasing, receiving and disposal cost calculations as they are calculated in the TCO analyses are provided in Figure 28 to Figure 31.

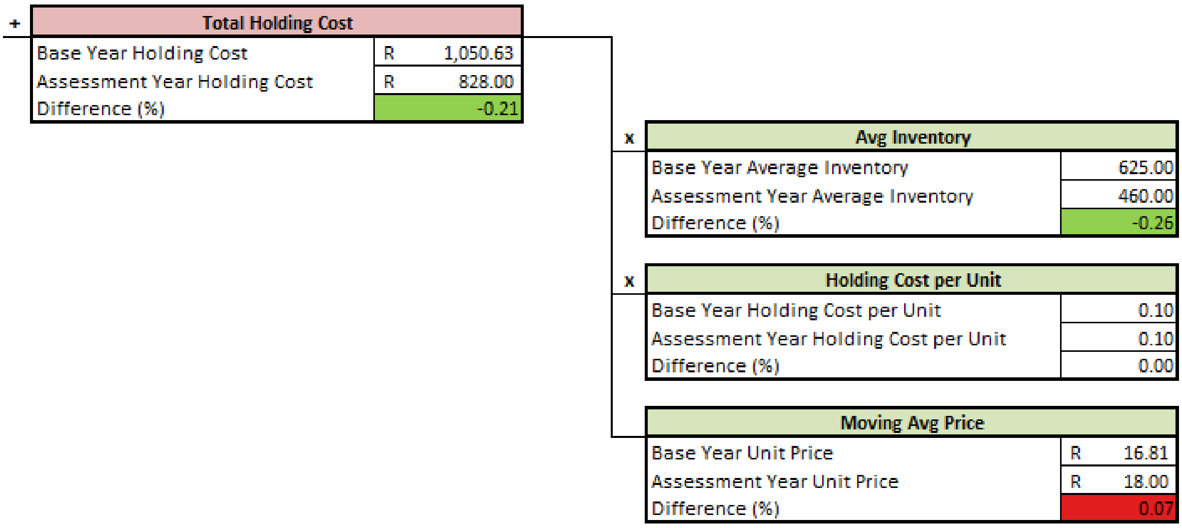


Figure 28: Holding cost calculation example

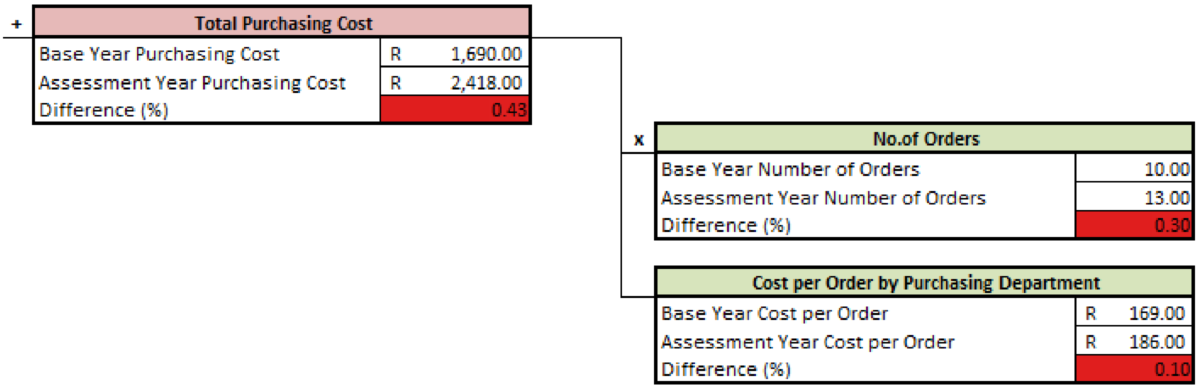


Figure 29: Purchasing cost calculation example

+

Total Receiving Cost		
Base Year Receiving Cost	R	2,430.00
Assessment Year Receiving Cost	R	3,380.00
Difference (%)		0.39

x

No.of Orders	
Base Year Number of Orders	10.00
Assessment Year Number of Orders	13.00
Difference (%)	0.30

Cost of Receiving Order		
Base Year Cost of Receiving Order	R	243.00
Assessment Year Cost of Receiving Order	R	260.00
Difference (%)		0.07

Figure 30: Receiving cost calculation example

While some of the cost elements like the holding, purchasing and receiving costs shown above may only be traced to a per-lubricant level, others cost elements like the spend, changing cost and monitoring cost may be traced all the way down to a per-equipment level for traceable lubricants. For the purpose of the spend cost element this is particularly important because the tracing of spend down to a per-equipment level constitutes a spend analysis.

The lubricant segmentation breakdown as shown in Figure 5 (page 13) was used for the purpose of tracing the changing cost, monitoring cost and spend of each of the traceable lubricants down to a per-equipment level. Examples of the calculation of the changing and monitoring cost elements are shown in Figure 32 and Figure 33, where it can be seen that each of the costs is first broken down according to how it is calculated, then traced per fleet (or type of equipment) and then to the individual piece of equipment.

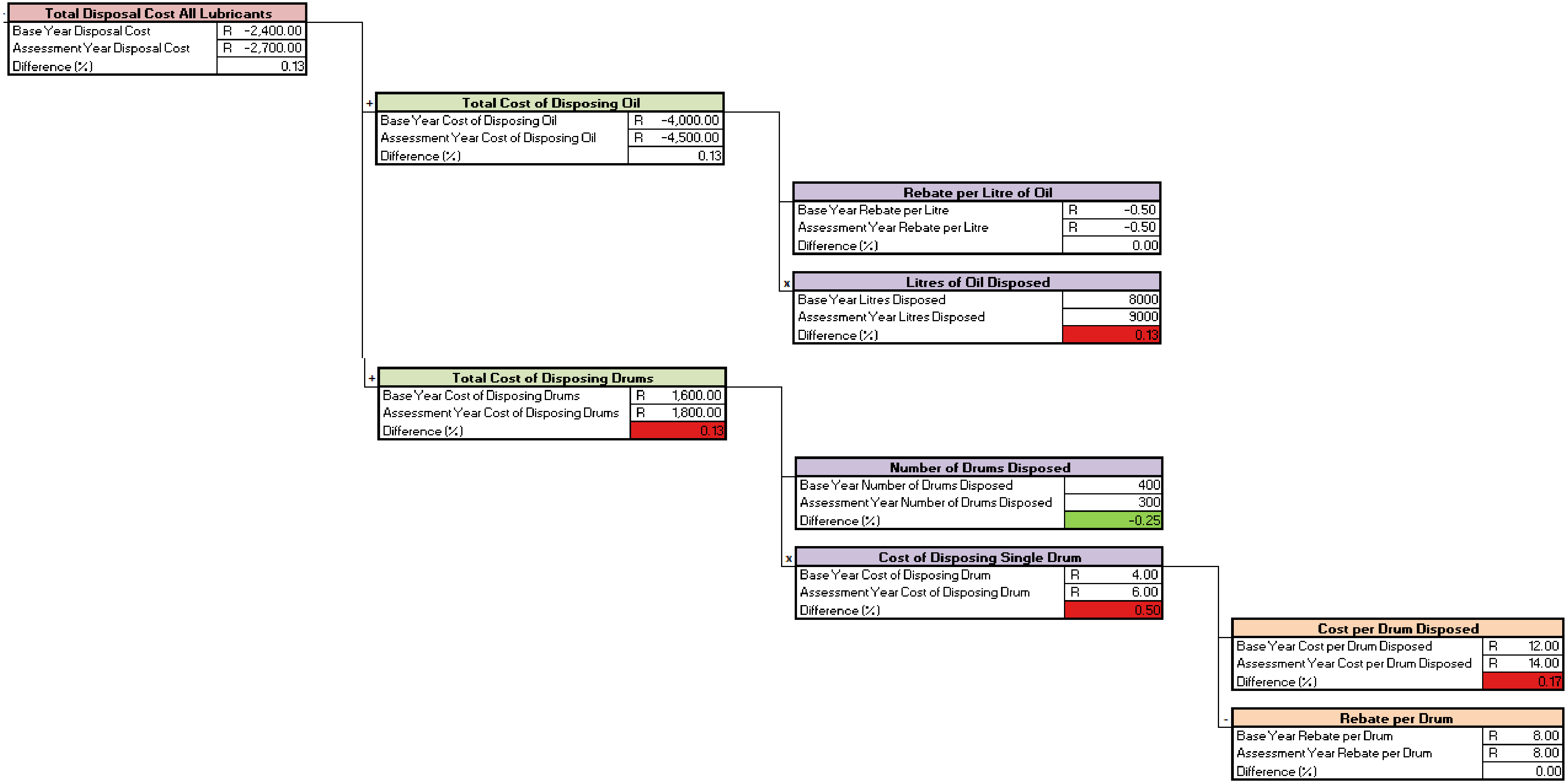


Figure 31: Disposal cost calculation example

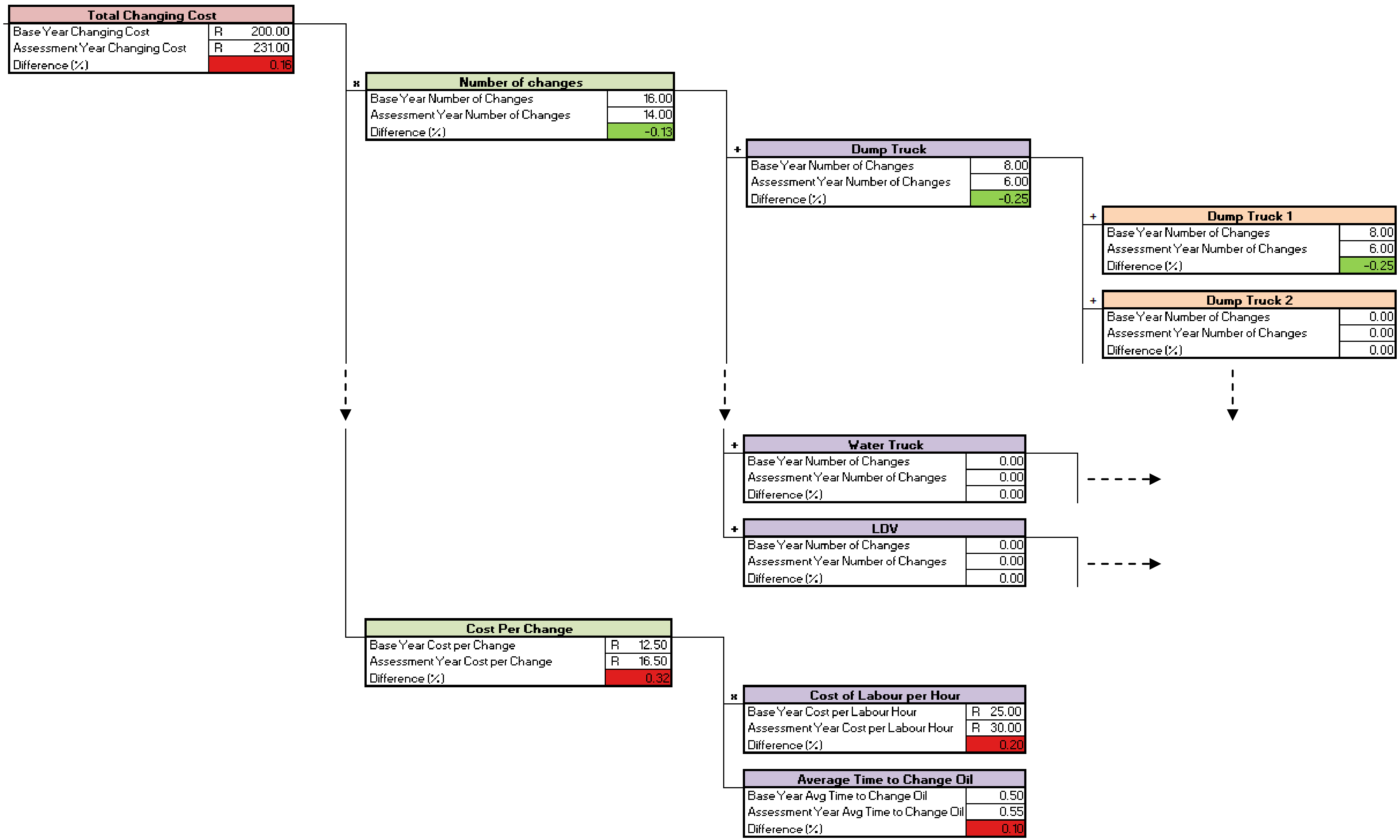


Figure 32: Changing cost calculation example

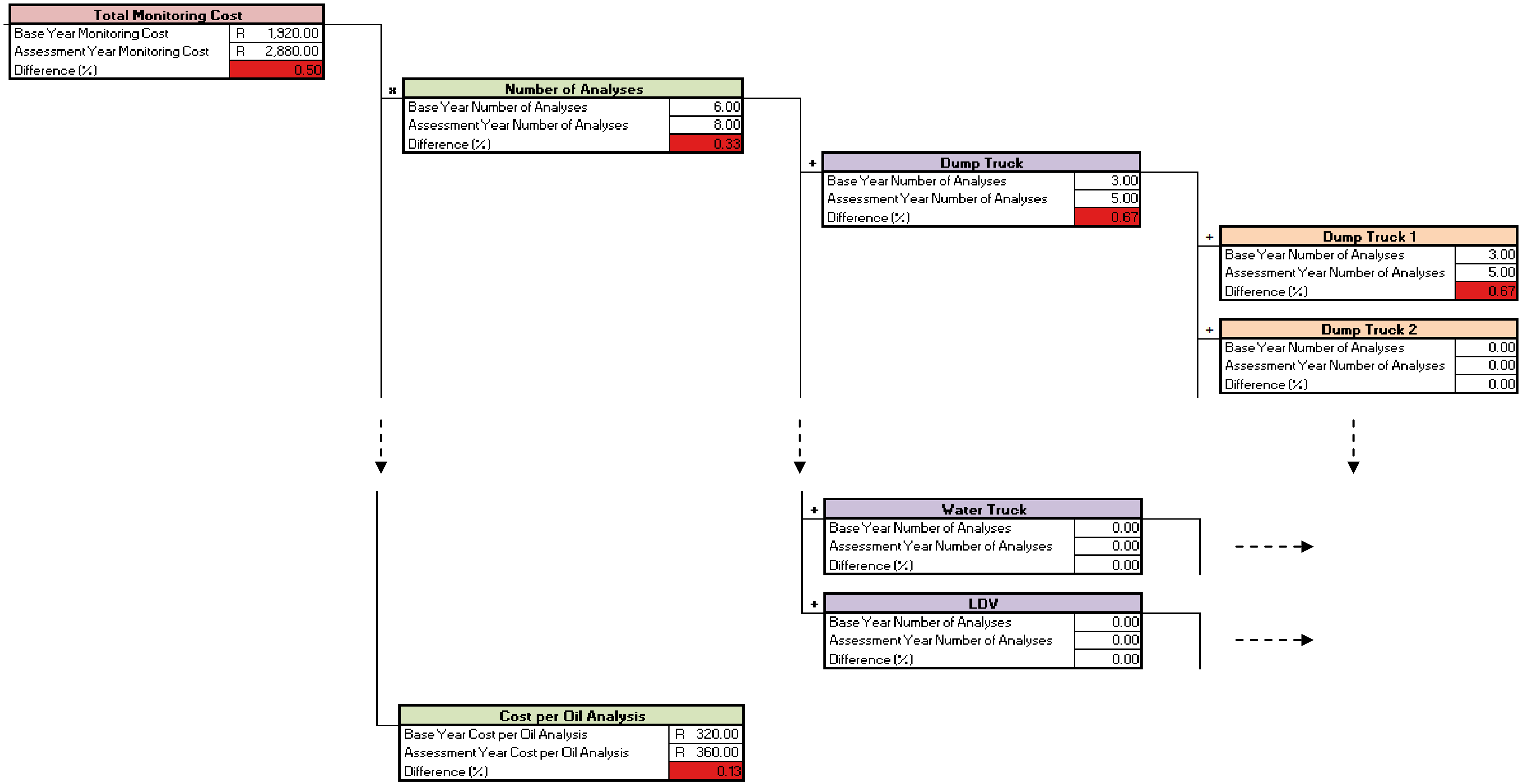


Figure 33: Monitoring cost calculation example

For the purpose of calculating the spend cost element, a similar layout to that for the changing and monitoring cost elements is used with the exception that the consumption per equipment type is broken down one level further to illustrate that the consumption per piece of equipment may be measured by the relationship *Consumption = Number of oil changes* × *Average litres per change*. This relationship is provided primarily because the data in the database is collected in this format. However, the reason for allowing the data to be recorded down to this level lies in the fact that value is added if the nature of the consumption for each equipment type is known. In addition to this, some of XYZ Mining's mines already have systems in place to measure both of these factors on an equipment level so it is in fact easier for the data to be recorded in this way than for just the total consumption per piece of equipment to be recorded. Figure 34 shows how this calculation is performed for each piece of equipment in the spend analysis and Figure 35 shows the calculation of the spend cost element as a whole. (It should be noted that the calculation of the spend cost element as it is shown in Figure 35 is only relevant to traceable lubricants)

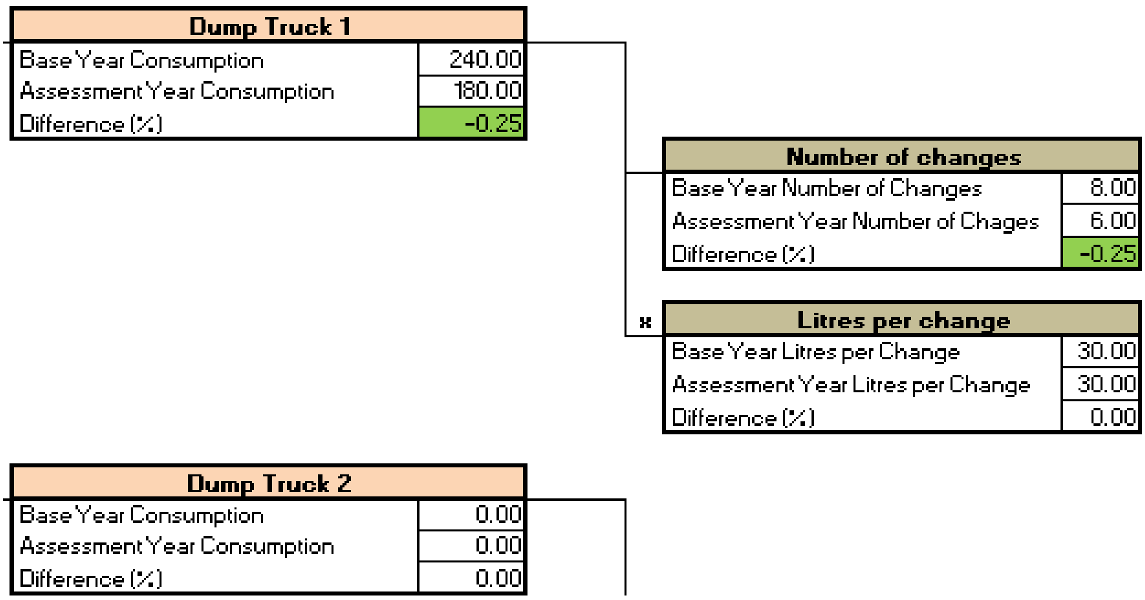


Figure 34: Consumption per equipment calculation example

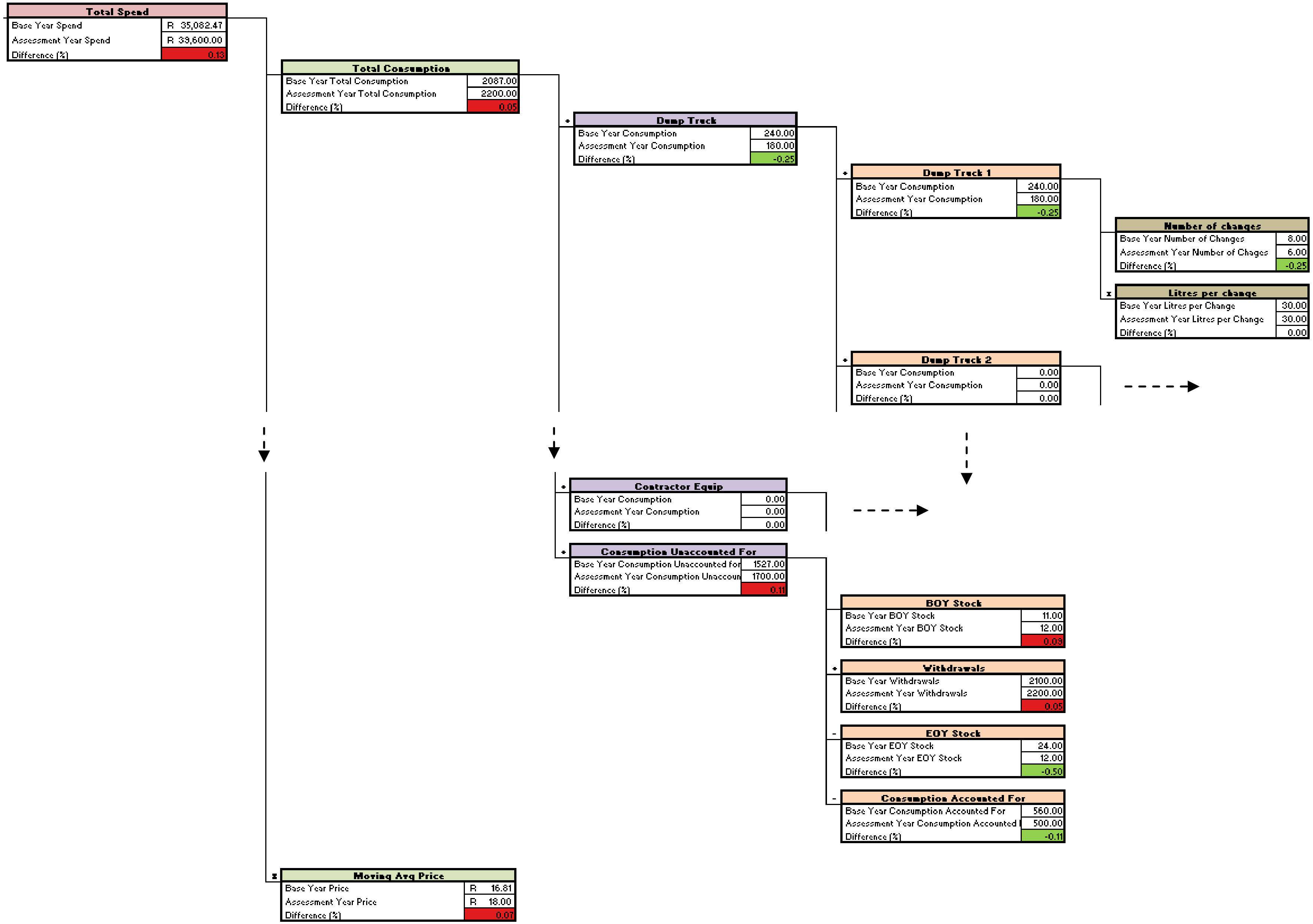


Figure 35: Spend cost element calculation example

Another difference that should be noted in the calculation of the spend cost element is the addition of consumption that is unaccounted for. The reason for this addition is that the consumption of a lubricant may be measured in two ways:

- Either the total consumption for a lubricant may be measured as the sum of the consumption for all individual pieces of equipment used across the whole mine, or
- The consumption may be measured using Equation 15:

$$Consumption = BOY\ Stock + Withdrawals\ from\ inventory - EOY\ Stock$$

Equation 15: Total consumption calculation

Equation 15 is a more accurate way to measure the total consumption of a lubricant because it takes into account losses and spillage, and in the case of non-traceable lubricants it is used to calculate their total consumption. However, because traceable lubricants' consumption must be measured down to a per-equipment level for the purpose of the spend analysis, provision for consumption that is unaccounted for (i.e. spillage) must be made separately. Figure 36 shows how this is done in the analysis by subtracting the consumption accounted for from the total consumption as calculated using Equation 15.

The main navigation menu for the analysis section of the database is shown in Figure 37 as it appears in the IS. The main menu is used to navigate between each of the TCO analyses, the dashboard (or KPD identification portion) and the project prioritisation analysis. In addition to this, the main menu allows users to update the data in the analyses and to choose a base and assessment year that will be used throughout the TCO analyses. The data used in the TCO analysis is gathered directly from the database that was described in Section 6.2.2.1 but it is only updated when the user chooses to do so from the main menu. The main purpose for this is that the amount of data contained in the database would cause delays in the IS if it were to be updated live. The purpose of the addition of the base and assessment year is that it allows the user to trace the impact of improvement projects over time, where the base year would show the status of the variable before a project was implemented and the assessment year would show the new status after the implementation of the project.

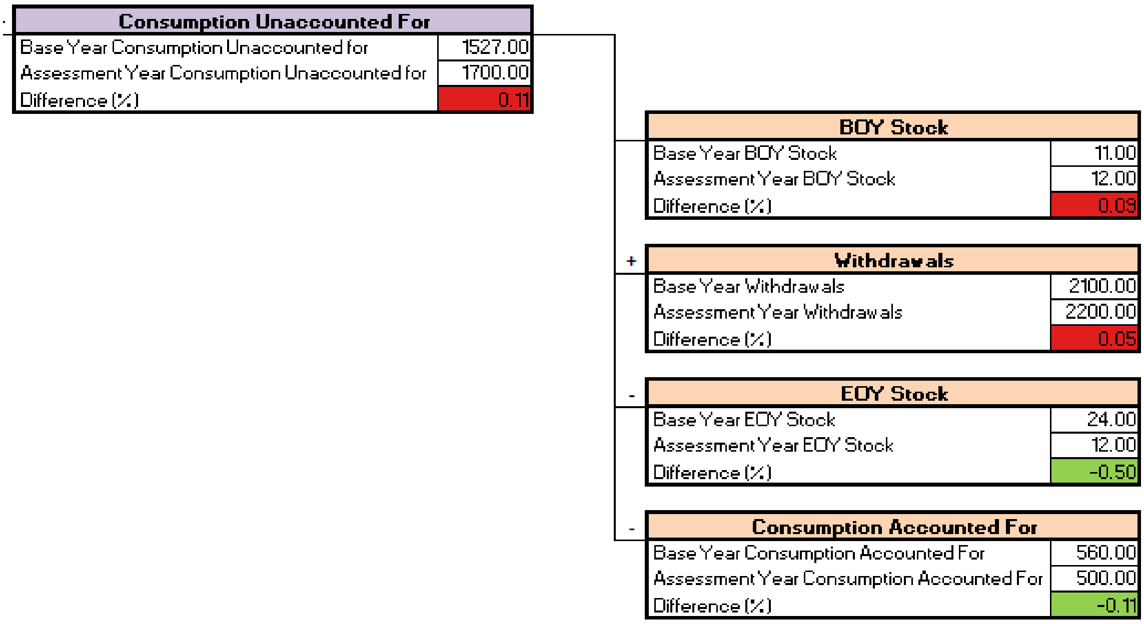


Figure 36: Calculation of consumption unaccounted for

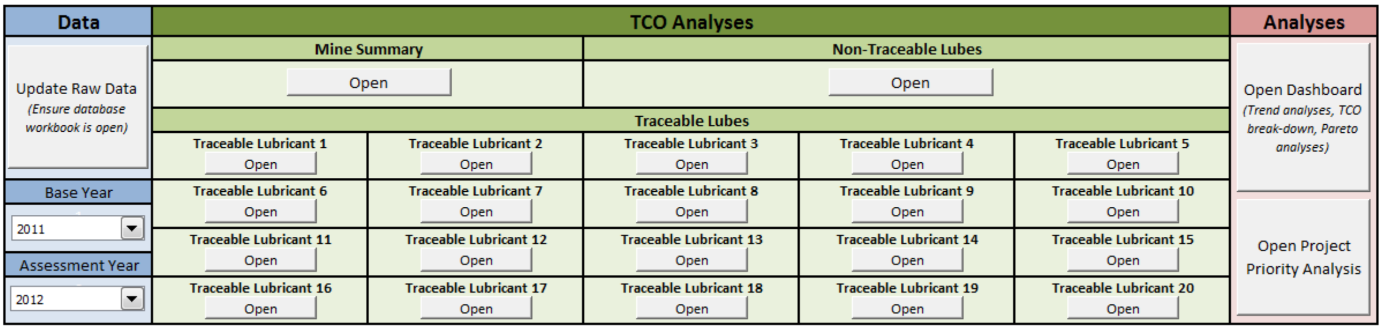


Figure 37: Main menu, analysis section of IS

6.2.2.3 Construction of KPD Identification Portion of IS

The section of the IS that identifies KPDs was expanded to include not only Pareto analyses but also year-on-year trend analyses of performance over time and the graphical TCO analyses as shown in Figure 10 (page 26). The reason for this expansion was to group all of the graphical analyses into a single section of the IS known as the 'dashboard' where the progress and drivers of all variables could be monitored at once.

The dashboard may best be explained by separating it into three main sections whose construction had to be carried out differently:

- The dashboard which shows the status of the mine as a whole,
- A set of dashboards that show the status of each traceable lubricant, and
- A set of dashboards that show the status of each non-traceable lubricant.

The layout for the dashboard section of the IS as a whole is shown in Figure 38 and each of the areas highlighted in a different colour will be zoomed-into for further explanation.

Construction of Dashboard for Mine

The dashboard drawn up for the mine as a whole includes three main sets of analyses as explained below:

- The *trend analysis* is a tool that allows the user to carry out a year-on-year analysis of any of the cost elements included in the TCO for the mine as a whole. With this tool, the user may compare three cost elements at once and they may compare them over the years 2011 to 2017 provided there is data in the system for each of the years. The user may choose which of the cost elements he/she wants to compare, or if he/she wishes to analyse one at a time, they may leave the extra two variables blank. Figure 39 shows an example of how this tool may be used to compare the TCO, spend and purchasing cost elements for a mine over the seven years. Also included, is an illustration of the controls that are used to choose which cost elements will be plotted in the analysis.

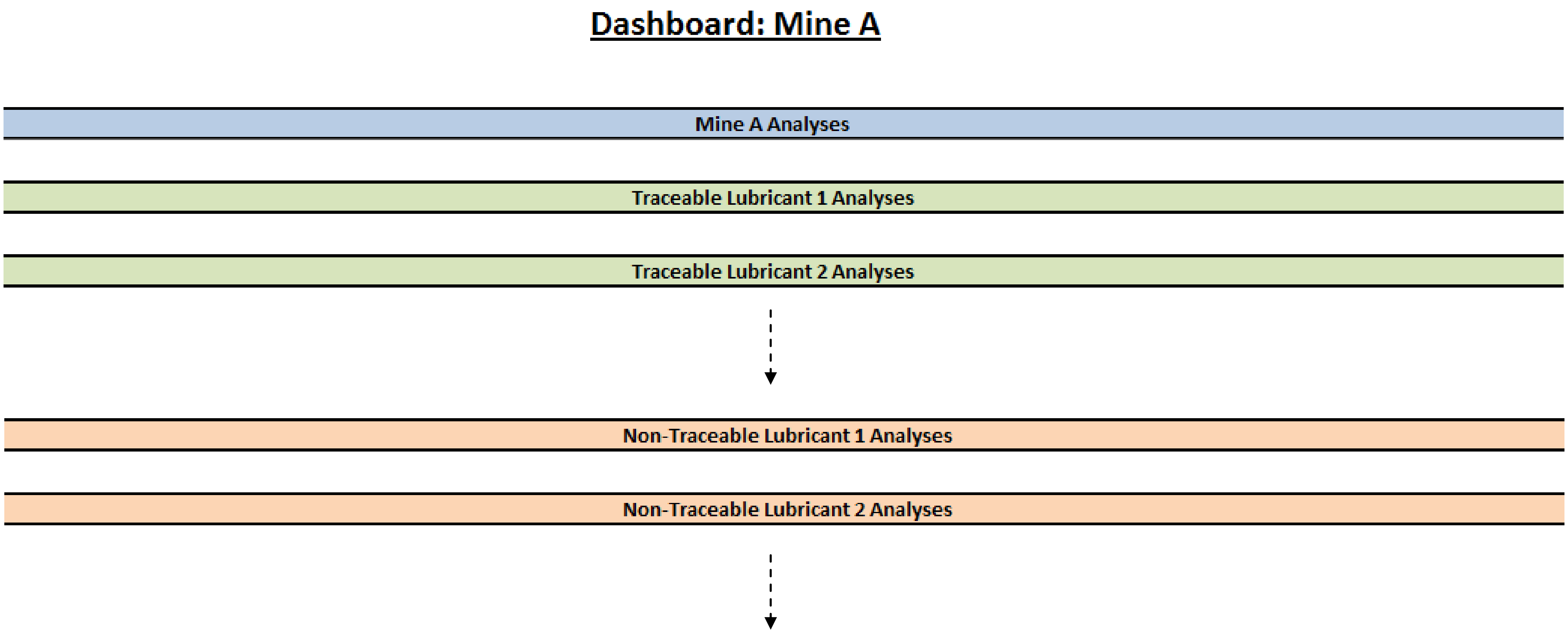


Figure 38: Overall layout of dashboard

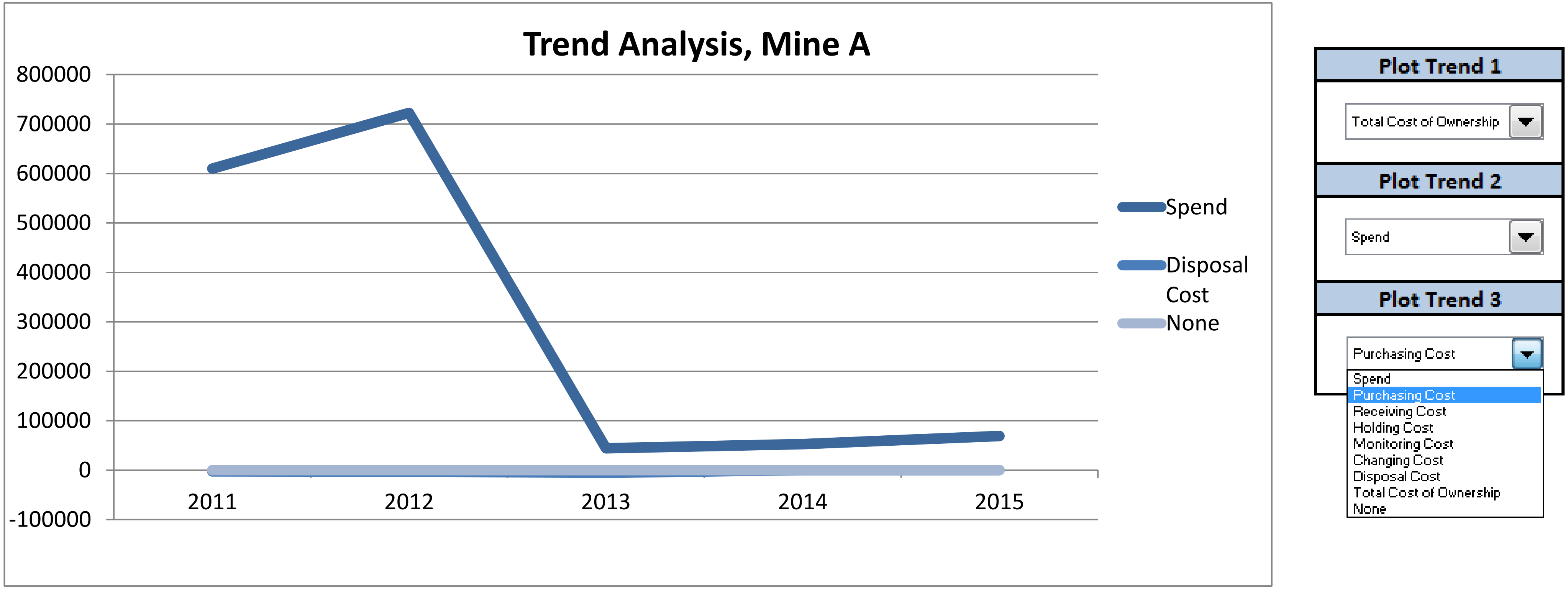


Figure 39: Trend analysis, Mine A

- The *TCO analysis* is a tool that allows the user to see the break-down of the TCO for the mine into each of its cost elements. The analysis plots the TCO cost elements for both the base and the assessment years so that a direct comparison can be made to see whether there have been improvements or declines in each cost element between the years. Figure 40 shows an example of a TCO analysis for a mine as it is constructed in the IS.
- The *Pareto analysis* is a tool that allows the user to identify which lubricants are driving the overall TCO of the mine. Because the behaviour of traceable and non-traceable lubricants differs in terms of the calculation of each one's TCO, the traceable and non-traceable lubricants which drive the TCO of the mine are identified separately. In addition to this, the lubricants driving the base and assessment year TCO's are also shown separately so that changes can be identified between the two years. Figure 41 shows a Pareto analysis which identifies the non-traceable lubricants driving the TCO in the base year. Figure 42 meanwhile shows a Pareto analysis which identifies the traceable lubricants driving the TCO in the assessment year.

Construction of Dashboard for Traceable Lubricants

The dashboard that was constructed for each traceable lubricant has a similar layout to that of the mine as a whole, with a few exceptions:

- The *trend analysis* carries out a year-on-year analysis of any of the cost elements that make up the TCO of the specific traceable lubricant whose dashboard is open. Apart from the fact that the trend analysis only analyses one traceable lubricant at a time, the layout of the analysis is identical to the layout shown in Figure 39.
- The *TCO analysis* shows a break-down of the TCO of the specific lubricant into its cost elements. This means that the disposal cost element will be excluded from the analysis; but apart from this exclusion the layout of the analysis is identical to that shown in Figure 40.

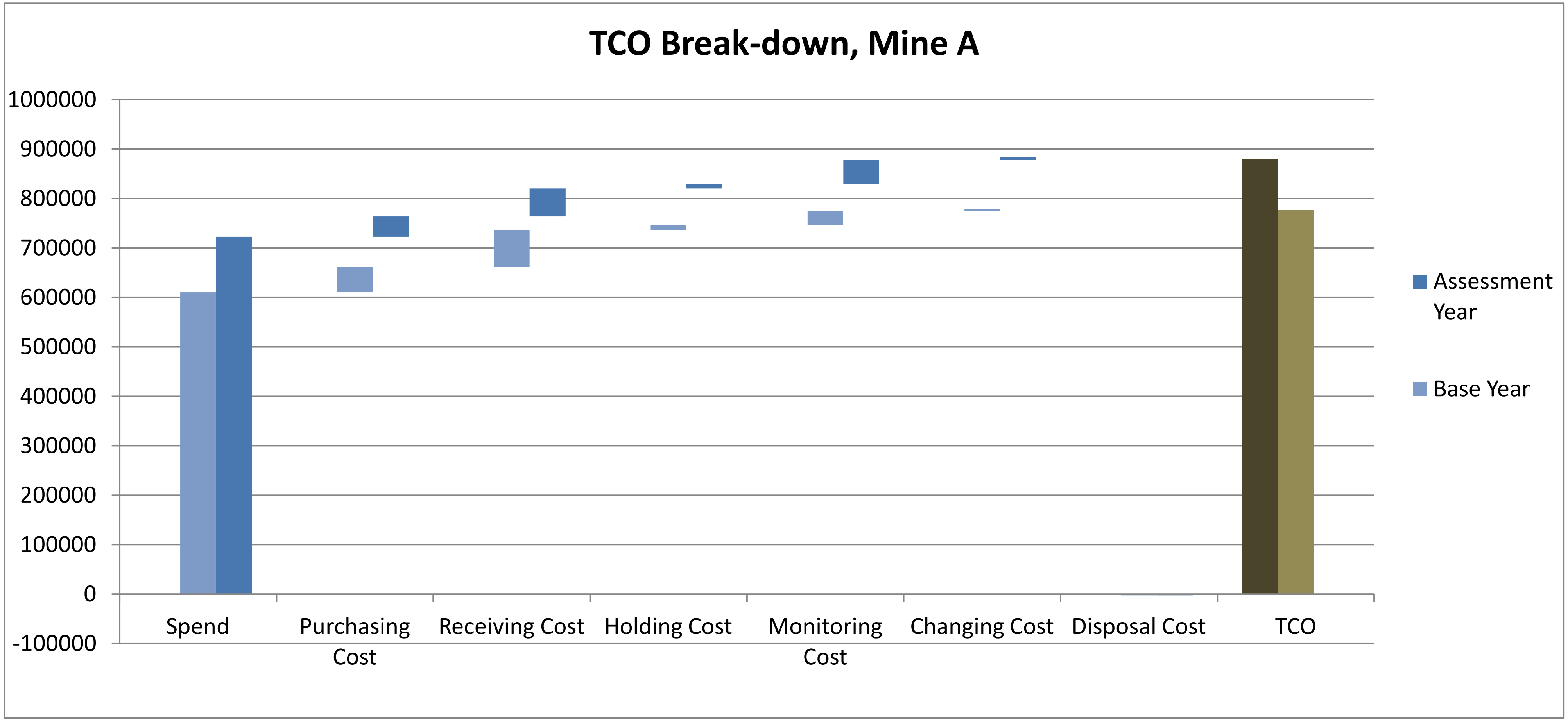


Figure 40: TCO break-down, Mine A

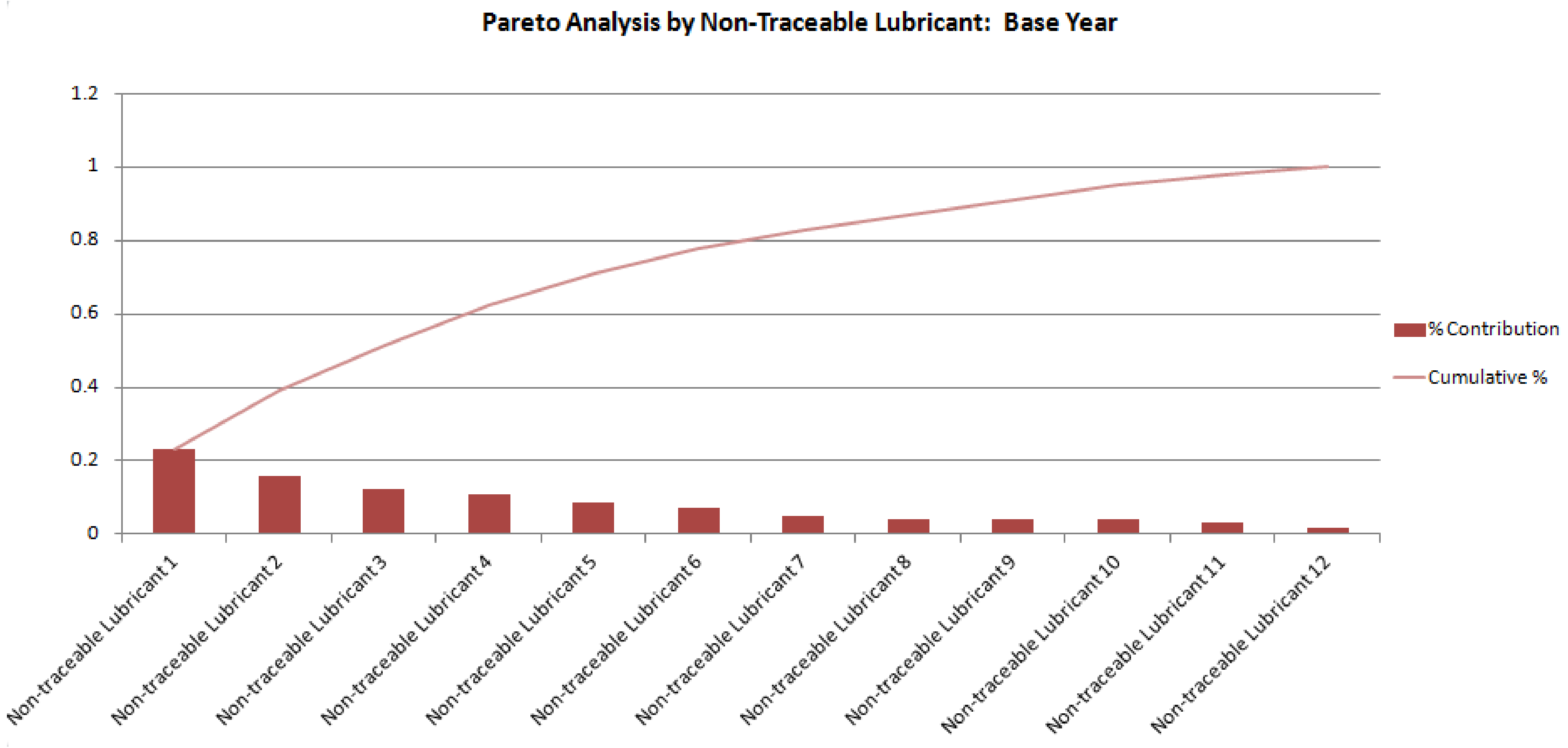


Figure 41: Pareto analysis, non-traceable lubricants driving TCO of mine

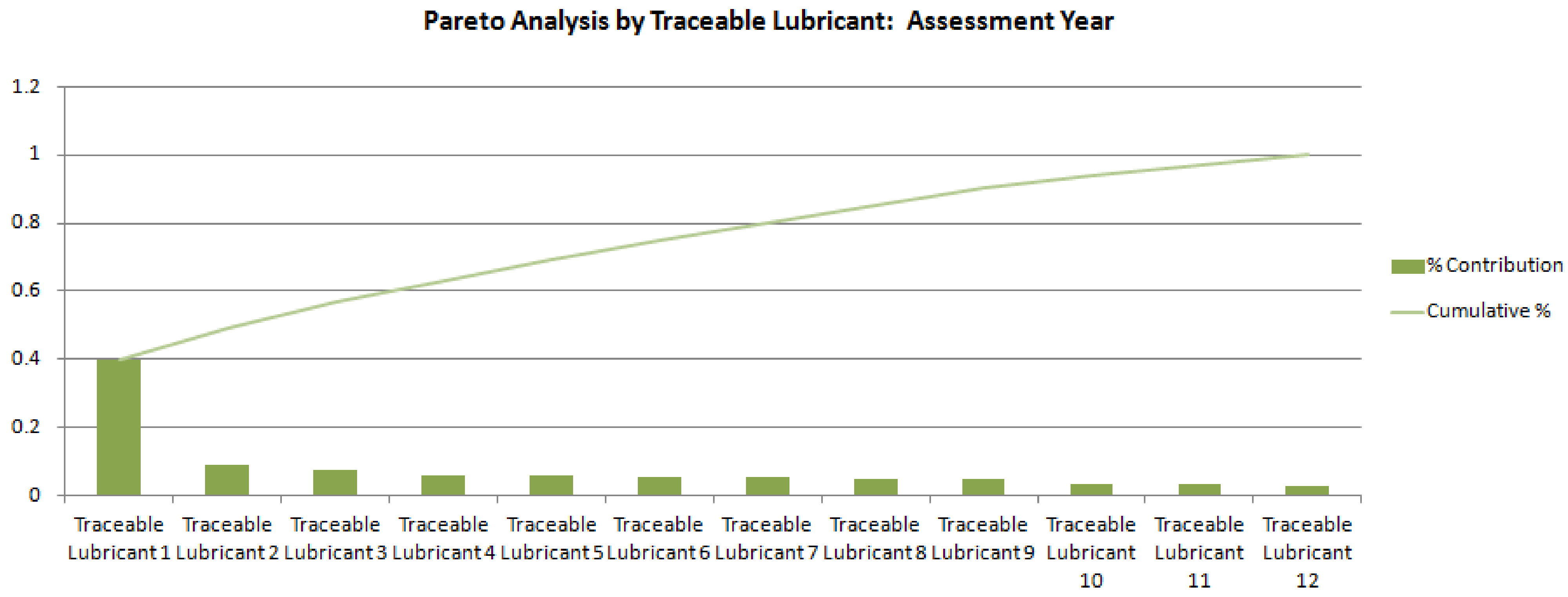


Figure 42: Pareto analysis, traceable lubricants driving TCO of mine

- The *Pareto analysis* that is drawn up for each traceable lubricant allows the user to identify which fleets are driving the TCO of the lubricant. The fleets driving the base and assessment year TCO's are shown separately so that changes can be identified between the two years. Figure 43 shows a Pareto analysis which identifies the top fleets driving the TCO of an arbitrary traceable lubricant in the base year.

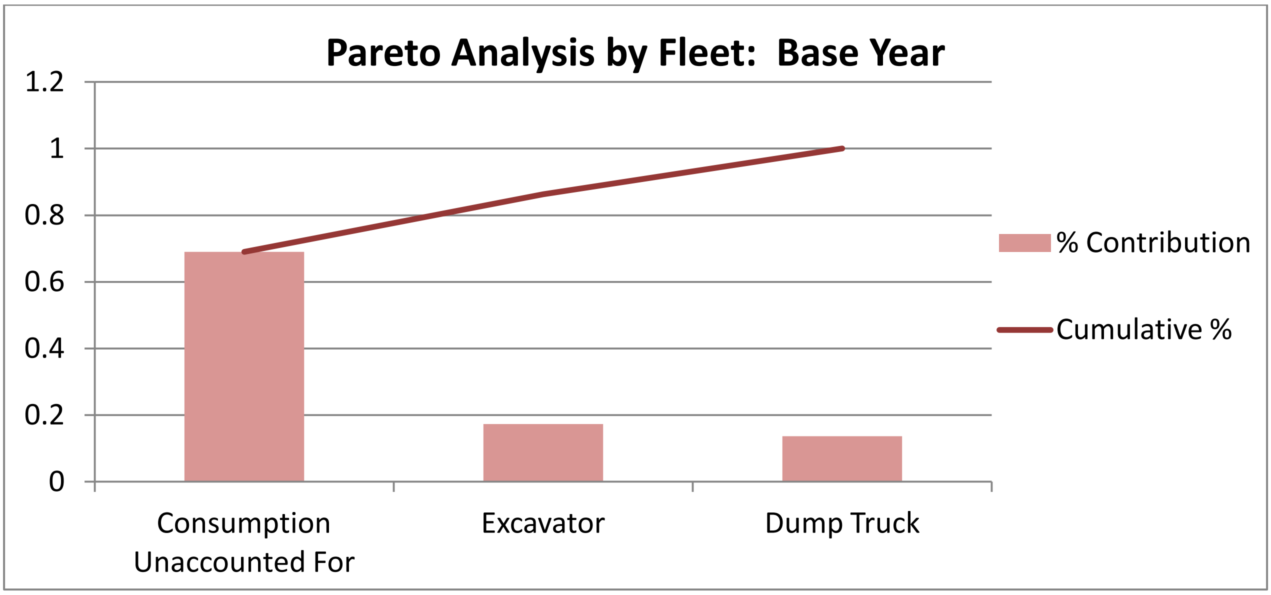


Figure 43: Pareto analysis, fleets driving TCO of traceable lubricant

Construction of Dashboard for Non-Traceable Lubricants

The dashboard that was constructed for each non-traceable lubricant has a similar layout to that of the other dashboards with a few exceptions:

- The *trend analysis* carries out a year-on-year analysis of any of the cost elements that make up the TCO of the specific non-traceable lubricant whose dashboard is open. Apart from the fact that the trend analysis only analyses one non-traceable lubricant at a time, the layout of the analysis is identical to the layout shown in Figure 39.

- The *TCO analysis* shows a break-down of the TCO of the specific non-traceable lubricant into its cost elements. This means that the disposal, monitoring and changing cost elements will be excluded from the analysis. The resulting TCO analysis is shown in Figure 44.

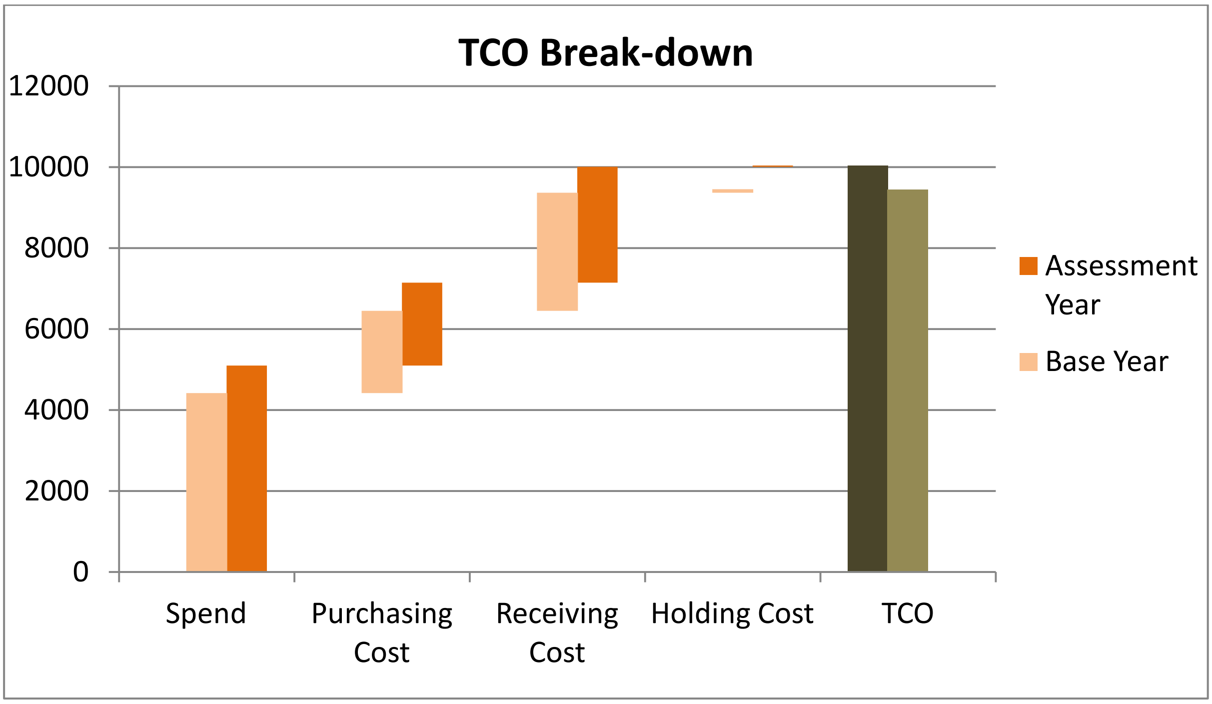


Figure 44: TCO break-down for non-traceable lubricant

- No *Pareto analysis* is included for non-traceable lubricants because by principle their TCO may not be traced down to individual fleets or pieces of equipment.

Using the Dashboard

The purpose of the dashboard is to identify which cost elements, lubricants and fleets of equipment are driving the TCO of a mine, and use this insight to focus idea generation on those areas where an improvement project would make the biggest impact. The user would typically start this analysis by identifying the largest cost elements and lubricants driving the TCO of the mine as a whole. Once the traceable and non-traceable lubricants which drive the TCO have been identified, the user may scroll to the dashboard constructed for those specific lubricants to further analyse them. Once in the dashboard for the specific lubricant, the user may investigate which cost elements are driving the TCO of the lubricant and in the case of traceable lubricants may even identify which fleets are driving the TCO of the lubricant. Any further investigation may be carried out in the TCO analysis section of the IS where specific pieces of equipment may be investigated or a specific part of one cost element may be traced.

In addition to helping with the identification of cost drivers and areas for improvement, the dashboard also allows the user to trace the progress of specific cost elements over time at different levels. This will be useful in tracking the progress of implemented projects and seeing whether those projects that were implemented actually caused changes in terms of the drivers of the TCO.

6.2.2.4 Construction of Project Evaluation Portion of IS

The project evaluation portion of the IS was developed to evaluate four projects at a time, and each project is evaluated according to the four criteria discussed in Section 5.2.9 before being compared using an AHP analysis. In order to evaluate each project according to the given criteria, data about each project's costs and implementation must be gathered. Figure 45 shows an example of the layout for evaluating a single project with respect to each of the four criteria and the data that needs to be collected for each evaluation. The time taken to implement the project and the difficulty of implementation may be changed directly by the user of the IS but the profitability and payback period criteria require a more detailed calculation to compute the final value.

Calculating the Profitability of a Project

The profitability of potential improvement projects is calculated by determining the capitalised cost of each project. However, as discussed in Section 5.2.9, recurring and non-recurring costs are treated differently when calculating the CC, as are cash inflows and cash outflows.

Project 2	
Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 2	R 700.00
Expand for calculation	

Criteria 2: Payback Period	
Payback Period in years	4
Expand for calculation	

Criteria 3: Time to Implement Project	
Amount of time (in months) to implement project	2

Criteria 4: Difficulty of Implementation	
Weighted Difficulty of Implementation	2.5

Factors affecting difficulty	Weight of factor	Factor rating	Weighted Rating
Operational changes	35%	Medium	1.05
Changes to business systems	35%	Low-medium	0.7
Changes to commercial strategies	15%	Medium	0.45
Changes to technical specs and/or designs	15%	Low-medium	0.3

Figure 45: Project evaluator for single project

For this reason, the cash flows associated with each project are split into four broad categories, namely:

- Annual savings gained by implementing the project,
- Once-off savings made at any stage of the implementation of the project,
- Recurring costs that are incurred due to the implementation of the project, and
- Once-off costs incurred at any stage during the implementation of the project.

The layout of the profitability calculation as it is carried out for each project is shown in Figure 46. Although not shown in this figure, the once-off savings, recurring costs and once-off costs categories make provision for five costs per category while the annual savings category only makes provision for one cost.

The *once-off savings* associated with the implementation of the project may be added directly to the appropriate section of the model, where the item column describes where the cost saving was incurred, the year column refers to the year in which the saving is incurred and the amount column refers to the amount of cash involved in the transaction. The NPV or CC (in this case the same figure but referred to as NPV in the IS for the user's understanding) of the once-off saving is calculated automatically by the IS.

The *recurring costs* associated with the project may be added directly to the appropriate section of the model, where the item column describes where the cost was incurred, the years between column refers to the number of years between each recurring cash flow and the amount column refers to the amount of cash involved in the transaction. The NPV of the recurring cost is calculated automatically by the IS.

The *once-off costs* associated with the implementation of the project may be added directly to the appropriate section of the model, where the item column describes where the cost was incurred, the year column refers to the year in which the cost is incurred and the amount column refers to the amount of cash involved in the transaction. The NPV of the once-off cost is calculated automatically by the IS.

Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 2	R 700.00

Annual savings (from scenario impact analysis)			
Item		**Amount**	**NPV**
decrease consumption		R 600.00	R 3,000.00

Open Scenario Impact Analysis

Once-off savings			
Item	**Year**	**Amount**	**NPV**
			R -

Recurring costs			
Item	**Years between**	**Amount**	**NPV**
			R -

Once-off costs			
Item	**Year**	**Amount**	**NPV**
maintenance	0	R 2,300.00	R -2,300.00
			R -
Expand for calculation			

Figure 46: Calculation of profitability of project

The *annual savings* associated with each project are calculated by making use of another portion of the IS known as the **Scenario Impact Analysis**. This tool calculates the impact that a change in one variable will have on the TCO of the BU as a whole. Figure 47 shows the layout of the scenario impact analysis in the IS. As can be seen from the figure, a potential project may either impact the BU as a whole, only a single lubricant and all the fleets that use that lubricant or it may impact only a single fleet and a single lubricant used by that fleet. Similarly to the database portion of the IS, the areas highlighted in blue indicate values that are calculated automatically while the areas highlighted in yellow indicate information that should be added or changed by the user.

In the case of a project that affects the whole BU, the potential decrease in the variable (expressed as a percentage) that would occur as a result of the implementation of the project should be filled in to the column highlighted in yellow. Using this figure, the IS calculates the impact that the change would have on the TCO.

In the case of a project that affects a single lubricant and all fleets using that lubricant, the lubricant that will be affected should be selected from a drop-down menu first. After selecting the lubricant, the potential decrease in the variable (expressed as a percentage) that would occur as a result of the implementation of the project should be filled in to the column highlighted in yellow. Using this figure, the IS calculates the impact that the change would have on the TCO.

In the case of a project that affects a single fleet and a single lubricant used by that fleet, the fleet and the lubricant that will be affected should be selected from drop-down menus first. After selecting both, the potential decrease in the variable (expressed as a percentage) that would occur as a result of the implementation of the project should be filled in to the column highlighted in yellow. Using this figure, the IS calculates the impact that the change would have on the TCO.

Once the impact that the project will have on the TCO is calculated using the Scenario Impact Analysis, this figure may be filled in to the amount column of the *annual savings* calculation shown in Figure 46. The item column describes where the cost was incurred and the NPV of the annual saving is calculated automatically by the IS.

Main Menu

Base Year	2011

Project Impacts Whole BU				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Holding Cost per Unit	0.10	5%	R 459.13	0.06%
Cost per Order by Purchasing Department	R 169.00	10%	R 5,205.20	0.67%
Cost of Receiving Order	R 243.00	10%	R 7,484.40	0.96%
Cost of Labour per Hour	R 25.00	10%	R 465.00	0.06%
Average Time to Change Oil	0.50	50%	R 2,325.00	0.30%
Litres of Oil Disposed	8000.00	-5%	R 200.00	0.03%
Rebate per Litre of Oil	R 0.50	-10%	R 400.00	0.05%
Number of Drums Disposed	400.00	-5%	R -80.00	-0.01%
Cost per Drum Disposed	R 12.00	10%	R 480.00	0.06%
Rebate per Drum	R 8.00	-10%	R 320.00	0.04%

Project Impacts Single Lubricant, and all Fleets				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Moving Avg Price	R 10.01	10%	R 28,023.00	3.61%
No.of Orders	23.00	10%	R 947.60	0.12%
Cost per Oil Analysis	R 320.00	10%	R 320.00	0.04%
Consumption	27995.00	5%	R 14,011.50	1.80%

Select Lubricant

Transmission oil AC1

Project Impacts Single Fleet and Single Lubricant				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Number of Oil Analyses	3.00	10%	R 96.00	0.01%
Consumption	240.00	10%	R 403.44	0.05%
Number of Changes (only affects changing cost)	8.00	5%	R 5.00	0.00%

Select Fleet

Dump Truck

and Select Lubricant

Anti-freeze

Figure 47: Scenario impact analysis

Calculating the Payback Period of a Project

The payback period for each project is calculated automatically by the IS using the method described in Section 5.2.9 where the unrecovered investment is calculated for each year and only when this figure reaches a value of zero will the project be paid off. Figure 48 shows an example of this calculation for the project shown in the examples above. As can be seen from this figure, all of the amounts used in the calculation of the payback period are gathered directly from the profitability data and the project's unrecovered cash flow is calculated for each year until it reaches zero. The calculation only makes provision for a payback period of up to twenty years as anything longer than this would not be seen as a worthwhile investment by the company.

Evaluating the Importance of the Criteria for the AHP

Once the data relating to the four projects that will be compared has been gathered, the AHP analysis of the four projects can be carried out. However, before the projects can be ranked according to how well they achieve each of the four criteria, the relative importance of each criterion must be determined. The ranking of the importance of each of the criteria is not an activity that the user will have to perform each time projects are compared as it should be more-or-less constant unless a drastic change in the strategy of the mine occurs.

The importance of each criterion with respect to another one is ranked on a scale of 1 to 9 as described in Section 5.2.9. Figure 49 shows how the criteria may be ranked by the user in the IS. For each pair of criteria, the more important one is selected and then scaled to show the extent of importance. This process is carried out by the user for each pair.

After scaling each pair of criteria, the relative importance of the four criteria is calculated by the IS using the AHP process and an intermediate matrix as discussed in Section 5.2.9. Figure 50 shows an example of how the relative importance of the criteria is calculated and how a warning may be provided to the user if the rankings are found to be inconsistent. (e.g. A is more important than B, B is more important than C but C is more important than A)

Criteria 2: Payback Period	
Payback Period in years	4

Year	BOY Unrecovered cash	Cash outflow	Cash inflow	EOY Unrecovered cash
1	R 2,300.00	R -	R 600.00	R 1,700.00
2	R 1,700.00	R -	R 600.00	R 1,100.00
3	R 1,100.00	R -	R 600.00	R 500.00
4	R 500.00	R -	R 600.00	R -
5	R -	R -	R 600.00	R -
6	R -	R -	R 600.00	R -
7	R -	R -	R 600.00	R -
8	R -	R -	R 600.00	R -
9	R -	R -	R 600.00	R -
10	R -	R -	R 600.00	R -
11	R -	R -	R 600.00	R -
12	R -	R -	R 600.00	R -
13	R -	R -	R 600.00	R -
14	R -	R -	R 600.00	R -
15	R -	R -	R 600.00	R -
16	R -	R -	R 600.00	R -
17	R -	R -	R 600.00	R -
18	R -	R -	R 600.00	R -
19	R -	R -	R 600.00	R -
20	R -	R -	R 600.00	R -
Expand for calculation				

Figure 48: Calculation of payback period for a project

More important criterion	Rate Importance of Criteria			Numerical rating
Profitability or NPV / Payback Period	Payback Period	is more important than	Profitability or NPV	5.0
Time to Implement Project / Difficulty of Implementation	Difficulty of Implementation	is more important than	Time to Implement Project	6.0
Profitability or NPV / Time to Implement Project	Profitability or NPV	is more important than	Time to Implement Project	4.0
Profitability or NPV / Difficulty of Implementation	Difficulty of Implementation	is more important than	Profitability or NPV	4.0
Payback Period / Time to Implement Project	Payback Period	is more important than	Time to Implement Project	5.0
Payback Period / Difficulty of Implementation	Payback Period	is more important than	Difficulty of Implementation	5.0

Numerical rating Scale

1: Objectives i and j are equally important
3: Objective i is weakly more important than objective j
5: Objective i is strongly more important than objective j
7: Objective i is very strongly more important than objective j
9: Objective i is absolutely more important than

Figure 49: Ranking relative importance of criteria for AHP

Criteria Comparison and Weight Calculation					
	Profitability or NPV	Payback Period	Time to Implement Project	Difficulty of Implementation	Criteria Weights
Profitability or NPV	1.00	0.20	4.00	0.25	0.13
Payback Period	5.00	1.00	5.00	5.00	0.55
Time to Implement Project	0.25	0.20	1.00	0.17	0.06
Difficulty of Implementation	4.00	0.20	6.00	1.00	0.26
					1.00

Warning, the ranking of the criteria is inconsistent

Figure 50: Calculation of relative importance of criteria

Overall Project Rating				
Project 1	0.31	**Therefore, in order of priority, implement:**	Project 4	first,
Project 2	0.27		Project 1	second,
Project 3	0.09		Project 2	third, and
Project 4	0.33		Project 3	last.

Figure 51: Overall rating of each project

Project Comparison With Respect to Profitability					
	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	1.74	0.98	0.19	0.13
Project 2	0.57	1.00	0.56	0.11	0.07
Project 3	1.02	1.78	1.00	0.20	0.13
Project 4	5.17	9.00	5.07	1.00	0.67
					1.00

Project Comparison With Respect to Payback Period					
	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	1.22	9.00	3.46	0.45
Project 2	0.82	1.00	7.40	2.85	0.37
Project 3	0.11	0.14	1.00	0.38	0.05
Project 4	0.29	0.35	2.60	1.00	0.13
					1.00

Project Comparison With Respect to Time to Implement the Project					
	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	5.21	9.00	1.94	0.55
Project 2	0.19	1.00	1.73	0.37	0.11
Project 3	0.11	0.58	1.00	0.22	0.06
Project 4	0.52	2.68	4.64	1.00	0.28
					1.00

Project Comparison With Respect to Difficulty of Implementation					
	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	0.34	0.40	0.11	0.06
Project 2	2.93	1.00	1.18	0.33	0.19
Project 3	2.48	0.85	1.00	0.28	0.16
Project 4	9.00	3.08	3.63	1.00	0.58
					1.00

Figure 52: Evaluation of projects with respect to criteria

After calculating the relative importance of the criteria, each project is evaluated according to how well it achieves each criterion. Because all of the criteria are measured numerically, the performance of each project is evaluated on a normalised scale of 1 to 9 where 1 represents the worst value of the four projects and 9 represents the best value. For profitability, the worst value would be the lowest profitability and the best value would be the highest profitability. However, for the other three criteria, the lowest value would be the best value and the highest value would be the worst value (i.e. a long payback period is bad, a short payback period is good). After rating the performance of each project, the relative performance is calculated using an intermediate matrix as discussed in Section 5.2.9. This process is carried out for each of the four criteria as shown in Figure 52.

Finally, the overall rating of each of the four projects is determined by combining the performance of the project with respect to each criterion with the specific criterion's ranking. An example of this calculation and the ranking of projects according to priority is shown in Figure 51.

6.3. System Testing and Implementation

6.3.1. Review of IS by XYZ Mining

The IS that was developed for XYZ Mining was reviewed and checked by the future users of the system. All components of the IS, including the database and all of the analyses were tested for logical accuracy and for user-friendliness and ease of understanding. The review was very positive and the system users felt that each of the initial requirements provided were fully met by the IS.

6.3.2. Creating Blank IS for Implementation

After the review of the IS was complete, it was emptied of all data and fictitious examples and made into a generic IS that could be implemented and used at any of XYZ Mining's mines. This generic IS was delivered to XYZ Mining for their use.

6.3.3. Development of User Manual

A complete user manual was also developed for the IS to assist the users of the system should they get stuck while using it or should they not understand any of the concepts used in it. The user manual was developed following the steps listed in Section 5.5, and as described below:

- *Planning:* The main users of the user manual will be the workers at the mines responsible for gathering raw data, and the systems analysts situated at the relative business improvement sectors. The workers at the mine will only use the database portion of the IS which is already built in a way that is easy to understand and contains only concepts like lubricants and equipment that are familiar to them. This means that the section of the user manual related to the database can be kept simple and straightforward to avoid the user losing interest. The user of the analysis portion of the IS will be an analyst who is already familiar with concepts of TCO, idea generation and Pareto analyses. This means that the user manual as a whole can be kept simple and to-the-point.
- *Style sheet creation:* The formatting of the user manual will be consistent with the formatting standards of XYZ Mining for the user's convenience.
- *Development:* The user manual was developed according to the basic layout provided in Section 5.5 and it was kept as simple and straightforward as possible. The complete user manual was not included in this document due to its length and the fact that it is highly similar to the description of the IS provided in Section 6.2.2. However, the table of contents from the user manual is provided in Appendix F to illustrate the basic contents of it.
- *Review:* The user manual was reviewed by a systems analyst at XYZ Mining and found to be relevant and sufficient to use for both the systems analysts and the workers who will gather the data used in the database.
- *Version Management:* Version management for the user manual was not required as it was developed in its entirety after the IS was completely developed due to time constraints.
- *Delivery:* The final user manual was delivered to XYZ Mining along with the generic IS ready for implementation.

6.4. Information System Validation

In order to demonstrate the validity of the IS that has been developed for the project, it is important to show how it would ultimately be used by the end user and to show how it has met all of their initial requirements as researched in the literature review. Therefore, the approach taken to prove the validity of the IS was to use it to complete the first two steps of the SS process provided in Figure 1, namely building a knowledge and understanding of the lubricant commodity and identifying areas for improvement in the commodity and selecting the best initiatives to implement. In order to validate each of the parts of the IS (each part meets a certain user requirement) and show how it aids in carrying out the SS cycle, the following steps will be followed in the validation process:

1. Enter data into the blank database portion of the IS,
2. Use this data to update the TCO analysis portion of the IS,
3. Use the data to update the dashboard (or KPD identifier) portion of the IS,
4. Analyse the results from the dashboard to generate potential improvement ideas, and
5. Use the project evaluation tool in the IS to prioritise the ideas that were generated in Step 4.

For the purpose of the project, it was impossible to complete the third and final steps in the SS process (implementing initiatives and monitoring the lubricant commodity) due to time constraints and the lack of actual data available. Instead, informed estimates of data were used for the validation of the IS and hypothetical situations were used when generating improvement ideas.

6.4.1. Database Portion of IS

The validation process began with illustrating how the database would be used to record data about lubricants at a mine.

Lubricant data relating to four traceable lubricants and four non-traceable lubricants was added to the database for the year 2011 as shown in Figure 54. Each of the traceable lubricants was linked to four fleets of equipment and data about the consumption of the lubricants was added for each piece of equipment in the four fleets as shown for the Dump

Truck fleet in Figure 55. Lastly, all the additional data relating to the mine as a whole was also added to the database for the year 2011 as shown in Figure 53. It should be noted that only rows with relevant data are shown in Figure 53 to Figure 55, any additional blank rows in the database were hidden for simplicity's sake.

2011	
Stores Department	
Holding Cost per Unit	0.1
Supply Chain Department	
Cost per Order by Purchasing Department	169
Cost of Receiving Order	243
Maintenance Department	
Cost of Labour per Hour	100
Average Time to Change Oil	0.5
Disposal Costs	
Litres of Oil Disposed	50000
Rebate per Litre of Oil	0.5
Number of Drums Disposed	400
Cost per Drum Disposed	12
Rebate per Drum	8

Figure 53: Database validation 1

6.4.2. TCO Analysis Portion of IS

The data gathered in the database was updated in the TCO analysis portion of the IS and an overview of the TCO drawn up for the Engine Oil traceable lubricant is shown in Figure 56. From this TCO analysis it can be seen that each of the cost elements can be traced down to how they are calculated and which fleets and pieces of equipment they are driven by.

The TCO analyses drawn up for validation will be used further in Section 6.4.4, the idea generation.

Traceable Lubricants				2011							
				Purchasing Department			Stores Department		Maintenance Department		
Material Number	Description	Purchase Unit	Unit of Measure	Moving Avg Price	No.of Orders	Units Purchased	Avg Inventory	Withdrawals	BOY Stock	EOY Stock	Cost per Oil Analysis
1	Anti-Freeze	210 Litre drum	Litre	17	10	650	280	600	20	10	0
2	Engine Oil	Litre	Litre	10	25	46000	25000	45600	200	100	150
3	Transmission Oil	Litre	Litre	9	2	5200	3000	4500	200	100	180
4	Hydraulic Oil	Litre	Litre	7	2	1000	600	800	200	100	400

Non-Traceable Lubricants				2011							
				Purchasing Department			Stores Department		Maintenance Department		
Material Number	Description	Purchase Unit	Unit of Measure	Moving Avg Price	No.of Orders	Units Purchased	Avg Inventory	Withdrawals	BOY Stock	EOY Stock	Cost per Oil Analysis
5	Penetration oil	500ml bottle	Each	57	12	84	15	78	1	1	
6	Carter Oil	210 Litre drum	Litre	15	4	1680	400	1400	25	25	
7	RD 100	210 Litre drum	Litre	16	3	1260	400	1100	25	30	
8	Nipple grease		Each	19	5	100	21	80	5	6	

Figure 54: Database validation 2

Equipment-Lubricant Matching					
Equipment Type	Fleet	Equipment Name	Cost Code	Lubricant Name	Compartment(s) Using Lubricant
Primary Equipment	DUMP TRUCK				
		CAT DT1	DT1	Anti-Freeze	Cooling System
				Engine Oil	Engine
				Transmission Oil	Transmission
				Hydraulic Oil	Hydraulics
		CAT DT2	DT2	Anti-Freeze	Cooling System
				Engine Oil	Engine
				Transmission Oil	Transmission
				Hydraulic Oil	Hydraulics
		CAT DT3	DT3	Anti-Freeze	Cooling System
				Engine Oil	Engine
				Transmission Oil	Transmission
				Hydraulic Oil	Hydraulics

2011				1		2		3	
Number of Analyses	Oil Change Interval								
	Total Hours	Number of changes	Litres per change	Litres	Hours	Litres	Hours	Litres	Hou
0	11746	2	5	5	5902	5	5844		
46	12740	52	20	20	208	20	260	20	2
4	11746	8	13	13	1469	13	1529	13	14
2	11746	4	4	4	2998	4	2904	4	28
0	12267	2	5	5	6092	5	6175		
10	13301	52	20	20	288	20	242	20	2
4	12267	8	13	13	1463	13	1604	13	14
2	12267	4	4	4	3067	4	3025	4	30
0	12153	2	5	5	6167	5	5986		
29	13176	52	20	20	258	20	223	20	2
4	12153	8	13	13	1470	13	1567	13	16
2	12153	4	4	4	3037	4	3130	4	30

Figure 55: Database validation 3

Engine Oil	
Base Year TCO	R 761,650.00
Assessment Year TCO	R -
Difference (%)	-1.00

Total Spend	
Base Year Spend	R 457,000.00
Assessment Year Spend	R -
Difference (%)	-1.00

Total Consumption	
Base Year Total Consumption	45700.00
Assessment Year Total Consumption	0.00
Difference (%)	-1.00

Dump Truck	
Base Year Consumption	29120.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

Excavator	
Base Year Consumption	8840.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

Bulldozer	
Base Year Consumption	3712.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB	
Base Year Consumption	3864.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 1	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 2	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 3	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 4	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 5	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 6	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

TLB 7	
Base Year Consumption	552.00
Assessment Year Consumption	0.00
Difference (%)	-1.00

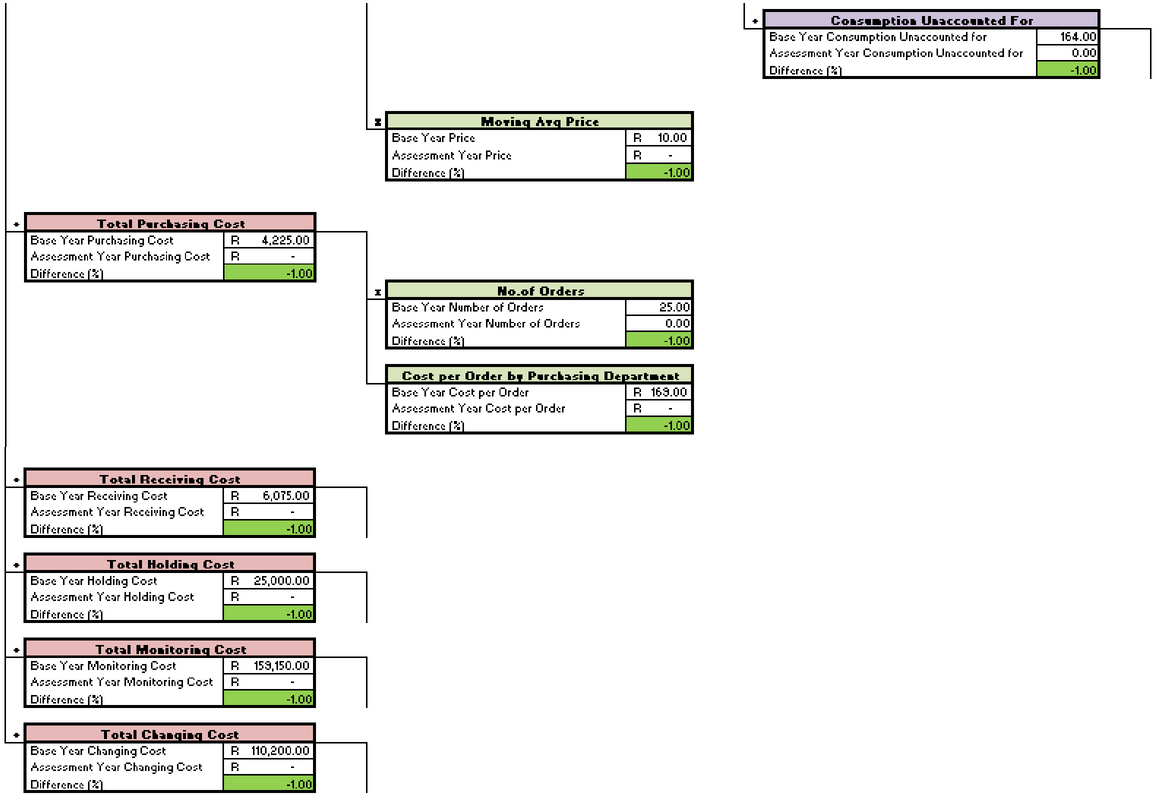


Figure 56: TCO Analysis validation

6.4.3. Dashboard Portion of IS

The data gathered in the database portion of the IS was also updated in the dashboard section of the IS to draw up the relevant analyses. The TCO analysis and Pareto analyses which identify the traceable and non-traceable lubricants driving the TCO for the mine as a whole are shown in Appendix G, Section 1. The TCO analyses and Pareto analyses which identify the fleets driving the TCO for each traceable lubricant are shown in Appendix G, Section 2. Lastly, the TCO analyses for each of the non-traceable lubricants are shown in Appendix G, Section 3.

6.4.4. Idea Generation

Each of the analyses shown in Appendix G was studied to identify areas for improvement in the lubricant commodity supply chain. Listed below are a number of issues that were identified from the analyses:

- The monitoring and changing cost elements for the mine as a whole were identified as being particularly high (spend cost element is expected to be high) while the disposal cost was found to be very low,
- Engine oil was found to be the largest traceable lubricant contributing towards the mines TCO while Carter oil and RD100 oil were found to be the largest non-traceable lubricants contributing towards the TCO,
- Anti-freeze was found to have a large amount of consumption unaccounted for,
- Dump trucks were found to account for the largest portion of engine oil (and in fact all traceable lubricant) consumption,
- Hydraulic oil was found to have a particularly high monitoring cost element figure,
- Penetration oil and nipple grease were both found to have particularly large purchasing and receiving cost elements.

Building on these issues, a number of ideas for potential improvement projects were developed as follows:

1. The consumption of engine oil by dump trucks should be decreased to help decrease the TCO of engine oil and therefore of the mine as a whole as it is the largest contributor towards the mine's TCO.
2. Using the TCO analysis drawn up for hydraulic oil, it was found that the biggest contributor towards its high monitoring cost was the cost of analysing hydraulic oil. This cost should be brought down to decrease the monitoring cost element for the lubricant. This idea can also be extended to try and decrease all lubricants' analysis costs as they are a large contributor to the mine's high monitoring cost element.
3. Using the TCO analyses drawn up for penetration oil and nipple grease, it was found that the reason for their large receiving and purchasing cost elements was the fact that many orders for small amounts were being placed throughout the year; and each order incurs a high purchasing and receiving cost. The number of orders placed every year for these lubricants should therefore be decreased to decrease their receiving and purchasing cost elements.
4. Using the TCO analysis drawn up for the mine as a whole, it was found that the main reason for the small disposal cost element was the fact that the rebate per litre of recycled oil was very low. If a better rebate could be gained from the current purchaser of used oils; or another more profitable purchaser could be found, the disposal cost could decrease further and thus decrease the TCO

6.4.5. Project Evaluator Tool

Each of the three potential projects discussed above was evaluated using the project evaluator to prove its validity and to decide on which projects to implement first. This process is discussed below:

1. For the purpose of decreasing the consumption of engine oil in dump trucks, it was decided that the overall consumption could decrease by 5% if leaks and spillages were decreased in all of the trucks. Using the scenario impact analysis, it was found that this would result in an annual saving of R 14 560 as shown in Appendix H. The cost of implementing this project would be an annual maintenance cost of R 2400 for checking for leaks; and the time taken to implement the project would be three

months for checking all of the trucks at first. The project would result in some operational changes at the mine but no changes to business systems, commercial strategies or technical designs. All of this data was added to the project evaluator as shown in Appendix H.

2. To decrease the monitoring cost of hydraulic oil, it was suggested that internal testing facilities be used to analyse the oil as opposed to external testing facilities as is currently done. This would decrease the analysis cost by 65% resulting in an annual saving of R 22 100 as calculated by the scenario impact analysis shown in Appendix H. This project would however result in a once-off upgrade cost of R75 000 to the current testing facilities and would take a year to implement because of installation time. The project would also result in reasonable operational and design changes and minor business systems and commercial strategy changes. All of this data was added to the project evaluator as shown in Appendix H.
3. In order to decrease the purchasing and receiving costs of nipple grease and penetration oil, it was decided that both of their number of orders would be decreased by 50% for the following year. This would result in an annual saving of R 2 472 and R 1 030 for penetration oil and nipple grease respectively, as shown in Appendix H. The project would not incur any other costs and could be implemented immediately. Also, the project would now cause any major changes to operational procedures, business systems, commercial strategies or technical designs. All of this data was added to the project evaluator as shown in Appendix H.
4. After conducting research, an alternative purchaser who would pay 100% more per litre of oil recycled was found. This increase in rebate would result in an annual saving of R 25 000 according to the scenario impact analysis shown in Appendix H. A once-off penalty of R 75 000 would have to be paid to the current purchaser for ending the contract with them but other than that there are no incremental costs involved in implementing the project. The project would take approximately two months to implement because of drawing up new contracts but it would have little to no impact on operations, technical designs, business systems and commercial strategies. All of this data was added to the project evaluator as shown in Appendix H.

After adding all relevant project data, an AHP analysis was drawn up for ranking the four projects. The ranking of the four criteria, all intermediate steps and the final ranking of the three projects was done as shown in the AHP section of Appendix H.

6.4.6. Conclusion: IS Validation

The Information System developed for XYZ Mining has been validated through an actual example of the process one would follow when using the IS for completing the SS cycle. Step 4 of the cycle would make use of the trend analyses and the TCO analyses to trace any changes over time and to trace changes down to an equipment level. Although the examples provided in this section are purely fictional, they show the application of a process and of logic that will ultimately be applied by the end users of the IS.

7. Conclusion and Recommendations

The aim of the project was to develop a tool that could be used throughout the lubricant commodity SS cycle carried out at XYZ Mining. This tool was developed in the form of an information system separated into two main parts; namely a database to collect all data about the lubricant commodity, and a set of analyses which could be used to meet all of the analysis requirements put forward by XYZ Mining and gathered from SS literature.

Each of the requirements was investigated in detail in the literature review and then translated into a system function using use case modelling. Logical designs were developed for the database and analysis portion of the IS, and for a user manual for the IS. Using these logical designs, the final IS and user manual were designed and constructed.

The IS was developed to fit the user requirements directly and it was developed using proven tools and techniques. User friendliness and ease of understanding were considered throughout the development of the IS and the user manual so that the ultimate implementation of the tool would be ensured.

Although the tool has not been implemented at XYZ Mining yet due to time constraints, the tool and the user manual have been delivered to the company for their use. The usefulness and importance of the IS have been demonstrated by the positive feedback from XYZ Mining and by the validation of the model provided in Section 6.4. It is the opinion of the author that it is simply a matter of time before the IS becomes fully implemented at XYZ mining's mines.

Future recommendations for the IS and its application include the following:

- Automating the data gathering process so that the IS pulls relevant data directly from XYZ Mining's ERP systems,
- Extending the application of the IS to be used for other commodities such as fuels, oil filters, gearboxes etc., and
- Extending the application of the tool to beyond the mining industry alone.

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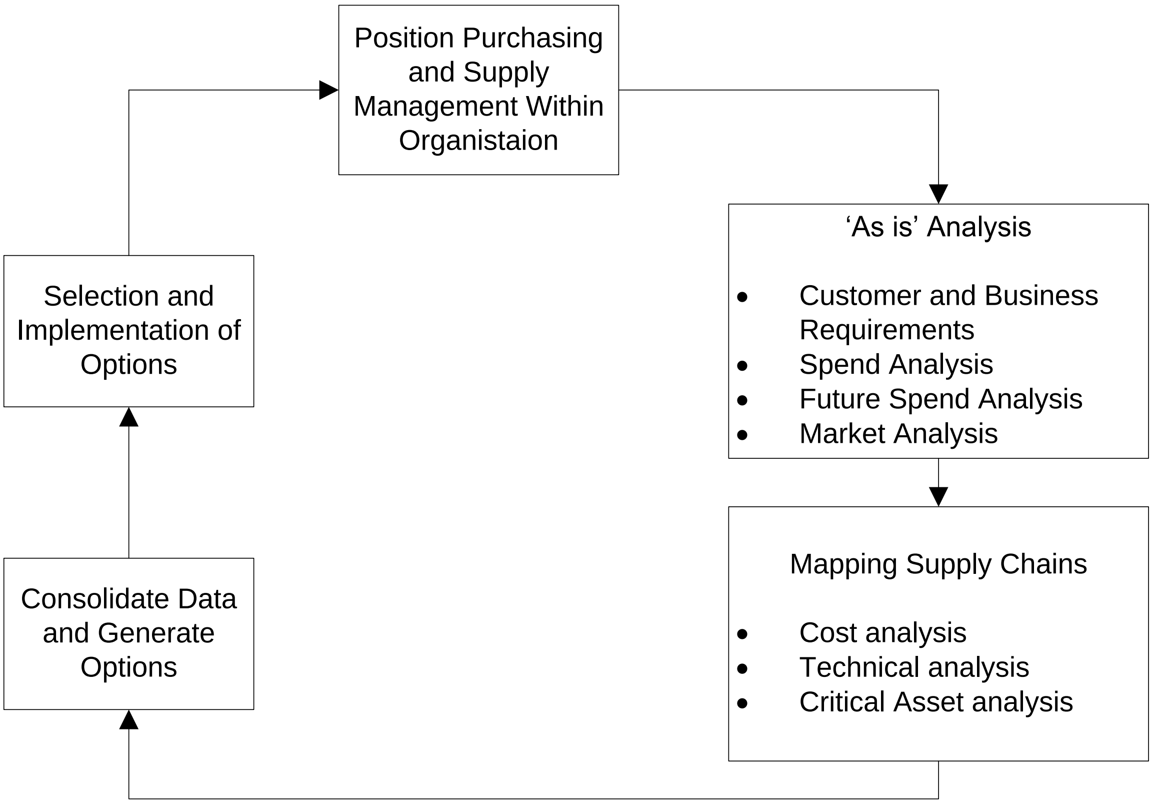
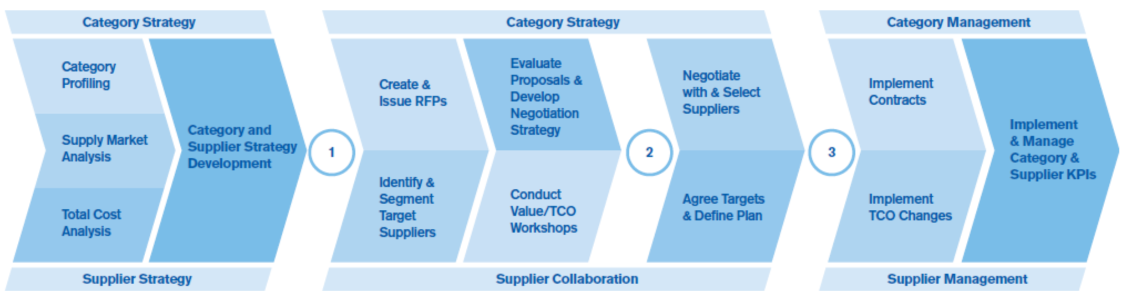
Appendix A

Strategic Sourcing Methodologies

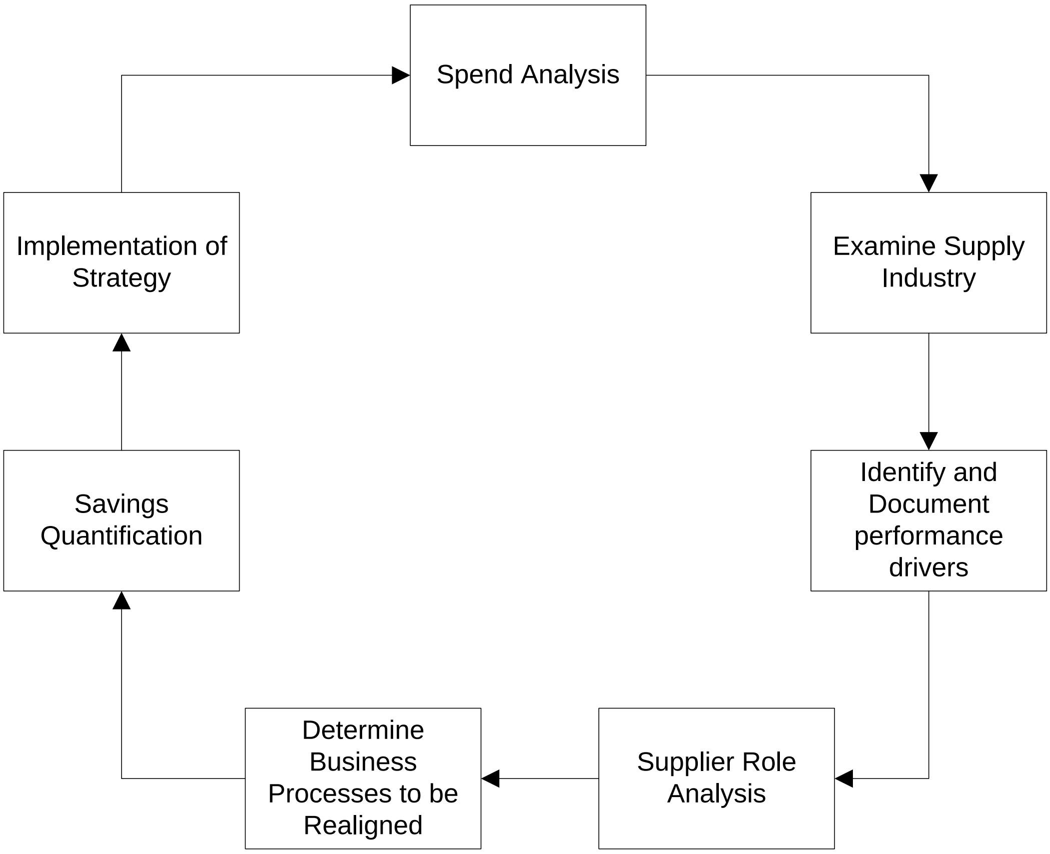
Strategic Sourcing Methodology used by CIPS (2012)



Strategic Sourcing Methodology used by Efficio Consulting (2012)



Lasseter's Balanced Sourcing Model (Rendon, 2005)



Appendix B

Project Plan

ID	Task Name	Start	Finish	Duration
1	**Project Topic**	3/28/2012	4/19/2012	23d
2	Identify topic, discuss with stakeholders	3/28/2012	4/10/2012	14d
3	Topic submission, study leader allocation	3/28/2012	3/31/2012	4d
4	**Project Proposal**	3/28/2012	4/12/2012	16d
5	Information gathering, discussion with stakeholders	3/28/2012	4/5/2012	9d
6	Compile project proposal	3/28/2012	4/3/2012	7d
7	Editing and finalising	3/28/2012	3/30/2012	3d
8	Submission of project proposal	3/28/2012	3/28/2012	1d
9	**Requirements Analysis: Literature Review**	3/28/2012	4/17/2012	21d
10	Detail Literature Review	3/28/2012	4/17/2012	21d
11	Selection of tools and techniques	3/28/2012	4/17/2012	21d
12	**Interim Report**	4/26/2012	5/8/2012	13d
13	Develop first draft of model	4/26/2012	5/2/2012	7d
14	Editing and finalising report	5/4/2012	5/5/2012	2d
15	Hand in interim report	5/8/2012	5/8/2012	1d
16	**Oral Presentation**	6/15/2012	2012/06/15	1d
17	**System Design and Construction**	5/9/2012	8/31/2012	115d
18	Data gathering: Basic data	5/9/2012	5/12/2012	4d
19	Development of IS for review	5/12/2012	8/31/2012	112d
20	**Testing & Finalising**	9/1/2012	9/9/2012	9d
21	Review of IS	9/1/2012	9/7/2012	7d
22	Create blank IS	9/7/2012	9/9/2012	3d
23	**System Implementation**	9/10/2012	9/20/2012	11d
24	Deployment of IS	9/10/2012	9/15/2012	6d
25	Development of User Manual	9/10/2012	9/20/2012	11d
26	**System Operation**	9/15/2012	10/6/2012	22d
27	Data gathering: Actual data	9/15/2012	9/25/2012	11d
28	IS demonstration, validation	9/25/2012	10/6/2012	12d
29	**Final Report**	10/7/2012	10/16/2012	10d
30	Compilation of report	10/7/2012	10/14/2012	8d
31	Editing and finalising	10/7/2012	10/14/2012	8d
32	Print report	10/14/2012	10/14/2012	1d
33	Submission of final report	10/16/2012	10/16/2012	1d
34	**Project Presentation**	10/20/2012	10/20/2012	1d

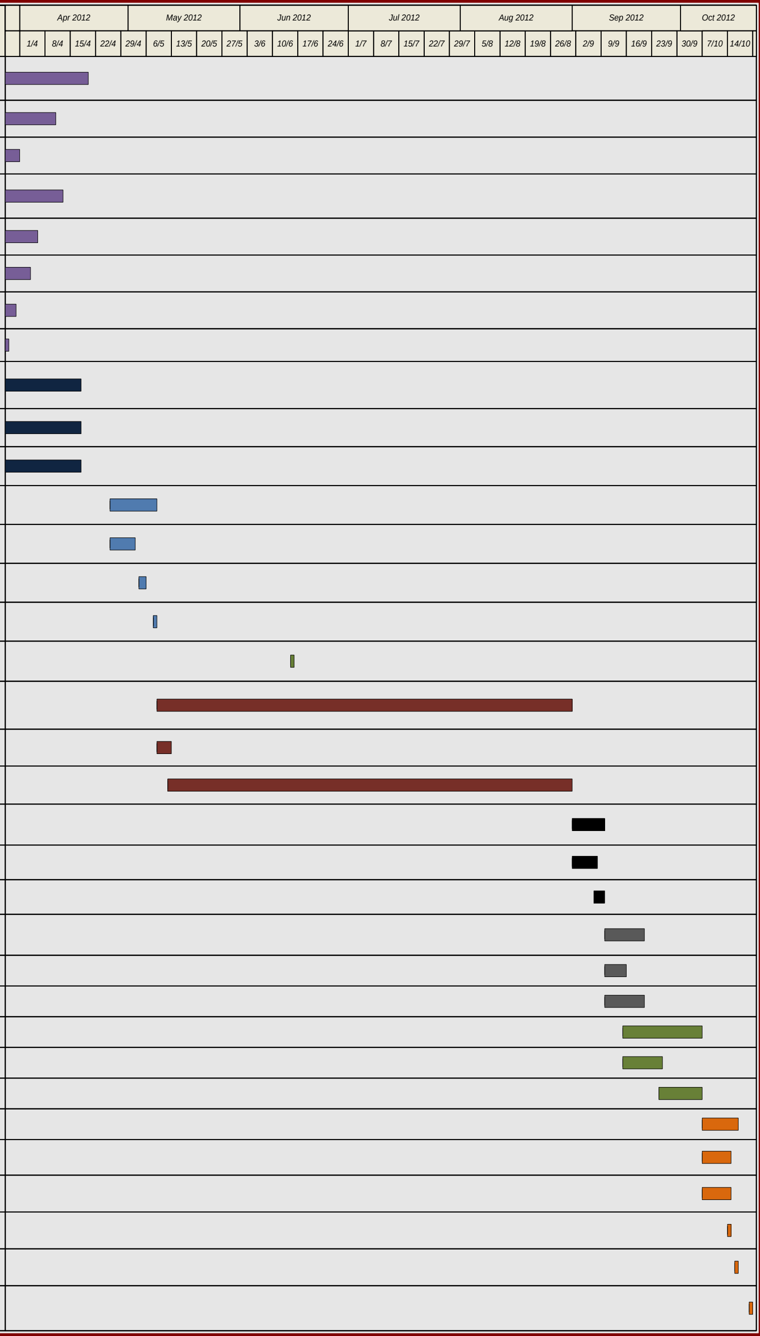


Table 6: Project Budget

Item	Cost
Printing of project proposal, interim report and final report	R 600
Printing of poster	R 450
Internet	R 200
Stationery	R 50
Transport	R 1000
TOTAL	**R 2050**

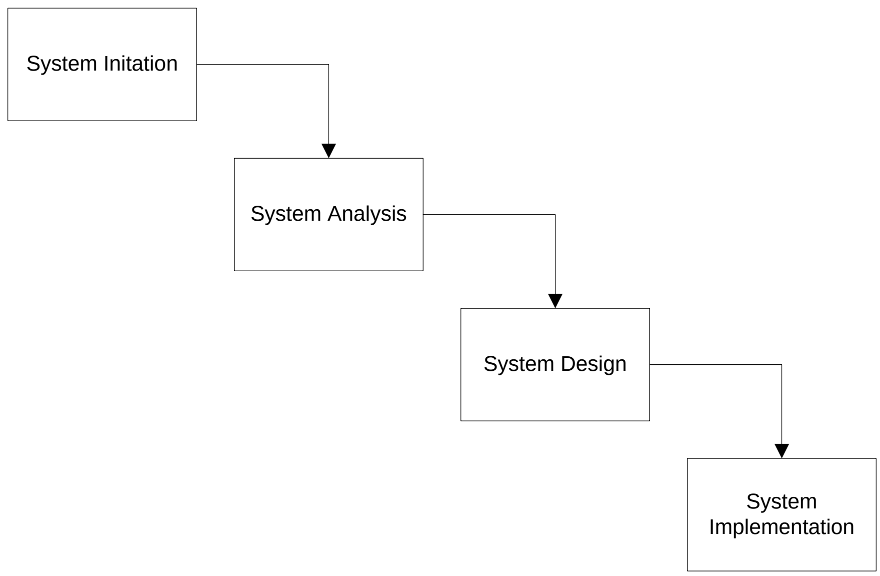
The resources needed to complete the project include, but are not limited to, the following:

- Personal computer,
- Software to develop IS in,
- Internet,
- Stationery,
- Transport to meet with stakeholders,
- Transport for site visits,
- Information about lubricants and the use of lubricants in the coal mining industry,
- Data pertaining to the use of lubricants at XYZ Mining,
- Stakeholders from XYZ Mining, and
- Project leader, Professor Paul Kruger.

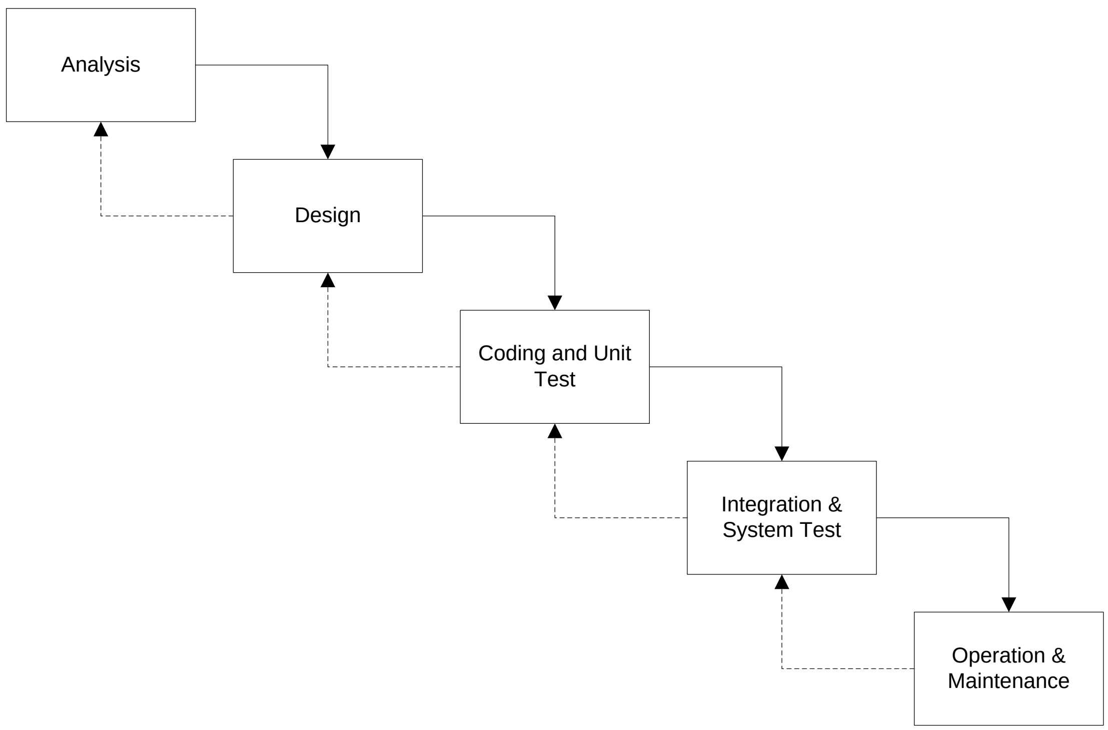
Appendix C

Linear Information System Development Models

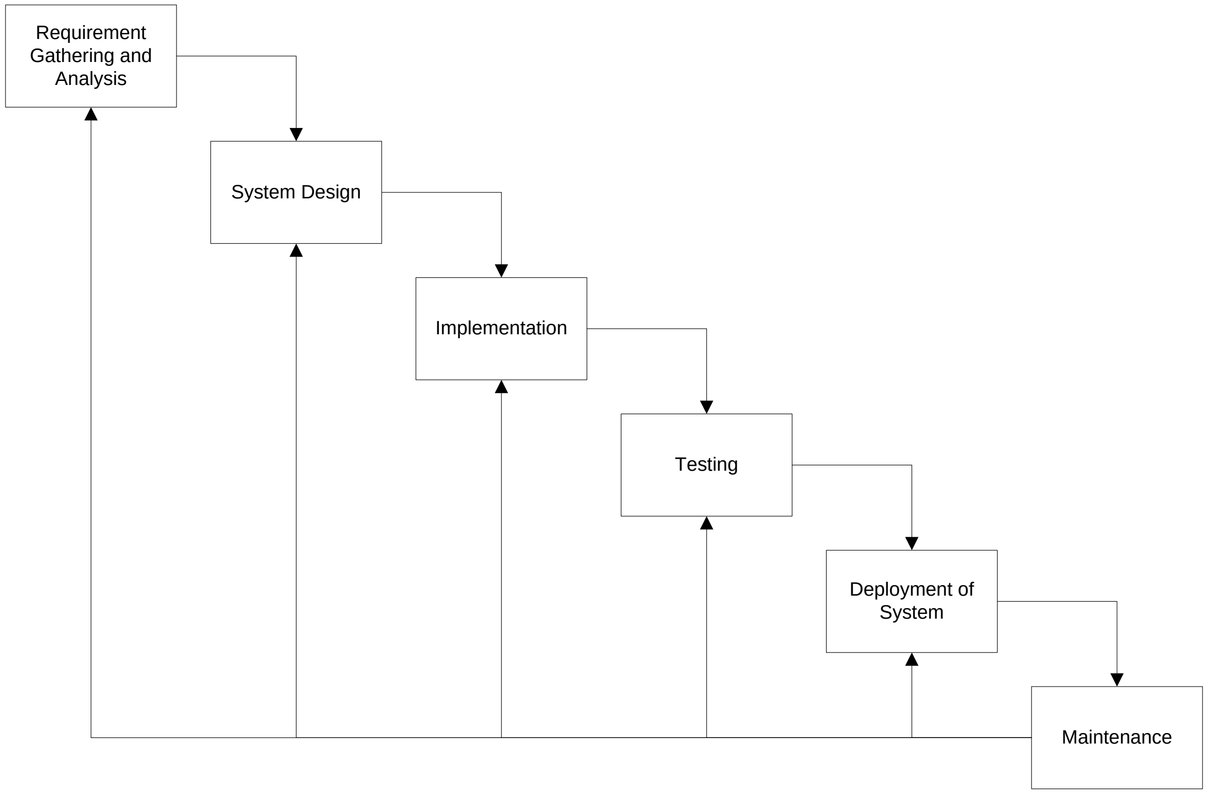
Waterfall model presented by Bentley & Whitten (2007)



Waterfall model presented by Kossiakoff et al. (2011)



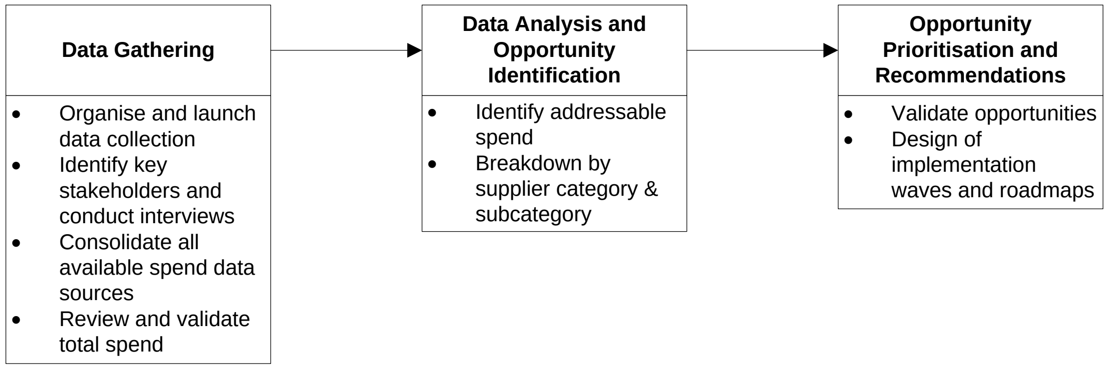
Waterfall model presented by OSQA (2009)



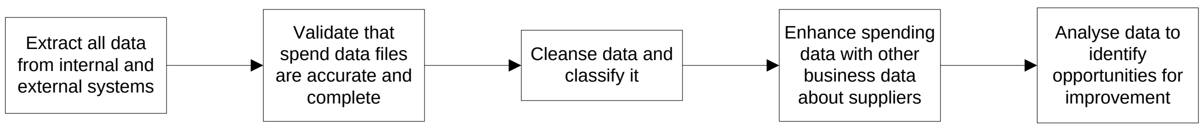
Appendix D

Spend Analysis Methodologies

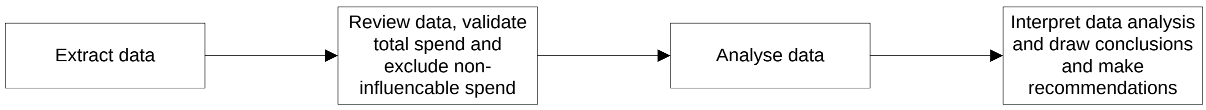
Spend analysis methodology used by Deloitte (2010)



Spend analysis methodology recommended by the Aberdeen Group (2004)



Spend analysis methodology used by the National eProcurement Project (2007)



Appendix E

Generic User Manual Structure

1. Introduction
    - The product
    - The manual
        - Scope/Purpose
        - Flow
        - Conventions
        - Glossary
2. Installing the software
    - System requirements
        - Platform Support
    - Information/resources required in the process of installation
    - Installation steps
3. Using the software
    - Introduction
        - Purpose of the software
        - Software capabilities
        - User levels and the implications
    - Configuration
    - Invoking the software
    - Interface elements
    - Steps to perform tasks
4. Administration
    - Administration level tasks and scenarios
5. Troubleshooting
6. Appendix

Appendix F

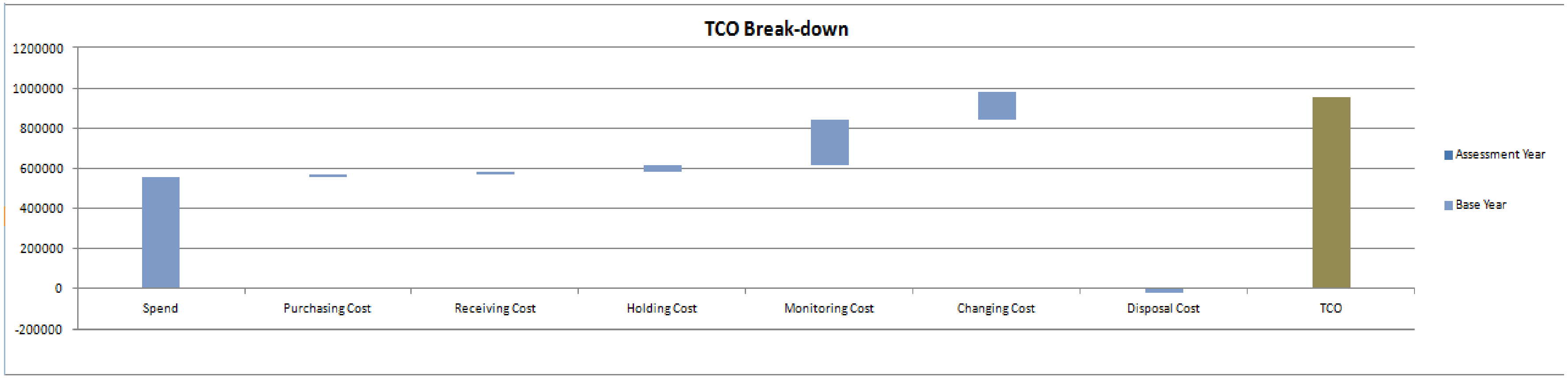
User Manual Table of Contents

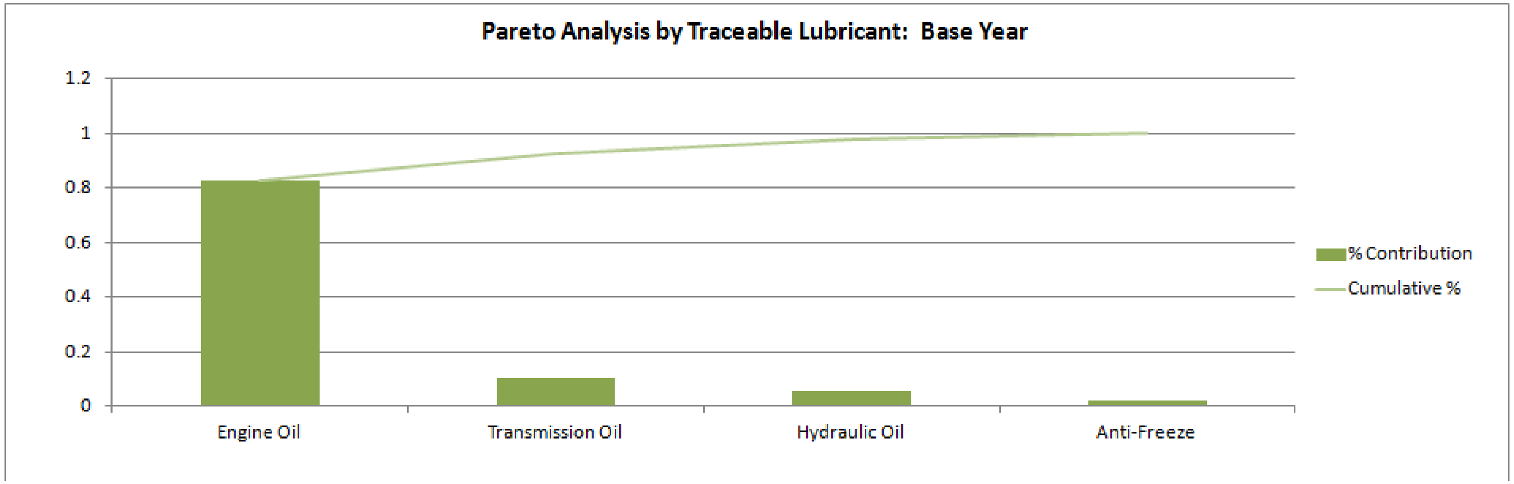
Table of Contents

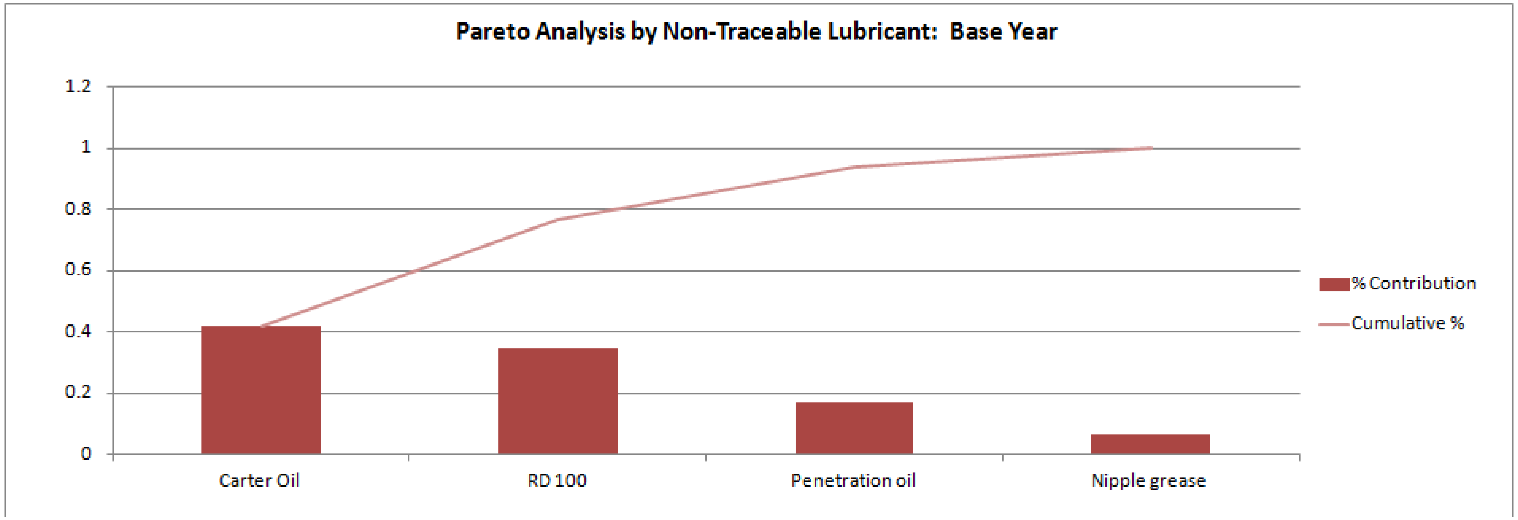
Appendix G

Validation of Dashboard portion of IS

Section 1: Analyses for mine as a whole

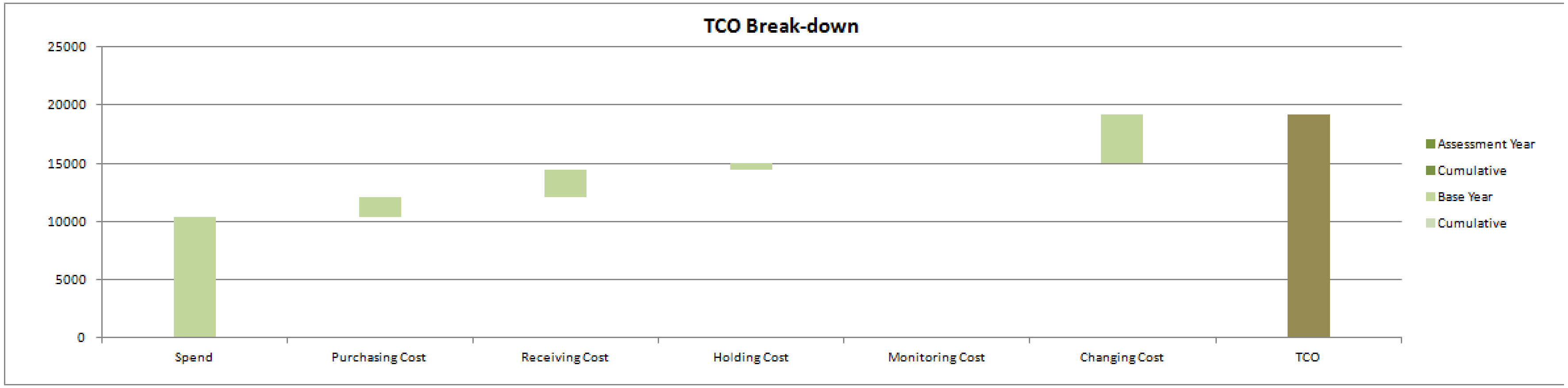


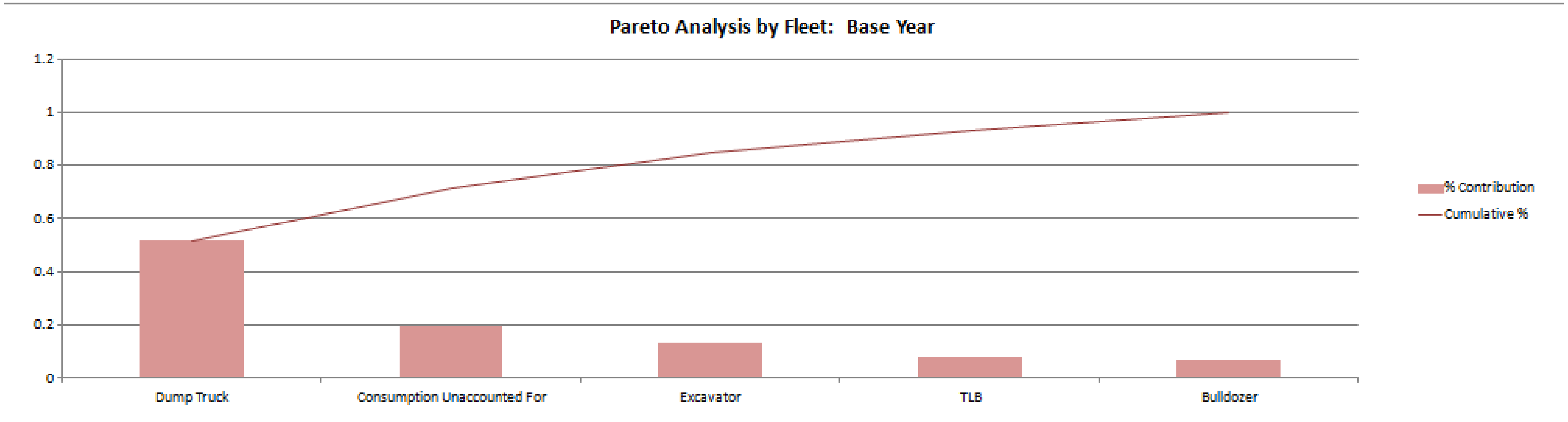



Pareto Analysis by Non-Traceable Lubricant: Base Year
1.2
1
0.8
0.6
0.4
0.2
0
Carter Oil
RD 100
Penetration oil
Nipple grease
% Contribution
Cumulative %

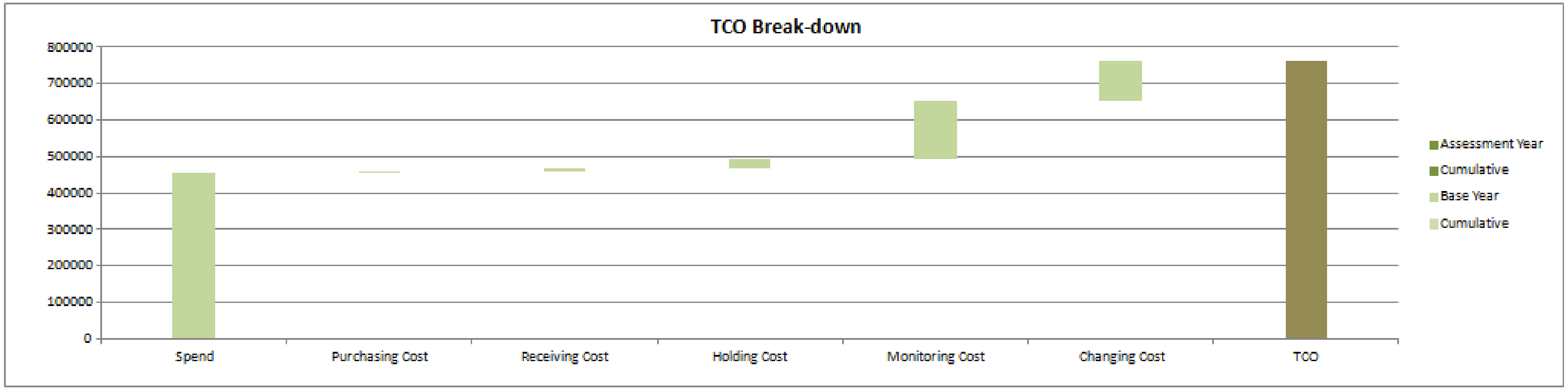
Section 2: Analyses for Traceable Lubricants

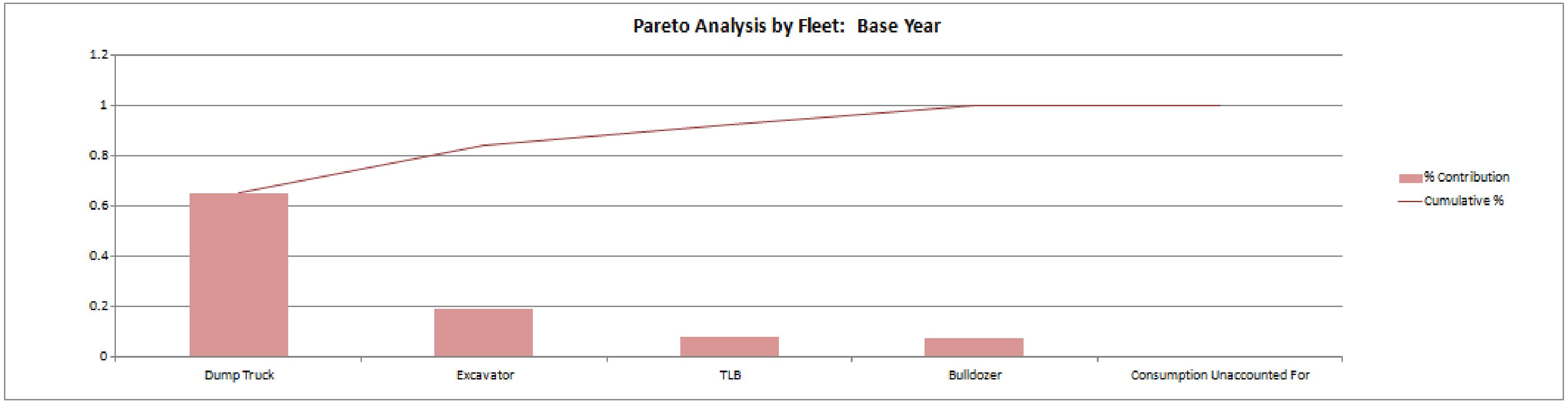
2.1 Anti-Freeze



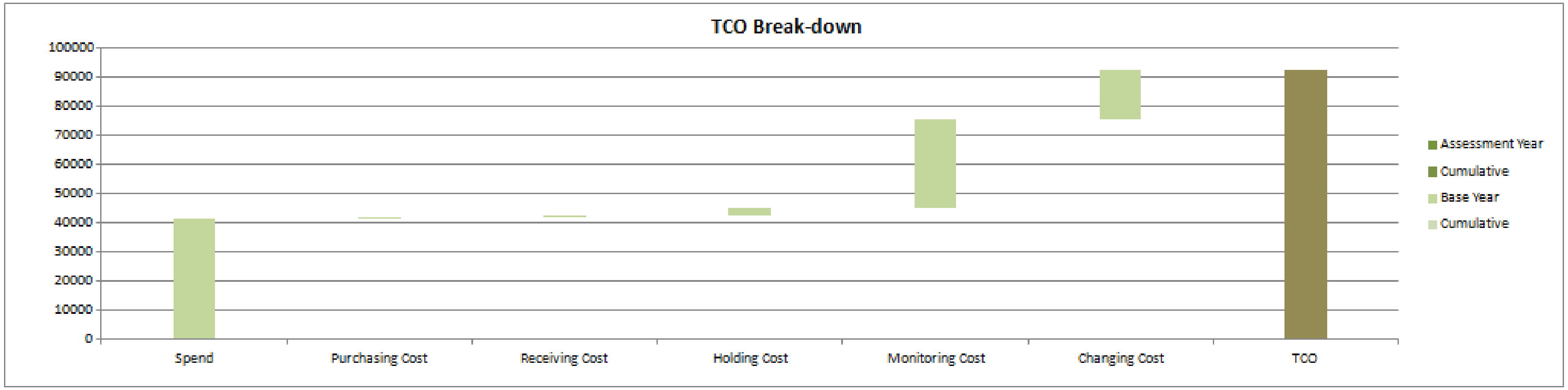


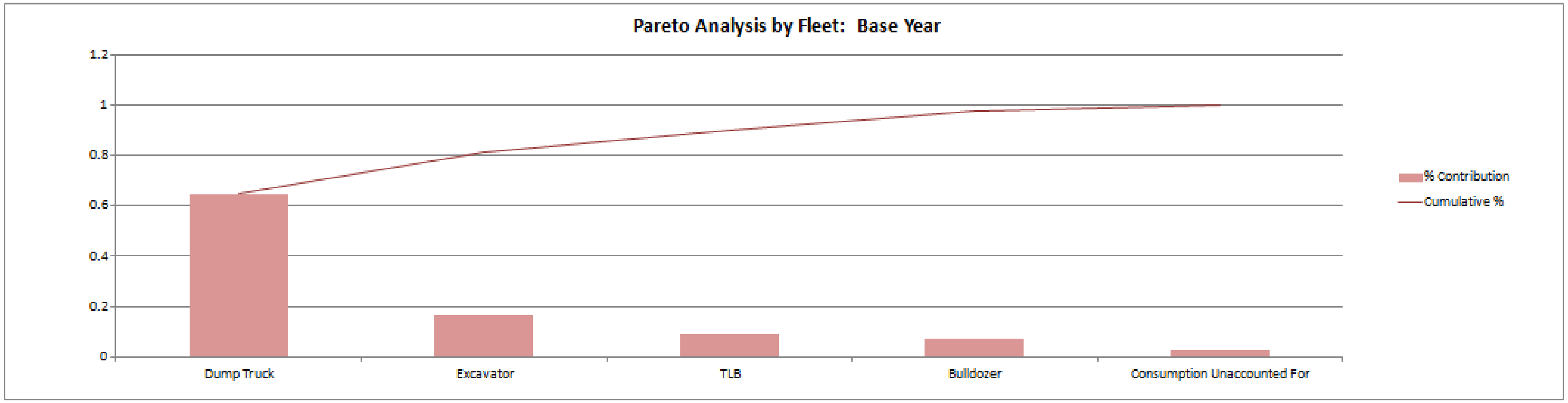
2.2 Engine Oil



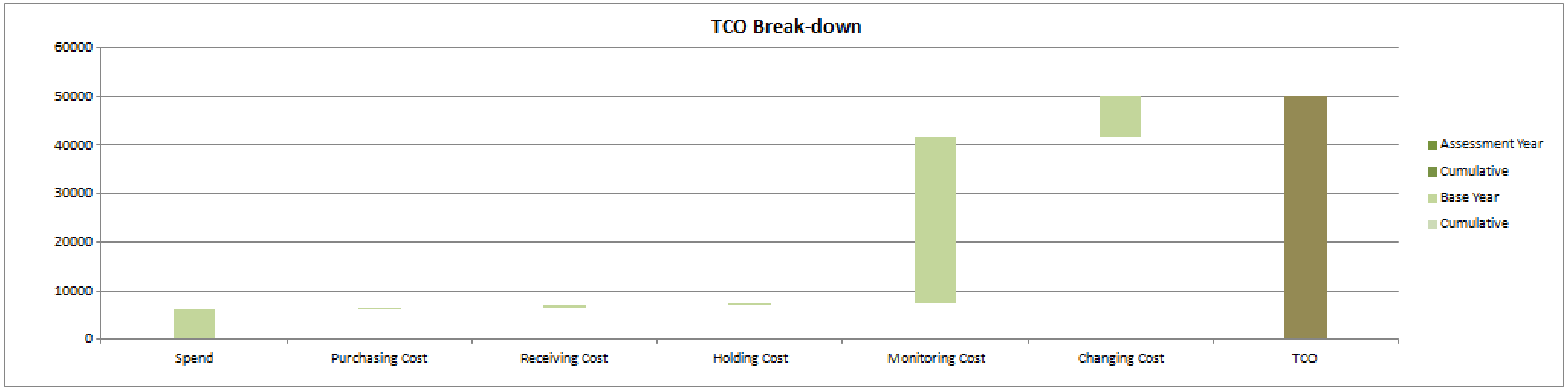


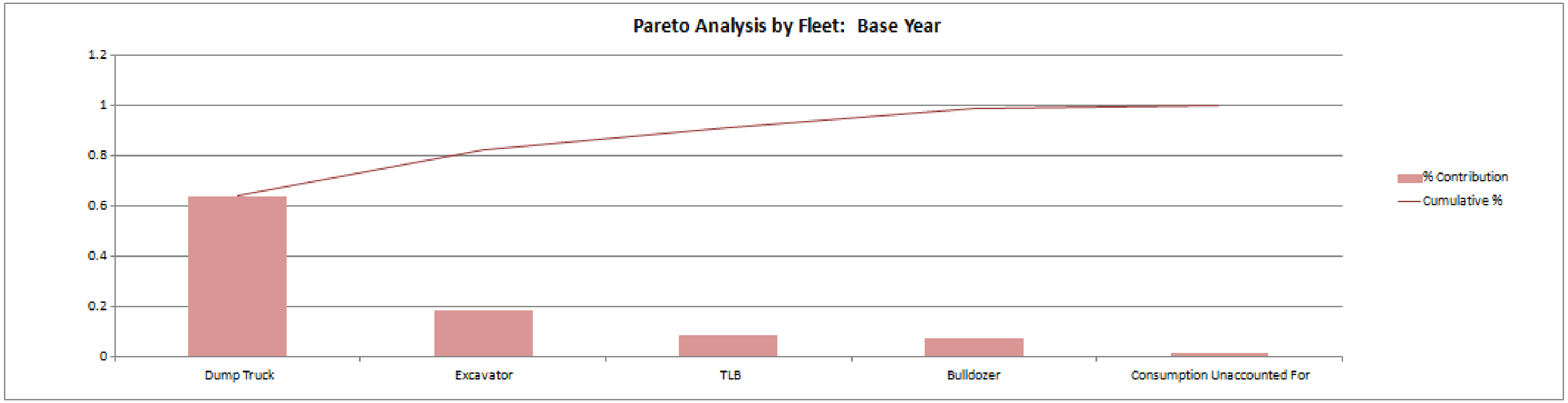
2.3 Transmission Oil





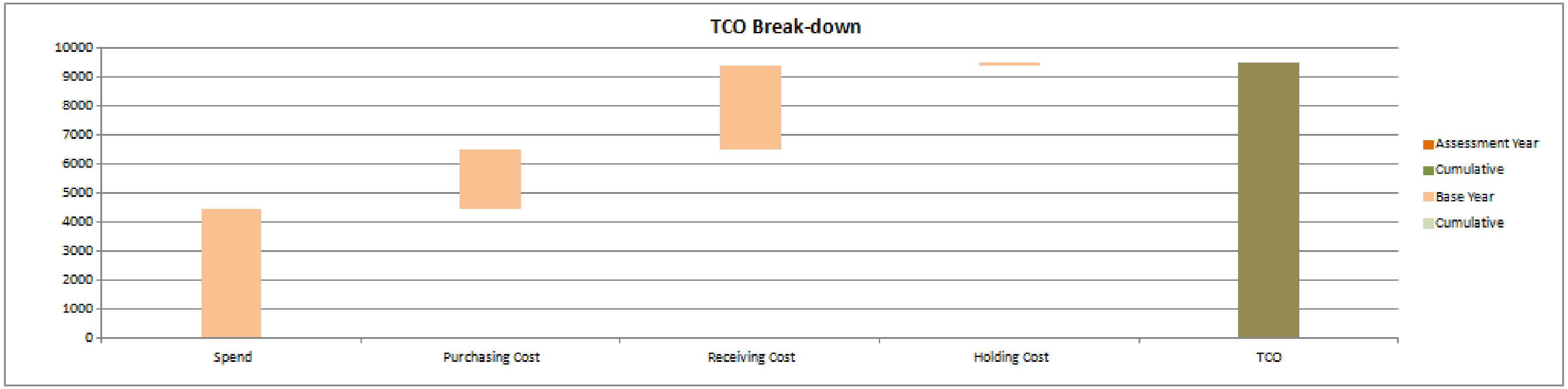
2.4 Hydraulic Oil



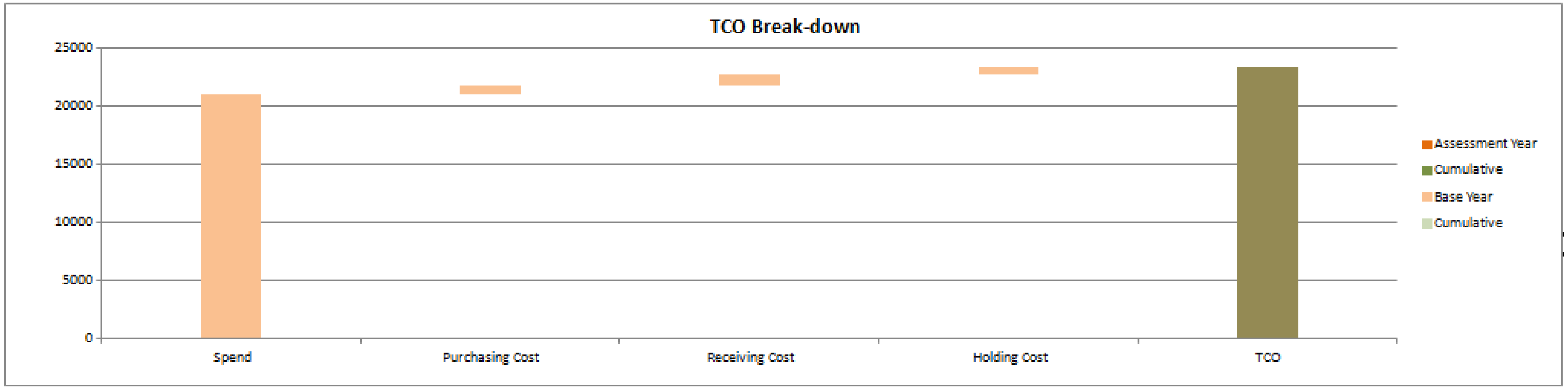


Section 3: Analyses for Non-Traceable Lubricants

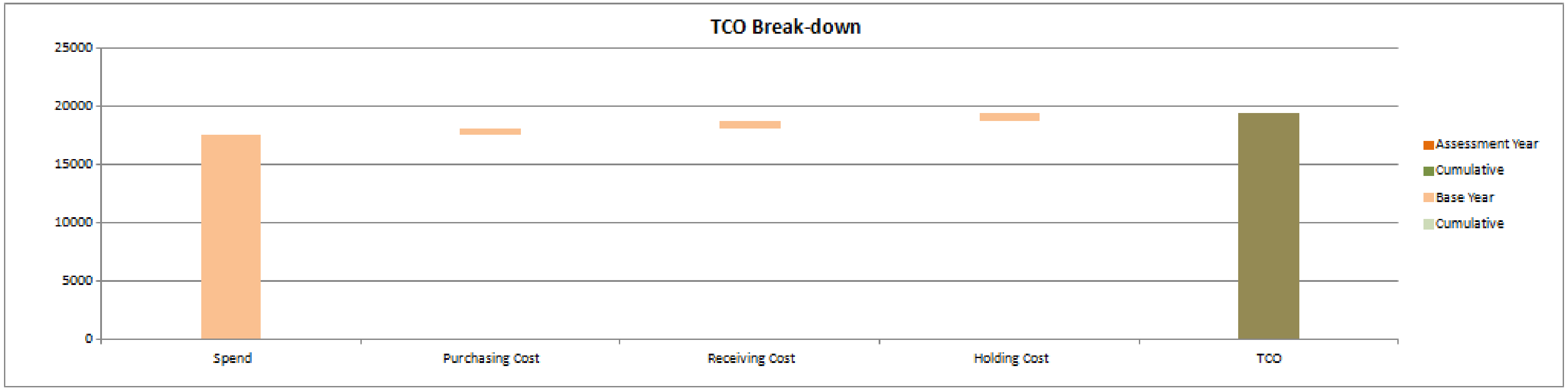
3.1 Penetration Oil



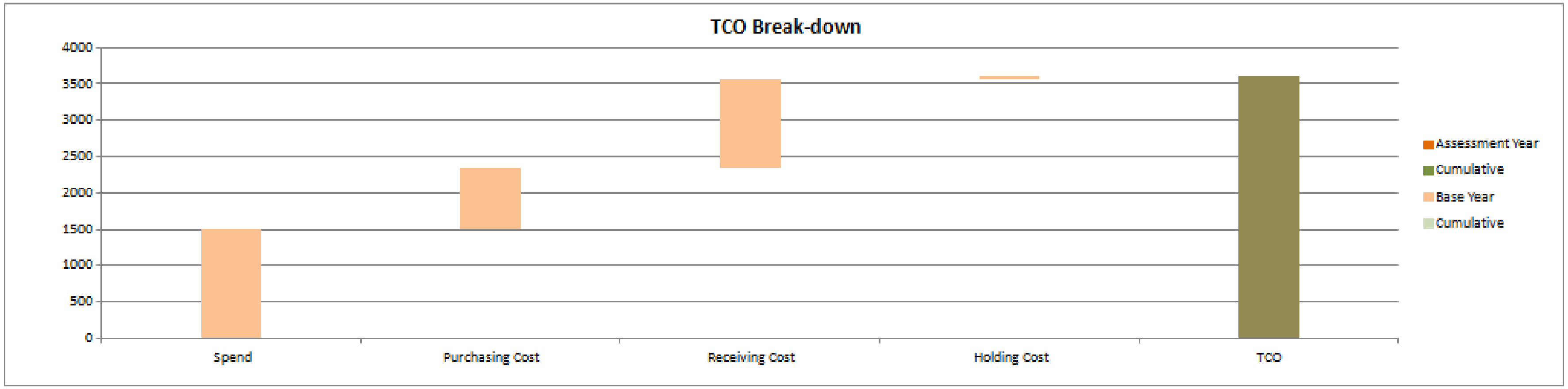
3.2 Carter Oil



3.3 RD100 Oil



3.4 Nipple Grease



Appendix H

Validation of Project Evaluator

Project 1

Scenario Impact Analysis

Project Impacts Whole BU				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Holding Cost per Unit	0.10		R -	0.00%
Cost per Order by Purchasing Department	R 169.00		R -	0.00%
Cost of Receiving Order	R 243.00		R -	0.00%
Cost of Labour per Hour	R 100.00		R -	0.00%
Average Time to Change Oil	0.50		R -	0.00%
Litres of Oil Disposed	50000.00		R -	0.00%
Rebate per Litre of Oil	R 0.50		R -	0.00%
Number of Drums Disposed	400.00		R -	0.00%
Cost per Drum Disposed	R 12.00		R -	0.00%
Rebate per Drum	R 8.00		R -	0.00%

Project Impacts Single Lubricant, and all Fleets				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Moving Avg Price	R -		R -	0.00%
No.of Orders	0.00		R -	0.00%
Cost per Oil Analysis	R -		R -	0.00%
Consumption	0.00		R -	0.00%

Select Lubricant
Transmission oil AC1

Project Impacts Single Fleet and Single Lubricant				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Number of Oil Analyses	722.00		R -	0.00%
Consumption	29120.00	5%	R 14,560.00	1.52%
Number of Changes (only affects changing cost)	1456.00		R -	0.00%

Select Fleet
Dump Truck
and Select Lubricant
Engine Oil

Project Data

Project 1	
Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 1	R 60,800.00

Annual savings (from scenario impact analysis)			
Item		Amount	NPV
Decreased consumption		R 14,560.00	R 72,800.00

Recurring costs			
Item	Years between	Amount	NPV
Maintenance costs	1	R 2,400.00	R -12,000.00

Criteria 2: Payback Period	
Payback Period in years	0

Year	BOY Unrecovered cash	Cash outflow	Cash inflow	EOY Unrecovered cash
1	R -	R 2,400.00	R 14,560.00	R -

Criteria 3: Time to Implement Project	
Amount of time (in months) to implement project	3

Criteria 4: Difficulty of Implementation	
Weighted Difficulty of Implementation	1.4

Factors affecting difficulty	Weight of factor	Factor rating	Weighted Rating
Operational changes	20%	Medium	0.6
Changes to business systems	25%	Low	0.25
Changes to commercial strategies	25%	Low	0.25
Changes to technical specs and/or designs	30%	Low	0.3

Project 2

Scenario Impact Analysis

Project Impacts Whole BU				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Holding Cost per Unit	0.10		R -	0.00%
Cost per Order by Purchasing Department	R 169.00		R -	0.00%
Cost of Receiving Order	R 243.00		R -	0.00%
Cost of Labour per Hour	R 100.00		R -	0.00%
Average Time to Change Oil	0.50		R -	0.00%
Litres of Oil Disposed	50000.00		R -	0.00%
Rebate per Litre of Oil	R 0.50		R -	0.00%
Number of Drums Disposed	400.00		R -	0.00%
Cost per Drum Disposed	R 12.00		R -	0.00%
Rebate per Drum	R 8.00		R -	0.00%

Project Impacts Single Lubricant, and all Fleets				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Moving Avg Price	R 7.00		R -	0.00%
No.of Orders	2.00		R -	0.00%
Cost per Oil Analysis	R 400.00	65%	R 22,100.00	2.31%
Consumption	900.00		R -	0.00%

Select Lubricant
Hydraulic Oil

Project Impacts Single Fleet and Single Lubricant				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Number of Oil Analyses	722.00		R -	0.00%
Consumption	29120.00		R -	0.00%
Number of Changes (only affects changing cost)	1456.00		R -	0.00%

Select Fleet
Dump Truck
and Select Lubricant
Engine Oil

Project Data

Project 2	
Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 2	R 35,500.00

Annual savings (from scenario impact analysis)			
Item		Amount	NPV
Decrease Monitoring Cost		R 22,100.00	R 110,500.00

Once-off costs			
Item	Year	Amount	NPV
Upgrade current testing facilities	0	R 75,000.00	R -75,000.00

Criteria 2: Payback Period	
Payback Period in years	4

Year	BOY Unrecovered cash	Cash outflow	Cash inflow	EOY Unrecovered cash
1	R 75,000.00	R -	R 22,100.00	R 52,900.00
2	R 52,900.00	R -	R 22,100.00	R 30,800.00
3	R 30,800.00	R -	R 22,100.00	R 8,700.00
4	R 8,700.00	R -	R 22,100.00	R -

Criteria 3: Time to Implement Project	
Amount of time (in months) to implement project	12

Criteria 4: Difficulty of Implementation	
Weighted Difficulty of Implementation	2.25

Factors affecting difficulty	Weight of factor	Factor rating	Weighted Rating
Operational changes	20%	Medium	0.6
Changes to business systems	25%	Low-medium	0.5
Changes to commercial strategies	25%	Low	0.25
Changes to technical specs and/or designs	30%	Medium	0.9

Project 3

Scenario Impact Analysis

Project Impacts Whole BU				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Holding Cost per Unit	0.10		R -	0.00%
Cost per Order by Purchasing Department	R 169.00		R -	0.00%
Cost of Receiving Order	R 243.00		R -	0.00%
Cost of Labour per Hour	R 100.00		R -	0.00%
Average Time to Change Oil	0.50		R -	0.00%
Litres of Oil Disposed	50000.00		R -	0.00%
Rebate per Litre of Oil	R 0.50		R -	0.00%
Number of Drums Disposed	400.00		R -	0.00%
Cost per Drum Disposed	R 12.00		R -	0.00%
Rebate per Drum	R 8.00		R -	0.00%

Project Impacts Single Lubricant, and all Fleets				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Moving Avg Price	R 57.00		R -	0.00%
No.of Orders	12.00	50%	R 2,472.00	0.26%
Cost per Oil Analysis	R -		R -	0.00%
Consumption	0.00		R -	0.00%

Select Lubricant

Penetration oil

Project Impacts Single Fleet and Single Lubricant				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Number of Oil Analyses	722.00		R -	0.00%
Consumption	29120.00		R -	0.00%
Number of Changes (only affects changing cost)	1456.00		R -	0.00%

Select Fleet

Dump Truck

and Select Lubricant

Engine Oil

Project Impacts Whole BU				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Holding Cost per Unit	0.10		R -	0.00%
Cost per Order by Purchasing Department	R 169.00		R -	0.00%
Cost of Receiving Order	R 243.00		R -	0.00%
Cost of Labour per Hour	R 100.00		R -	0.00%
Average Time to Change Oil	0.50		R -	0.00%
Litres of Oil Disposed	50000.00		R -	0.00%
Rebate per Litre of Oil	R 0.50		R -	0.00%
Number of Drums Disposed	400.00		R -	0.00%
Cost per Drum Disposed	R 12.00		R -	0.00%
Rebate per Drum	R 8.00		R -	0.00%

Project Impacts Single Lubricant, and all Fleets				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Moving Avg Price	R 19.00		R -	0.00%
No.of Orders	5.00	50%	R 1,030.00	0.11%
Cost per Oil Analysis	R -		R -	0.00%
Consumption	79.00		R -	0.00%

Select Lubricant

Nipple grease

Project Impacts Single Fleet and Single Lubricant				
Variable	**Base Data**	**Potential Decrease in Variable (%)**	**Decrease in TCO (Rand)**	**Decrease in TCO (%)**
Number of Oil Analyses	722.00		R -	0.00%
Consumption	29120.00		R -	0.00%
Number of Changes (only affects changing cost)	1456.00		R -	0.00%

Select Fleet

Dump Truck

and Select Lubricant

Engine Oil

Project Data

Project 3	

Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 3	R 17,510.00

Annual savings (from scenario impact analysis)			
Item		Amount	NPV
		R 3,502.00	R 17,510.00

Criteria 2: Payback Period	
Payback Period in years	0

Year	BOY Unrecovered cash	Cash outflow	Cash inflow	EOY Unrecovered cash
1	R -	R -	R 3,502.00	R -

Criteria 3: Time to Implement Project	
Amount of time (in months) to implement project	1

Criteria 4: Difficulty of Implementation	
Weighted Difficulty of Implementation	1

Factors affecting difficulty	Weight of factor	Factor rating	Weighted Rating
Operational changes	20%	Low	0.2
Changes to business systems	25%	Low	0.25
Changes to commercial strategies	25%	Low	0.25
Changes to technical specs and/or d	30%	Low	0.3

Project 4

Scenario Impact Analysis

Project Impacts Whole BU				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Holding Cost per Unit	0.10		R -	0.00%
Cost per Order by Purchasing Department	R 169.00		R -	0.00%
Cost of Receiving Order	R 243.00		R -	0.00%
Cost of Labour per Hour	R 100.00		R -	0.00%
Average Time to Change Oil	0.50		R -	0.00%
Litres of Oil Disposed	50000.00		R -	0.00%
Rebate per Litre of Oil	R 0.50	-100%	R 25,000.00	2.62%
Number of Drums Disposed	400.00		R -	0.00%
Cost per Drum Disposed	R 12.00		R -	0.00%
Rebate per Drum	R 8.00		R -	0.00%

Project Impacts Single Lubricant, and all Fleets				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Moving Avg Price	R 19.00		R -	0.00%
No.of Orders	5.00		R -	0.00%
Cost per Oil Analysis	R -		R -	0.00%
Consumption	79.00		R -	0.00%

Select Lubricant
Nipple grease

Project Impacts Single Fleet and Single Lubricant				
Variable	Base Data	Potential Decrease in Variable (%)	Decrease in TCO (Rand)	Decrease in TCO (%)
Number of Oil Analyses	722.00		R -	0.00%
Consumption	29120.00		R -	0.00%
Number of Changes (only affects changing cost)	1456.00		R -	0.00%

Select Fleet
Dump Truck
and Select Lubricant
Engine Oil

Project Data

Project 4

Criteria 1: Profitability or NPV	
Minimum Acceptable Rate of Return (%)	20%
Total NPV, Project 4	R 50,000.00

Annual savings (from scenario impact analysis)			
Item		Amount	NPV
Increase rebate per litre of oil		R 25,000.00	R 125,000.00

Once-off costs			
Item	Year	Amount	NPV
Penalty, breach of contract	0	R 75,000.00	R -75,000.00

Criteria 2: Payback Period	
Payback Period in years	3

Year	BOY Unrecovered cash	Cash outflow	Cash inflow	EOY Unrecovered cash
1	R 75,000.00	R -	R 25,000.00	R 50,000.00
2	R 50,000.00	R -	R 25,000.00	R 25,000.00
3	R 25,000.00	R -	R 25,000.00	R -

Criteria 3: Time to Implement Project	
Amount of time (in months) to implement project	2

Criteria 4: Difficulty of Implementation	
Weighted Difficulty of Implementation	1

Factors affecting difficulty	Weight of factor	Factor rating	Weighted Rating
Operational changes	20%	Low	0.2
Changes to business systems	25%	Low	0.25
Changes to commercial strategies	25%	Low	0.25
Changes to technical specs and/or designs	30%	Low	0.3

AHP Analysis

Criteria ranking

More important criterion	Rate Importance of Criteria			Numerical rating
Profitability or NPV Payback Period	Profitability or NPV	is more important than	Payback Period	7.0
Time to Implement Project Difficulty of Implementation	Difficulty of Implementation	is more important than	Time to Implement Project	5.0
Profitability or NPV Time to Implement Project	Profitability or NPV	is more important than	Time to Implement Project	5.0
Profitability or NPV Difficulty of Implementation	Profitability or NPV	is more important than	Difficulty of Implementation	4.0
Payback Period Time to Implement Project	Time to Implement Project	is more important than	Payback Period	2.0
Payback Period Difficulty of Implementation	Difficulty of Implementation	is more important than	Payback Period	4.0

Numerical rating Scale

1: Objectives i and j are equally important
3: Objective i is weakly more important than objective j
5: Objective i is strongly more important than objective j
7: Objective i is very strongly more important than objective j
9: Objective i is absolutely more important than

Intermediate Calculations

Criteria Comparison and Weight Calculation

	Profitability or NPV	Payback Period	Time to Implement Project	Difficulty of Implementation	Criteria Weights
Profitability or NPV	1.00	7.00	5.00	3.00	0.55
Payback Period	0.14	1.00	0.50	0.25	0.06
Time to Implement Project	0.20	2.00	1.00	0.20	0.10
Difficulty of Implementation	0.33	4.00	5.00	1.00	0.29
					1.00

Project Comparison With Respect to Profitability

	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	2.08	9.00	1.28	0.42
Project 2	0.48	1.00	4.32	0.62	0.20
Project 3	0.11	0.23	1.00	0.14	0.05
Project 4	0.78	1.62	7.00	1.00	0.33
					1.00

Project Comparison With Respect to Payback Period

	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	9.00	1.00	7.00	0.41
Project 2	0.11	1.00	0.11	0.78	0.05
Project 3	1.00	9.00	1.00	7.00	0.41
Project 4	0.14	1.29	1.00	1.00	0.13
					1.00

Project Comparison With Respect to Time to Implement the Project

	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	3.67	0.41	0.70	0.19
Project 2	0.27	1.00	0.11	0.19	0.05
Project 3	2.45	9.00	1.00	1.73	0.46
Project 4	1.42	5.21	1.00	1.00	0.31
					1.00

Project Comparison With Respect to Difficulty of Implementation

	Project 1	Project 2	Project 3	Project 4	Project Weights
Project 1	1.00	2.53	0.28	0.28	0.12
Project 2	0.40	1.00	0.11	0.11	0.05
Project 3	3.56	9.00	1.00	1.00	0.42
Project 4	3.56	9.00	1.00	1.00	0.42
					1.00

Final Project Ranking

Overall Project Rating

Project 1	0.31
Project 2	0.13
Project 3	0.22
Project 4	0.34

Therefore, in order of priority, implement:		
	Project 4	first,
	Project 1	second,
	Project 3	third, and
	Project 2	last.