A SYSTEMS ENGINEERING APPROACH TO IMPROVE THE MEASUREMENT AND VERIFICATION PROCESS OF ENERGY SERVICES COMPANIES

Alicha L. Meek

24083127

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Supervisor: Prof. M. Kleingeld

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ABSTRACT

The extensive use of fossil fuels coupled with its decreasing availability has ignited many countries to enact policies on energy usage. Energy Services Companies (ESCOs) all over the world are implementing initiatives to save energy. The South African ESCO industry must still overcome many barriers for it to be as effective as other global ESCOs. One of the stakeholders of an energy-savings intervention is the measurement and verification (M&V) team. The M&V team aims to provide objective and independent quantification of energy savings realised during an intervention. Despite the importance of the M&V function, the M&V process was shown to be inefficient, lacking in standardisation and research.

The focus of this dissertation is to identify opportunities for improvement within the M&V process and to determine methods for the easy management thereof. The first two research aims are met by evaluating the process and determining the requirements for improving the process with regard to the critical areas that were identified. It is realised that the management of the M&V process could be simplified by using an information management system. This leads to the design of an information management system for the M&V process using the knowledge obtained during the evaluation.

A case study is performed on one of South Africa's largest ESCOs. The findings of the case study underline improvements regarding certain performance indicators. Moreover, the findings suggest that an information management system can support all the desired process requirements.

KEYWORDS

Measurement and verification (M&V); M&V process; business process; ESCO; business process improvement.

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List of Abbreviations

BDS	Baseline Development Sheet
BPM	Business Process Management
BPMN	Business Process Modelling Notation
BPR	Business Process Reengineering
DBMS	Database management system
DHT	Data-Handling Technologies
DSM	Demand Side Management
EA	Energy Audit
EE	Energy Efficiency
EPC	Energy Performance Contract
ESCO	Energy Services Companies
EU	European Union
EVO	Energy Valuation Organisation
GUI	Graphical User Interface
IDEF	Integration Definition
IDM	Integrated Demand Management
IPMVP	International Performance Measurement and Verification Protocol
IS	Information System
IT	Information Technology
LS	Load Shifting
M&V	Measurement and Verification
MAVIS	Measurement and Verification Information System
MOM	Minutes of Meetings
NEC	New Engineering Contract
PAIS	Process-aware Information Systems
PC	Peak Clipping
PE	Project Engineer
PIECES	Performance, Information, Economy, Control, Efficiency, Service
QMS	Quality Management System
RDMS	Relational database management system
SD&L	Skills Development and Localisation
SQL	Structured Query Language
UML	Unified Modelling Language

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 PREAMBLE

The extensive use of fossil fuels coupled with the decreasing availability of the resource has motivated many countries to enact policies regarding energy usage (Fang, 2012). In South Africa, Energy Services Companies (ESCOs) assist the local electricity utility, Eskom, to supply the energy demand of the country. Alongside the implementation of energy cost-saving projects an ESCO must carefully consider the task of correctly calculating the savings achieved. This is because savings as a result of energy interventions are in effect the absence of energy. For this reason special methods were established to measure and verify the savings achieved during energy cost-saving projects.

1.2 ENERGY SERVICES COMPANIES

1.2.1. GENERAL

The extent to which the world relies on and uses fossil fuels may be a significant contributor to greenhouse gas emissions (Fang, 2012). As a result climate change and environmental concerns have arisen (Vine, 2005). Apart from the environmental challenges, the energy demand in developing countries is also on the increase (Ellis, 2010). All across the globe the

high energy prices and energy shortage intensify the interest in, and the development of the ESCO industry (Vine, 2005; Ürge-Vorsatz *et al.*, 2007).

A global ESCO is a company that specialises in developing, installing and financing energy performance contracts (EPC) (Vine, 2005; Ellis, 2010). The ESCOs remuneration is dependent on the energy savings achieved during the lifetime of an EPC (Satchwell, 2010). Measurement and verification (M&V) of energy cost savings is a main area of performance contracting and will be discussed in the next section.

ESCO projects also include energy efficiency technology, installation and maintenance of energy efficiency equipment and finally the M&V of the project's contracted energy savings (Vine, 2005; 2008; Ellis, 2010; Marino, 2011). While EPC forms the largest part of the ESCO model there are a number of additional energy cost-saving methods that are employed.

1.2.2. ESCOs WORLDWIDE

It is said that performance contracting was pioneered in Europe over 100 years ago (Vine, 2005; Bertoldi, 2006 cited in Ürge-Vorsatz *et al.*, 2007). The industry experienced a dormant period from its birth until the 1970s when the need for ESCOs resurfaced in the USA. An oil crisis led to an increase in energy prices and the need to take action towards energy-saving measures were evident. USA has been the leader in ESCO activities ever since (Fang, 2012). This is in many parts due to the support provided by the US government.

In the late 20th century the ESCO industry was once again found in Europe. The strength of the industry, however still varies greatly. Bertoldi (2006) and Ellis (2010) concur that Germany and Austria are the two European Union (EU) nations that have seen the most success in the ESCO industry. Most of the other EU countries, such as Denmark and the Netherlands, are still struggling to establish their ESCO status. In contrast Marino (2011) pointed out that a decrease in Austria's ESCO market has been observed and France and Italy have a large number of ESCOs. Denmark, Sweden and Romania's markets experienced growth during 2007-2010. As a whole the status of the ESCO industry across Europe is unstable and must overcome some barriers before it can reach its full potential.

The growth of the ESCO industry in developing countries has received some attention in recent years. Ürge-Vorsatz *et al.* (2007) noted that in some of the largest developing countries (such as India, China and Brazil) there is a lack of growth in their ESCO industry.

According to Kostka and Shin (2013) ESCOs in China are constricted by organisation size and as a result are struggling to create trust between them and their customers. However, fortunately for Brazil, the country has received significant aid from the Canadian government and international consultants to increase the stability of its ESCO industry (Ellis, 2010). In contrast India's ESCO industry is underdeveloped despite its efforts to increase energy efficiency in the public sector (Hansen *et al.*, 2009). According to Dhingra and Julena (2005) the situation is likely to remain so if the Indian government does not provide the industry with adequate support.

As is the case for European countries, the maturity of the ESCO industry across the globe depends on many factors. These factors are as diverse as the countries influencing them; from developing countries that lack government support to developed countries with stable ESCO markets expanding their energy efficiency initiatives.

1.2.3. THE SOUTH AFRICAN ESCO INDUSTRY

South Africa is considered as a developing country and therefore has some difficulties to overcome where the ESCO industry is concerned. Kellerman (2009) identified five barriers in the South African ESCO industry, which are:

- Lack of support and leadership from the government and the electricity utility (Eskom),
- Incompetent energy efficiency project financing,
- Administrative and hidden costs enlarged by the lack of relevant procedures and policies, as well as the elongated response times associated with demand side management (DSM) programmes,
- Consumers who are not wholly informed and aware of energy efficiency measures, and
- Still relatively low energy prices in South Africa are not enough incentive for potential customers to engage in energy efficiency measures.

Eskom has a monopoly regarding the provision of energy in South Africa. The utility company has been under strain due to high electricity demand. The need for ESCOs in South Africa is mainly as a result of Eskom's need to increase its reserve margin.

Eskom established an Integrated Demand Management (IDM) division that is dedicated to managing ESCO activities (Eskom IDM, 2010). Many of the barriers identified by Kellerman (2009) have since been addressed. In support of improved energy efficiency the division established three programmes: Standard Offer Programme, Standard Product Programme and ESCO Model Programme (Eskom IDM, 2010).

For the Standard Offer Programme the project initiator receives a rebate at a predetermined rate per unit of electricity saved (Hibberd, 2012). The financial risk for both Eskom and the project developer is clearly related to the process of determining the savings. The process of independently and objectively determining energy savings is called M&V. The M&V process is therefore vital to the success of projects funded by the Standard Offer Programme.

During a Standard Product Programme less efficient technologies are replaced by more efficient counterparts. Eskom funds the alternative solution and provides a selection of IDM-approved standard products. To qualify the project must adhere to certain conditions. These conditions are all related to the measurement of the projected energy savings (Eskom IDM, 2010). Again the M&V process is essential for projects funded by the Standard Product Programme.

In the ESCO Model Programme an ESCO uses its expertise to decide on the most optimal method of obtaining results at client sites (Eskom IDM, 2010). The ESCO model of funding contains penalty clauses for underperforming projects. The penalties are put in place to ensure that the ESCO provides projected energy cost savings that are accurate, reasonable and achievable (Eskom IDM, 2010). For this reason the M&V process from an ESCO's perspective is essential to the success of its projects.

For a project from any of these programmes there are a number of stakeholders with an interest in the outcome of the project. In South Africa the stakeholders are Eskom IDM, the ESCO (project developer), the M&V team and Eskom Energy Audits (EA). The relationship between these stakeholders can be seen in Figure 1.

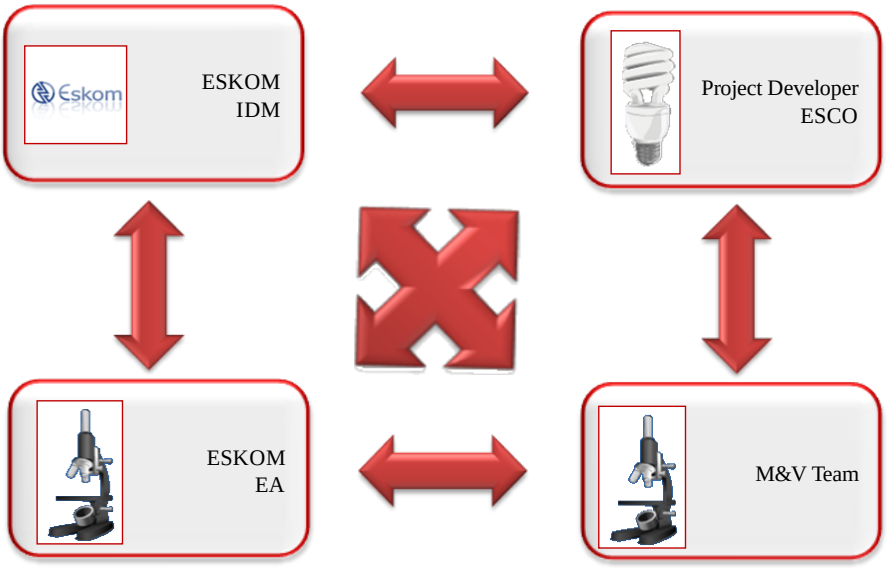

FIGURE 1: PERFORMANCE CONTRACTING PROGRAMME PROJECT STAKEHOLDERS (DEN HEIJER, 2011)

The project developer, or ESCO, performs all of the activities related to project management. They interact with Eskom IDM to approve funding for their initiatives. The M&V team has the responsibility to objectively measure energy cost savings from the project. They report the savings to the project developer, Eskom IDM as well as Eskom EA.

The client is excluded from the stakeholder group, because they do not carry any financial risk. Nevertheless, something has to be said about their imperative role in the investigation, implementation and success of energy cost-saving projects. Without the buy-in of the client, energy-cost saving projects are not possible. Energy-cost saving projects are driven by Eskom to help them manage energy demand, but the client also realises cost savings. This fact, however, makes it greatest impact not on an operational level, but on an executive one. For the simple reason that it is on an executive level where energy budgets can be observed in totality and the potential for energy-cost savings fully appreciated.

1.2.4. THE SOUTH AFRICAN ENERGY MANAGEMENT PROJECTS

In South Africa there are three types of energy cost-saving projects: load-shifting projects, peak-clipping projects and energy efficiency projects. The M&V for each of these projects differ depending on the objective of the project type.

LOAD-SHIFTING PROJECTS

Load-shifting projects are focused on shifting the energy of a system from peak periods to off-peak periods. The Eskom Megaflex tariff structure defines peak periods (as shown in red

in Figure 2) as 07:00 – 10:00 and again 18:00 – 20:00 on weekdays. Off-peak periods (shown in green in Figure 2) are weekends and 22:00 – 06:00 on working weekdays.

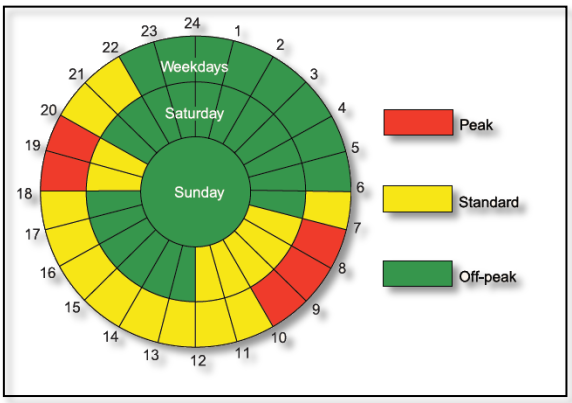

FIGURE 2: ESKOM MEGAFLEX TARIFF STRUCTURE

For example, to do load shifting a pumping system can be switched off during the evening peak. This will in effect lower the energy consumption profile of the system during that time. The project control philosophy must, however, take into consideration that the *water volumes* of the system must be maintained. In order to maintain water levels the energy use will have to be increased somewhere during the day. This is called a comeback load and will increase the energy consumption during the off-peak periods. The baselines of load-shifting projects must be scaled by M&V to be energy neutral. This means that the same amount of energy is consumed before and after project implementation. Load-shifting projects focus exclusively on energy *cost* savings.

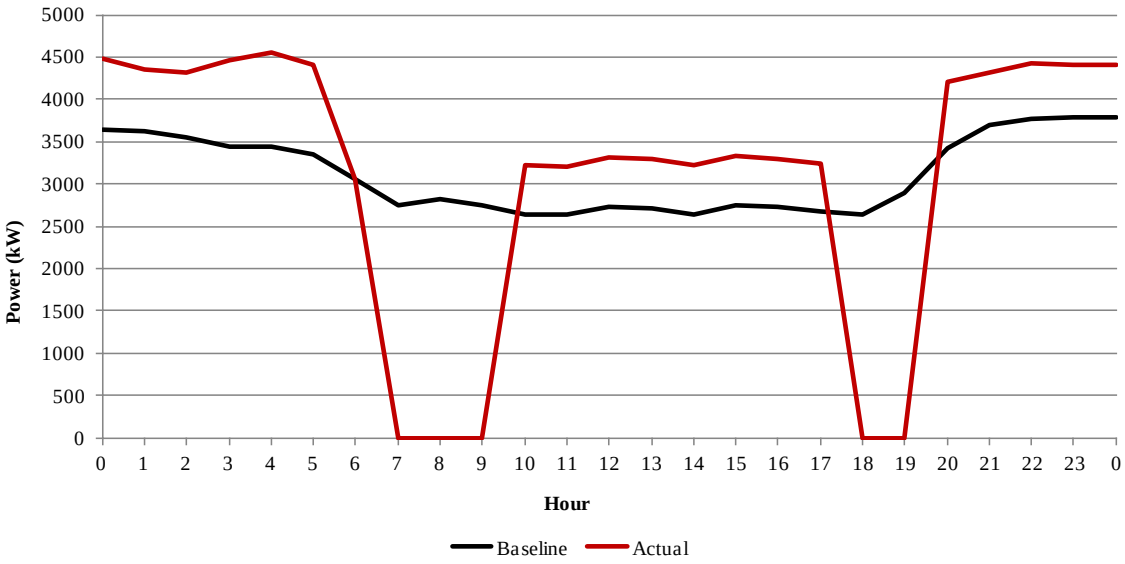

FIGURE 3: EXAMPLE OF A TYPICAL LOAD-SHIFTING BASELINE

PEAK-CLIPPING PROJECTS

Peak-clipping projects aim to permanently reduce the usage of energy during the evening peak periods (18:00 – 20:00). The energy consumption by the system decreases and therefore the baseline must be adjusted. This is called a service level adjustment (Den Heijer, 2011); the baseline that would have been is determined by scaling the established baseline according to the production of the system.

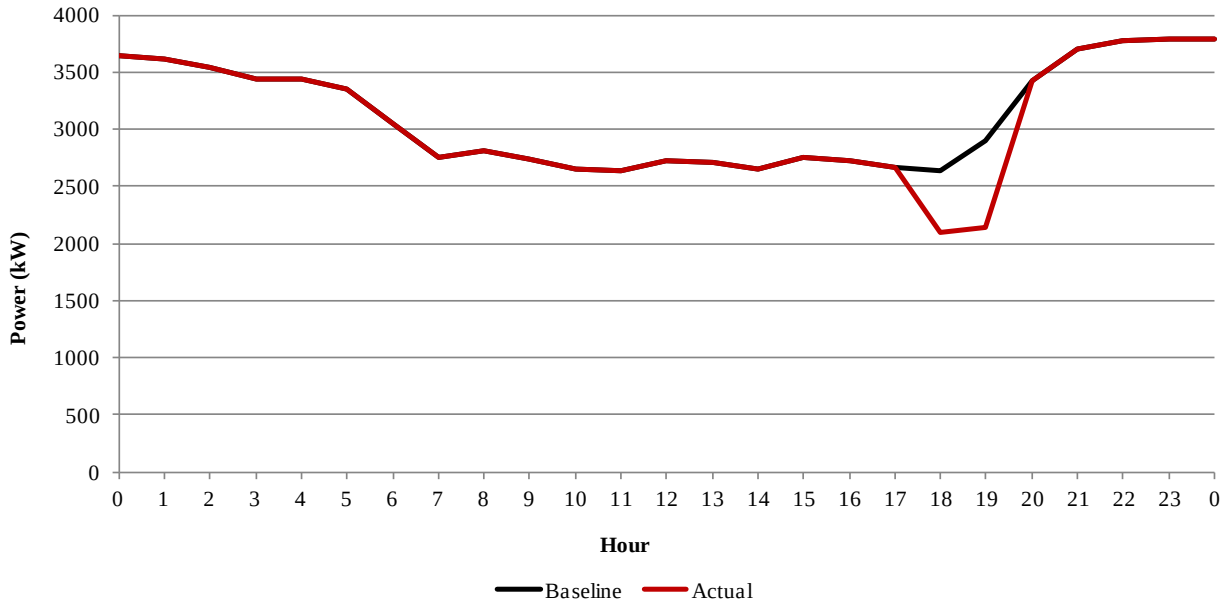

FIGURE 4: EXAMPLE OF A TYPICAL PEAK-CLIPPING BASELINE

ENERGY EFFICIENCY PROJECTS

Energy efficiency projects decrease the overall energy usage of a system by enforcing a more effective control strategy. The service level adjustments usually associated with energy efficiency projects can become complex. This is because more than production must now be taken into account. Most of the variables that cause the system to either use more or less energy must be considered.

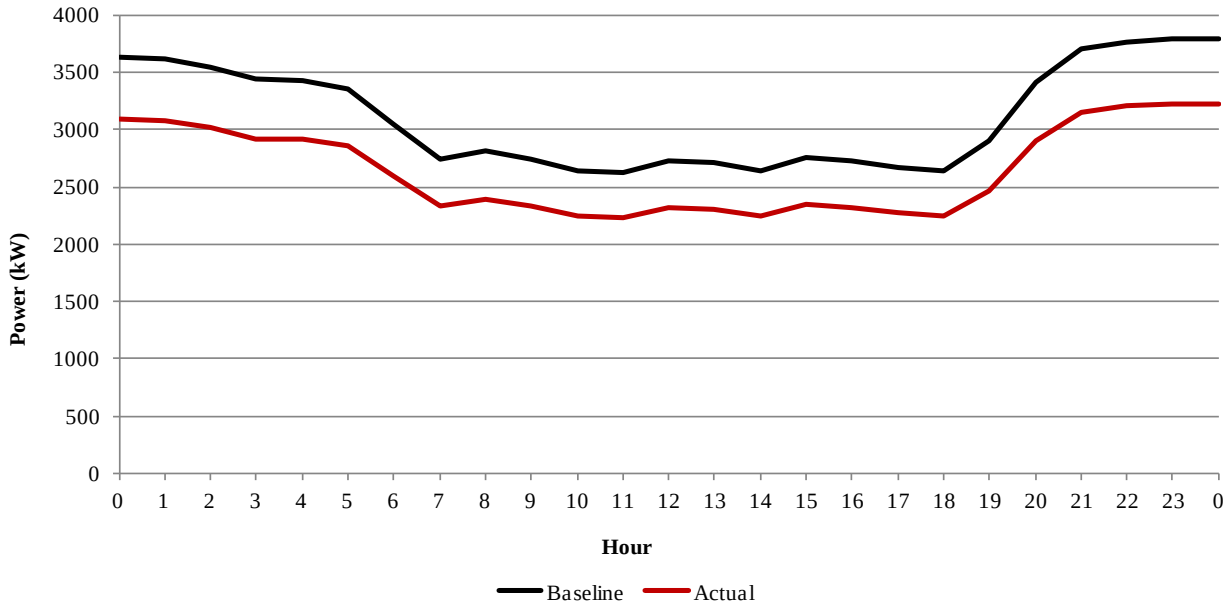

FIGURE 5: EXAMPLE OF A TYPICAL ENERGY EFFICIENCY BASELINE

M&V is a critical success factor for an energy cost-saving project that is funded by any of the three funding programmes. Strategically M&V is vital because it affects the financial aspects of an energy cost-savings project. A closer examination of the project types for the programmes reveals that M&V remains crucial. On a tactical level M&V is essential because the M&V approach may influence the energy cost savings reported.

1.3 MEASUREMENT AND VERIFICATION REQUIREMENTS

1.3.1. GENERAL

M&V is defined by the Efficiency Valuation Organization (EVO, 2010) as "the process of using measurement to reliably determine actual savings created within an individual facility by an energy management program". Since energy savings means the absence of energy, the energy saving cannot be measured directly. Another approach must therefore be taken to calculate energy savings realised from energy cost-saving projects.

M&V evaluates the impact of a project by measuring and comparing the energy consumption of a client before and after the interference by an ESCO. This is done while taking into consideration changes in system conditions.

The baseline is measured and finalised before the project is implemented. Afterwards the situation is compared to the baseline that would have been if not for the intervention from the ESCO. The difference between the two profiles is the energy savings realised. Figure 6 is an example of a baseline.

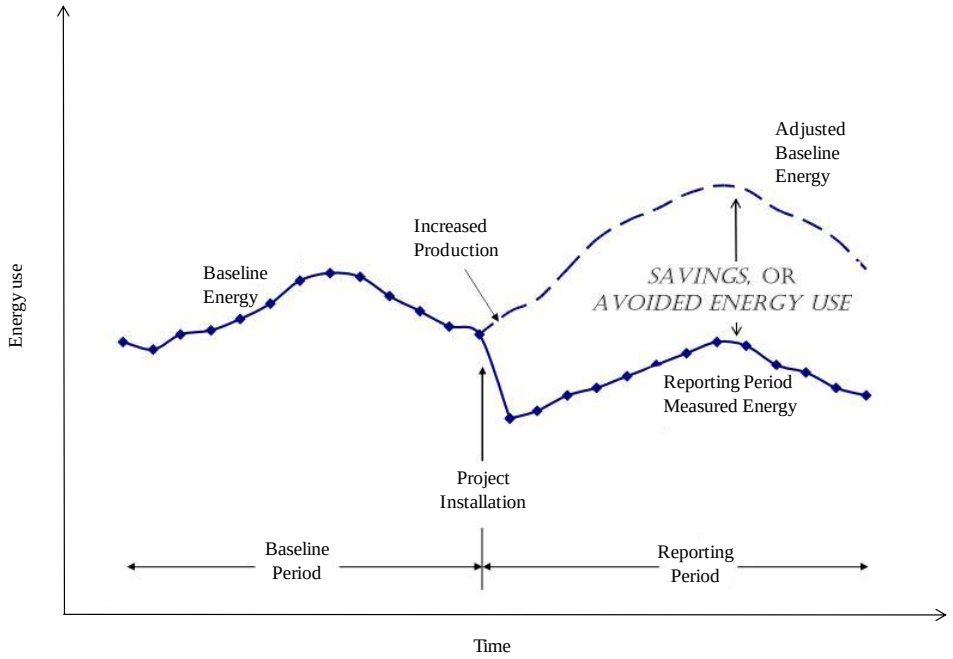

FIGURE 6: EXAMPLE OF AN ENERGY SAVINGS BASELINE

1.3.2. INTERNATIONAL MEASUREMENT AND VERIFICATION

The EVO promotes standardised methods for the M&V of energy cost-saving projects. The EVO set forth the International Performance Measurement and Verification Protocol (IPMVP) that outlines the rules for formatting and transmitting data regarding energy savings.

The IPMVP lists M&V activities as the following (EVO, 2010):

- Data-handling technologies (DHT) and its installation, calibration and maintenance**,**
- Collecting data**,**
- Determining the approach to the M&V,
- Developing the baseline, and
- Reporting.

The activities are comprehensive and give a general overview of what is needed to determine energy cost savings. The protocol outlines in great detail the framework required for M&V

plans, options and calculations. IPMVP is summarised in a guidance document detailing the usual methods of measuring, computing and reporting on savings achieved by energy cost-saving projects. The focus mainly falls on the plans and methods to determine energy savings as opposed to the process of activities.

1.3.3. HOW M&V WORKS

The M&V process consists of the following stages: investigation, Eskom approval, baseline development, performance assessment and performance tracking. Each of these stages has specific deliverables. The six deliverables of M&V are (Den Heijer, 2011):

- M&V scoping report (including metering evaluation),
- M&V plan,
- M&V baseline report (draft and final),
- Post-implementation M&V report,
- Performance assessment reports, and
- Performance tracking reports (monthly, annual, or per agreed interval).

INVESTIGATION

Once a project has been identified, the ESCO will perform energy audits and make assumptions based on findings obtained during an investigation phase. Infrastructure upgrades or implementations that facilitate the project's aim will be recommended. These recommendations are based on projected energy-saving opportunities. The ESCO submits a proposal to Eskom detailing possible savings and recommended changes to achieve the savings. The ESCO determines the saving opportunities using M&V techniques and must therefore have knowledge of M&V.

ESKOM APPROVAL

The ESCO will keep in contact with the Eskom IDM subdivision throughout the approval stages to assess project status. Once the stages are close to completion the independent M&V team will be allocated by the EA division. The M&V team will then contact the ESCO for a pre-implementation site visit. During the site visit, the ESCO will communicate the project scope and M&V plan to the team. This means that the ESCO will inform the M&V team of

available DHT and electricity-measurement technologies. The ESCO must also be aware of baseline development techniques so that the ESCO may aid the M&V team in correctly determining the M&V scope of the project. The M&V team will conclude the purpose of the meeting by preparing M&V scope and plan reports.

The *M&V plan* and *scoping report* generally describe the method for obtaining electricity consumption data, the measuring technologies involved and the project system boundary.

BASELINE DEVELOPMENT

Depending on the client's electricity-measurement technologies the process of acquiring data can take up to twelve months. This process can commence directly after the pre-implementation site visit. Once the data is obtained the M&V team can draft a *baseline report*.

The baseline report will detail the client's actual electricity consumption before project implementation. The baseline is the measure against which the performance of the project will be evaluated. The baseline report must be signed off by all the stakeholders. According to the Eskom New Engineering Contract (NEC) the baseline report must be signed off before project implementation can commence.

Things can become difficult for the ESCO if baselines were calculated incorrectly. It is therefore in the best interest of the ESCO to collaborate with the M&V team in obtaining data and to understand the process of constructing a baseline. Thus, when the M&V team is uncertain about aspects of the project and/or baseline the ESCO can step in and give guidance in the matter. The timeframe in which the M&V team and ESCO collaborate on activities with the M&V team can be a measure of the performance of the M&V process.

If the ESCO receives approval from all of the relevant stakeholders, project implementation will begin. After the project is implemented another site visit is conducted by the ESCO and the M&V team. A post-implementation report will convey that all promised installations by the ESCO have been delivered.

PERFORMANCE ASSESSMENT

The *performance assessment* period is the most crucial period during energy cost-saving projects. During this period, the electricity consumption will be measured and compared to

the aforementioned baseline. If the electricity consumption has changed according to the scope, purpose and type of project, the project is deemed a success. Monthly performance assessment reports detail the operation of this period.

It is once again in the best interest of the ESCO to give active guidance to the M&V team during the performance assessment period. If the savings reported by the M&V team are incorrect the ESCO is negatively affected.

PERFORMANCE TRACKING

Performance assessment is followed by a period during which the performance of the project is tracked. Performance tracking lasts the duration as stipulated in the contract between Eskom, the ESCO and the client. The client is expected to maintain the energy savings obtained during the performance assessment period. A performance tracking report is compiled by the M&V team at predetermined intervals during the performance tracking period.

1.4. RESEARCH MOTIVATION AND AIM

1.4.1. RESEARCH MOTIVATION

Background on the worldwide and South African ESCO industry is given and emphasis is placed on the M&V process that forms part of almost all ESCO models. Extensive detail on the activities and process stages for M&V within the South African ESCO industry is provided. These details highlight the importance of the M&V process.

PHILOSOPHICAL MOTIVATION

The motivation for this research resides in the importance of the M&V process, but more specifically, from the ESCO's point of view. Firstly, the process is essential to determine and verify the success of the ESCO's projects. Secondly, there are financial implications for the ESCO. Lastly, the ESCO's project dealings and stages influence the M&V process and vice versa. The complexity of an energy cost-savings project directly affects the M&V process

timeline; complexity of the project will influence the effort to compile, amend and adjust the baseline. So, this means that project specifics have an influence on the M&V process; ESCOs are aware of technical project variables and the effect they may have on the M&V of its energy cost savings. For this reason it is recommended that ESCOs perform their own internal M&V process.

Emphasis on the internal M&V process of an ESCO has not been a priority for the South African ESCO industry. Consequently, the benefits of improving an ESCO's M&V process have not been realised. It is important to remember that the M&V framework cannot be changed and that the improvements made to the ESCO's M&V process take place within that fixed framework.

THEORETICAL MOTIVATION

Further motivation for this research topic stems from a quick analysis of the current M&V process performed within an ESCO. Wetherbe and Vitalari (1994) developed a framework to classify problems, opportunities and directives. It is called the *PIECES* framework, because each letter in the word represents a category of the framework. The categories are:

P *Performance*
I *Information* (and data)
E *Economics*
C *Control*
E *Efficiency*
S *Service*

PERFORMANCE

The performance of the M&V process within an ESCO has never been measured before. This means there is uncertainty regarding the amount of work performed over a period of time, or the response times of the process. This may have a negative impact on the ESCO's organisational performance as a project's implementation is postponed until the baseline report is signed by stakeholders.

INFORMATION

Data and information for the M&V process is not captured and stored in a centralised storage unit. Inadequate documentation control is a result of not having an organised system to store information.

ECONOMICS

Knowledge of costs related to the M&V process is unknown.

CONTROL

There is a lack of standardised procedures, templates and guidelines to aid the management of the M&V process.

EFFICIENCY

Measuring efficiency can be an ambiguous task. When it comes to the M&V process it will be characterised as the following: correct resources performing the correct activities in the correct amount of time.

SERVICE

There is no official system providing a service to the role players of the M&V process.

1.4.2. RESEARCH AIM

There is a lack of cognisance as far as the M&V process is concerned. According to an analysis based on categories of problems, opportunities and directives virtually nothing is known about the M&V process. Along with the ignorance of the impacts of the M&V process on an ESCOs performance potential problems may arise. These problems, however, are only speculation until the effects are quantified.

The motivation for this research is twofold. A proposal to perform and improve an M&V process within an ESCO is formed on the basis of logical reasoning. Breaking down the M&V process reveals the lack of quantifiable knowledge.

Based on the research motivation three objectives for this study are put forward:

- Evaluate the internal M&V process of an ESCO and obtain measurable data to quantify performance indicators for the process,
- Improve the M&V process of an ESCO based on the opportunities identified during evaluation (if necessary), and
- Design an information system that will support the improvements and aid the management of the M&V process.

1.5. OVERVIEW OF DISSERTATION

CHAPTER 1

In this chapter the ESCO industry throughout the globe and in South Africa is discussed. The M&V of the energy cost-saving projects developed and implemented by ESCOs were discussed. The research motivation and aim followed as a result of the recognition of M&V's importance in energy cost-saving projects.

CHAPTER 2

In Chapter 2 literature on the subject of business process environment is researched. The research includes emerging and present trends, strategies and methods in the evaluation, improvement and management of business processes; quality standards and conformance; and current trends in information systems design. Finally a strategy to absorb the research into a systems engineering approach is presented.

CHAPTER 3

In Chapter 3 the M&V process is evaluated based on the concept of the PIECES framework of Wetherbe and Vitalari (1994). Performance indicators for the M&V process are measured and hypothesised problems are validated. In conjunction with the identification of poor performance, opportunities for improvement are presented.

CHAPTER 4

Opportunities for the advancement of the M&V process are transformed into requirements followed by detail into the operational implementation. Furthermore an information system is designed to support and manage the M&V process.

CHAPTER 5

In Chapter 5 the new and improved M&V process model is applied to an actual energy cost-saving project of an ESCO. The results are compared to the measured performance data presented in Chapter 3.

CHAPTER 6

Chapter 6 concludes the dissertation and provides recommendations for further study.

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CHAPTER 2: BUSINESS PROCESS ENVIRONMENT

2.1. INTRODUCTION

The need to improve an ESCO's internal M&V process was established in Chapter 1. In this chapter literature regarding the business process environment is researched. Recent trends in the study of business processes are canvassed to determine an approach best suited to the M&V process of an ESCO.

Chapter 2 explores methods and techniques to evaluate and improve business processes. This is followed by a reflection on approaches to design information systems, as well as quality standards to consider while applying the aforementioned improvement methods and techniques.

Finally, a systems engineering approach that absorbs the relevant literature sets the course for the methodology to improve the M&V process.

2.2. BUSINESS PROCESSES

2.2.1. PREAMBLE

The ever-increasing globalisation of economic markets places persistent competitive demands on companies. So far an effective strategy to stay competitive has been to increase the value of an organisation's business performance indicators. Improving and focusing on business processes allow for a subsequent improvement of business performance indicators. (Abdolvand *et al.*, 2008; Neubauer, 2009; Trkman, 2010; Becker, 2012).

2.2.2. PROCESS ORIENTATION

Process orientation has been used as a term to describe the focus on an organisation's business processes instead of on its products and/or services (McCormack & Johnson, 2001). The benefits of process orientation have been considered by researchers such as Kohlbacher (2010). Performance indicators that showed positive effect as a result of process orientation were in the areas of speed, customer satisfaction, quality, cost and financial performance (Kohlbacher, 2010).

Kohlbacher (2010) used 26 studies to provide evidence of the benefits of process orientation. These studies support the objective of researching trends in the study of business processes.

2.2.3. BUSINESS CHANGE

Harmon (2010) regarded popular business change efforts to be in one of two classes: *Enterprise level* and *business process level*; these are categorised in terms of levels. *Enterprise level* business change is for organisations that are more established in terms of their process orientation. Researchers refer to an organisation's level of process orientation as *process maturity level* (McCormack *et al.*, 2009). Škrinjar and Trkman (2013) explain that an integrated or high level of process maturity means an organisation has based most, if not all, organisational structures and jobs on processes.

On the other side of the spectrum *business process* level change may be more appropriate for the M&V process. This is due to its focus on redesign or improving of one core business process.

In addition to the level of business change there are also degrees of change (Harmon, 2010). Degrees of change range from small improvements to complete restructuring of a business process. Business process reengineering (BPR), for example, is a process change effort with a high degree of change.

BUSINESS PROCESS REENGINEERING

BPR is the revolutionary redesign of processes with the aim of improving on business performance measures such as cost, output quality, speed and responsiveness. (Hammer & Champy, 1993; Zigiaris, 2000; Doomun & Jungum, 2008). Since it is the purpose of this dissertation to improve an ESCO's M&V process such a construct should be considered.

Vergidis (2008) feels that the BPR concept has not delivered on the improvements that have been promised. While Ozcelik (2010) claims that the impact of BPR slowly increases after execution rather than being realised during implementation. Abdolvand *et al.* (2008) further states that an organisation's readiness to implement such revolutionary change is imperative to its success. Finally Smart (2009) considers BPR to be insignificant amongst recent and upcoming approaches to process improvement.

It appears that researchers' observations about BPR vary. There are still, however, some researchers that suggest BPR has been implemented in recent years (Budiono & Loice, 2012; Cheng *et al.* 2012; Tka & Ghannouchi 2012). Smart (2009), however, supports his claim by explaining that a broader concept has emerged which in a way absorbed the methodologies of BPR. This new concept, called business process management (BPM), adds the value of continuous improvement and automation within business processes. This is also supported by Ko *et al.* (2009) who agrees that BPR was in a sense a predecessor for BPM.

BUSINESS PROCESS MANAGEMENT

The purpose of BPM is to analyse, improve and automate existing processes in an organisation (Van der Aalst, 2009). BPM was defined by Van der Aalst *et al.* (2003:p4) as "Supporting business processes using methods, techniques, and software to design, enact, control, and analyse operational processes involving humans, organisations, applications, documents and other sources of information".

The apparent difference between BPM and other business change initiatives is the involvement of information technology (IT) and the continuous improvement thereof. Advocates for the use of IT in BPM include Neubauer (2009) and Weske *et al.* (2004). Smart (2009) goes so far as to synonymously refer to business process automation as BPM. Vergidis (2008), to the contrary, expresses that the IT used to aid the operation of business processes are not restricted to BPM methodologies only.

Qualitative improvements from the implementation of BPM are brought to the foreground by Hung (2006) and Palmberg (2010). There is, however, still speculation that most research solely focuses on the critical factors that are needed to ensure the success of BPM (Škrinjar & Trkman, 2013). These researchers include, amongst others, Ariyachandra & Frolick (2008), Trkman (2010) and Bai and Sarkis (2013). Regrettably little is said about concrete guidelines to aid in the implementation of BPM (Rohloff, 2009). The focus therefore shifts from a strict BPM approach to business process improvement.

BUSINESS PROCESS IMPROVEMENT

Hanafizadeh *et al.* (2009) claims great differences between business process improvement, redesign and BPR. These differences were classified into levels of IT involvement, risk, degree of change, expectations of results, time and cost of improvement and executive involvement needed. To the contrary Trkman (2010) observes that the same concepts and principles are put forth by different "buzzwords".

Given the diverse views of researchers on this subject it is difficult to decide which enterprise would be most beneficial for the M&V process of an ESCO. There are more important issues to consider; such as truly developing an improved business process. As stated by Reijers and Limanmansar (2005) the actual improvement becomes a low priority compared to the

development of the best methodology for improvement; or as shown by previous studies, finding critical success factors for the implementation of BPM.

As a result it seems that many forms of business change can be accomplished through many different tools, methods and combinations of methodologies. What must now be considered is the existing M&V process of an ESCO and the desired change within the process. This dissertation will focus on a BPM-like approach, but much less rigid, since there is still a lot to learn about BPM. Moreover, small and medium-sized enterprises (ESCOs in South Africa as an example) will most likely not be inclined to large amounts of change and restructuring.

For this reason we will focus on correctly using the tools and methods prescribed during any of the initiatives as mentioned above. Whatever the approach, the study of improving business processes is qualitatively beneficial and is a worthwhile endeavour.

2.3. BUSINESS PROCESS KNOWLEDGE

2.3.1. PREAMBLE

The analysis of people and performance management has become a concern in recent studies regarding business processes (Davenport, 2006). Process knowledge is essential to realise benefits from process change (Škrinjar & Trkman, 2013). For this reason the author's knowledge of the M&V process is presented through business process modelling. Process modelling is the graphical representation of how organisations conduct business processes (Indulska *et al.*, 2009).

Doomun and Jungum (2008) endorsed modelling of processes for its contribution to their understanding and analysis through a systems perspective.

2.3.2. MODELLING CONSIDERATIONS

LEVELS OF ABSTRACTION

A recurring theme in business process modelling is the concept of levels of abstraction (Pedrinaci *et al.*, 2008; Monsalve *et al.*, 2011). Different levels of abstraction are used to portray a business process from different perspectives. The drive behind levels of abstraction is to satisfy the conceptualisation requirements of different stakeholders. As was communicated in Chapter 1, many types of project will have a number of stakeholders. Levels of abstractions aim to present a business process in a manner understandable to each stakeholder, albeit management, IT personnel or employees.

Monsalve *et al.* (2011) conveyed that most research recommends three levels of abstraction. They used an established partitioning set forth by Anthony (1965). Pedrinaci *et al.* opposes three levels of abstraction with a partitioning of five levels. The different views are graphically displayed in Figure 7.

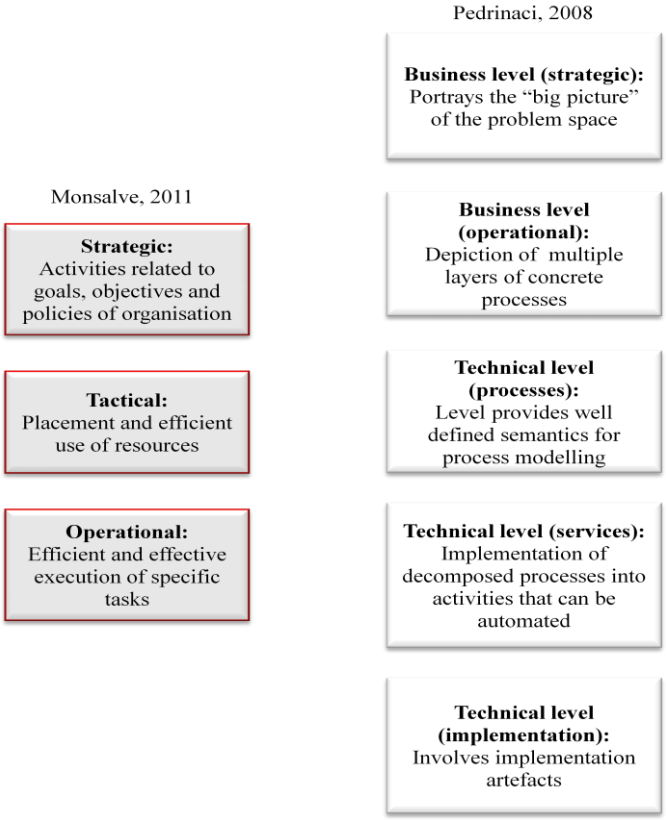

FIGURE 7: MONSALVE AND PEDRINACI'S LEVELS OF ABSTRACTION PARTITIONING

Although the aim of the two models is the same there are some differences that may influence the application of each. The first and most noticeable difference is that Pedrinaci's model

(indicated in white in Figure 7) has five levels of abstraction whereas Monsalve's model (indicated in grey and red in Figure 7) only has three. In other words, Pedrinaci's model aims to present the business process to five different stakeholders.

Monsalve's model will represent the arrangement of resources executing the process in the tactical level. Pedrinaci's model lacks clarity on where resources are staged and employed. This makes Monsalve's model more appealing to diverge M&V process knowledge.

Monsalve's model uses the concept of hierarchy and expansion to perceive a process on different levels; first the big strategic picture is displayed and then the process is broken down into more detail in subsequent levels. On the other hand, Pedrinaci focuses on the goal of a perception level to aid in the automation of a process.

Three things came to light by comparing the two abstraction models:

1. Each model has a unique aim and philosophy.
2. Monsalve's model can be useful for the analysis of a process as it uses a spread-out view of the process in each level.
3. Pedrinaci's model can assist in the development of an automated business process.

The differences indicate that Monsalve's model will be more suited to the M&V process. Firstly, it simplifies the action of modelling a business process, because there are only three levels of abstraction. Secondly, it allows for the distinction of resource allocation that is lacking in Pedrinaci's model.

MODELLING GUIDELINES

Despite the recent standardisation of modelling software there is still some uncertainty as to how business processes should be modelled. To ease the understanding and analysis of process models Mendling *et al*. (2010) proposed seven modelling guidelines. These guidelines are simple to understand and practical to apply:

1. Define fewer elements. Less is more; having fewer elements in modelling decrease the chance of interpretation errors.
2. Minimise the amount of inputs and outputs per element.
3. Define only one start event and one end event in the model.

4. Structure the model by always connecting sequence flows that split with the same gateway type.
5. Structure the model in such a manner that a gateway should not provide the analyst with the option to choose a path without specifying conditions for the path.
6. Label activities with verbs to ease understanding of activity purpose.
7. Split models with more than 50 elements into smaller models.

Providing frameworks, standardising, adding new concepts and considering different perspectives have added to the number of research papers focusing on process modelling. Such modelling topics can be seen, amongst many others, in Becker *et al.* (2000), Kock *et al.* (2009) and Capelli *et al.* (2010). From all these the two most valuable suggestions for the M&V process are the levels of abstraction by Monsalve *et al.* (2011) and the modelling guidelines by Mendling *et al*. (2010).

2.3.3. BUSINESS PROCESS MODELLING CONSTRUCTS

There are many different standards to use for the purpose of graphically representing a business process. Table 1 lists modelling standards together with the corresponding authors that investigated the modelling standards.

TABLE 1: BUSINESS PROCESS MODELLING STANDARDS

BUSINESS PROCESS MODELLING STANDARDS	RESEARCH
Workflow management	Dreiling *et al*.(2008)
Integration Definition (also known as IDEF)	Lin *et al.* (2002) Jeong and Hong (2009)
Unified Modelling Language (also known as UML)	Muehlen and Recker (2008)
Petri Nets	Jahangirian *et al.* (2010)
Business process modelling notation (BPMN)	Koliadis *et al.* (2006) Dreiling *et al*.(2008) Muehlen and Recker (2008) Kous (2010) Chinosi and Trombetta (2012)

Ottensooser *et al.* (2012) noted that all these languages are essentially flowcharts. There may be slight or substantial differences between standards, but these are irrelevant when modelling the M&V process. Since BPMN is emerging as a standard language (Muehlen & Recker, 2008) and it is aimed at business analysts (Ko *et al.*, 2009) the M&V process will be modelled according to BPMN standards.

2.3.4. BUSINESS PROCESS MODELLING NOTATION

BPMN has five basic categories of elements as can be seen in Figure 8. In each of these categories there are a number of elements. All the elements put together graphically represent a business process. Using all of the elements that are available is not necessary for the M&V process. The focus will therefore fall on the elements essential to the representation of the M&V process.

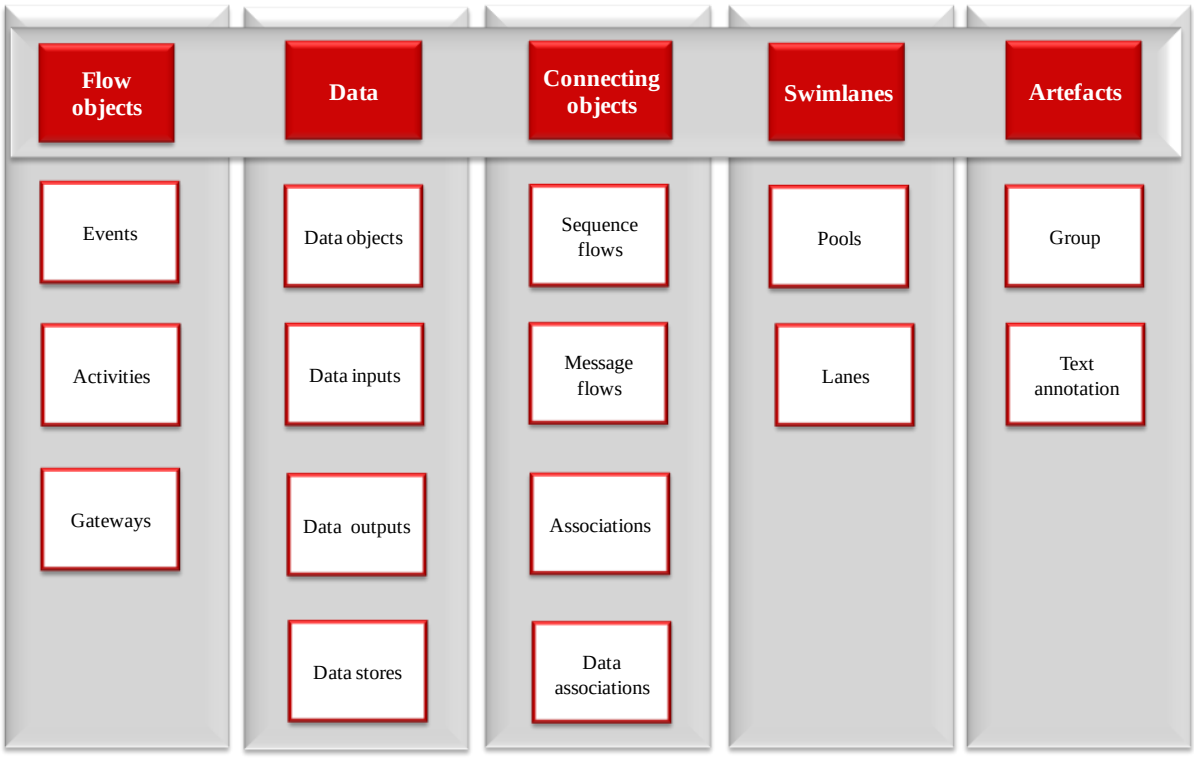

FIGURE 8: CATEGORICAL ELEMENTS OF BPMN STANDARD

FLOW OBJECTS

Flow objects define the behaviour of a business process (OMG, 2011). Events affect the flow of the model, either in the beginning, middle or end of the business process. They usually

have a cause and effect. Activities are the actions performed by human resources during the business process. Gateways are elements that indicate optional paths that are conditionally dependent.

CONNECTING OBJECTS

Sequence flows help the stakeholder to see the order in which activities are performed. Message flows indicate the travelling of messages between participants or activities.

POOLS

Pools indicate the business process participants. For the purpose of this dissertation the ESCO will be the centred pool. Lanes are further subpartitioned within a pool and assist the analyst in organising activities. The activities for the M&V process will be organised according to the resources responsible for said activities.

Figure 9 is an example of an incident management business process. Events are indicated by both empty and filled circles. Rounded rectangles describe the activities and are labelled with verbs as per the guidelines of Mendling *et al*. (2010). Diamonds represent gateways. The sequence flow out of a gateway, which is shown by solid arrows, is dependent on the corresponding condition of the gateway. Finally, it can be seen that for this example there are a number of different pools or participants. Numerous message flows are denoted by dashed arrows between participants. It is important to note that only message flows can cross pool borders (OMG, 2011). Message flows allow for the receiving participant to continue with the flow of the business process, because they trigger an event. What this means is that one participant waits for another to send a message, this message then triggers the sequence flow of the former participant.

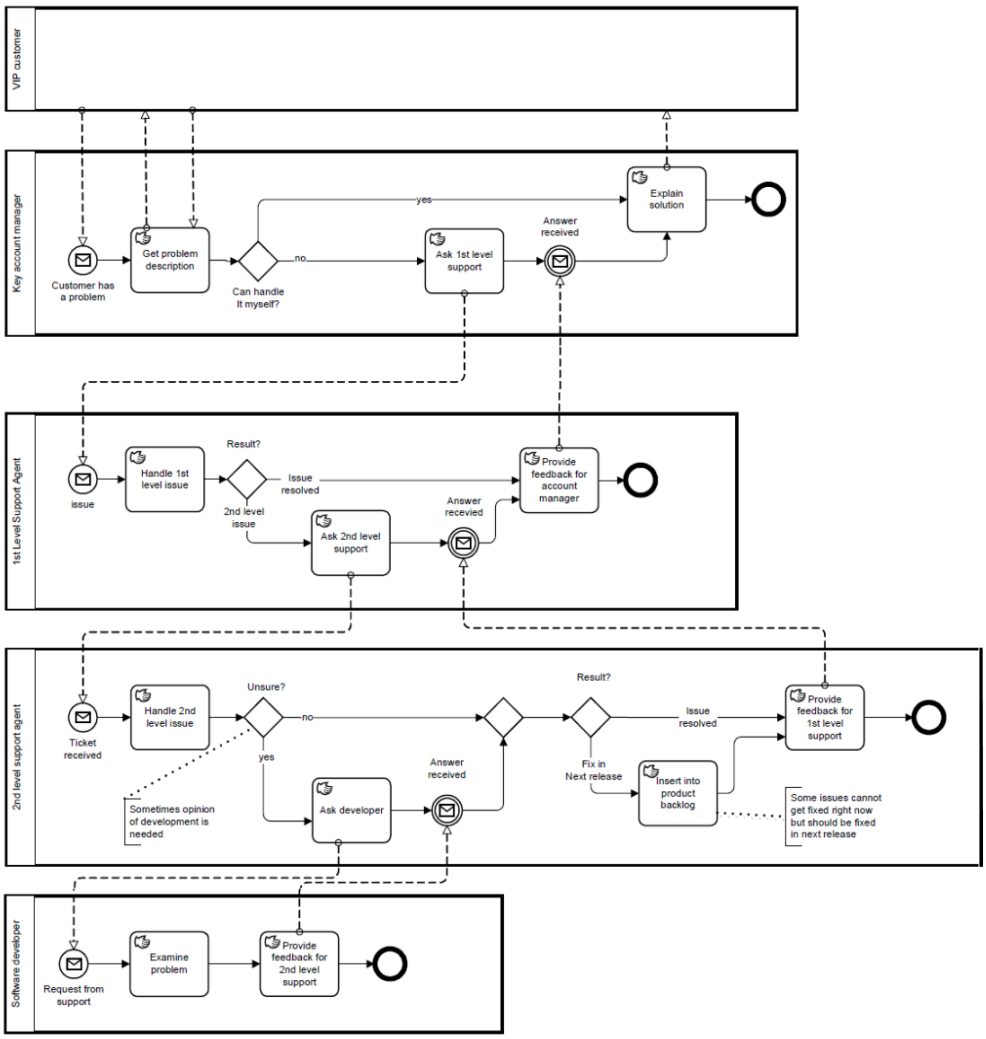

FIGURE 9: INCIDENT MANAGEMENT EXAMPLE USING BPMN

The first goal of BPMN is to provide a graphical representation of a business process that can be comprehended by any and all business users (Owen & Raj, 2003). Vergidis (2008), on the other hand, stated that although modelling may help with analysis it does nothing for the improvement of a business process. His belief was that to improve one must first quantify.

This section detailed methods and tools for the qualitative analysis of the M&V process through process modelling using the BPMN standard. The next section will focus on methods for quantifiable analysis of the M&V process.

2.4. STATISTICAL DISTRIBUTIONS FOR DATA ANALYSIS

2.4.1. PREAMBLE

According to Montgomery and Runger (2006) "the field of statistics deals with the collection, presentation, analysis, and use of data to make decisions, solve problems, and design products and processes". There is a lack of quantifiable analysis of the M&V process. If any quantifiable data can be collected for the M&V process, statistical tools can be used to present the data in a comprehensive manner.

2.4.2. PROBABILITY DENSITY FUNCTIONS

Probability density functions are used in the study of probabilities associated with a random variable X (Montgomery & Runger, 2006). Random variables can be categorised as either discrete or continuous. A discrete random may take on only a countable number of distinct values (University of Glasgow, 2013). In contrast, a continuous random variable takes on an infinite number of possible values and is usually a measurement (University of Glasgow, 2013). This can be described in laymen's terms: the probability density function gives the probability that a discrete or continuous random variable will take on a value X.

This literature study will focus on continuous random variables for the reason that any data from the M&V process will most likely be measurements.

The probability density function of a continuous random variable x, is given by:

$$\boldsymbol{P(a \leq X \leq b) = \int_a^b f(x)\, dx}$$

EQUATION 2.4-1

Where X is the random variable, and the probability that X will be between a and b is given by the area under the graph of f; that is the integral of the function f with parameters a and b.

2.4.3. NORMAL DISTRIBUTION

The normal distribution is the most widely used model for the distribution of a random variable (Montgomery & Runger, 2006). Data received for the M&V process is presumed to follow a normal distribution. This is because most of the data that can be obtained from observing or tracking the M&V process will most likely be measurements. Measurements are a key attribute of the data associated with continuous random variables and their distributions; such as the normal distribution. The distribution's probability function is given by the following equation:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

EQUATION 2.4-2

Where μ is the mean, σ the standard deviation and x the random variable. The mean determines the centre of the function and the standard deviation determines the width.

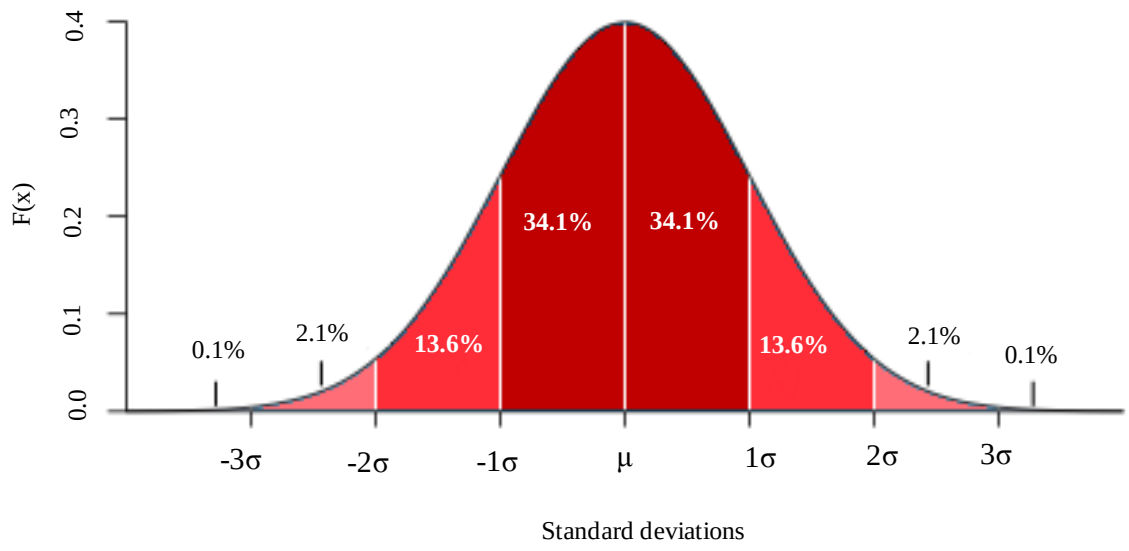

FIGURE 10: EXAMPLE OF A NORMAL DISTRIBUTION (PROBABILITY DENSITY)

The area under the graph gives the probability of a random variable x falling between experimental values. Probabilities associated with a normal distribution are showcased in Figure 10. The graph signifies that if a sample or population is normally distributed there is a 0.6827 probability that a random variable x will fall within one standard deviation from the mean. The closer the tails of the distribution graph reach 0 on the y-axis, the smaller the chance (probability) becomes that a random variable will fall within those bounds; that is, as

the probability density function nears 0 the smaller the probability is of a random variable taking on that value of $f(x)$.

There are various methods to determine if a particular distribution is a correct model for data. Constructing a normal probability plot is one example of such a method for which the general procedure is simple (Montgomery & Runger, 2006). The normal probability plot assesses if a dataset is approximately normally distributed. Observations in a sample are ranked from smallest to largest. They are then plotted against their observed cumulative frequency. If the plotted points fall approximately along a straight line, the hypothesised distribution is an adequate description of the data.

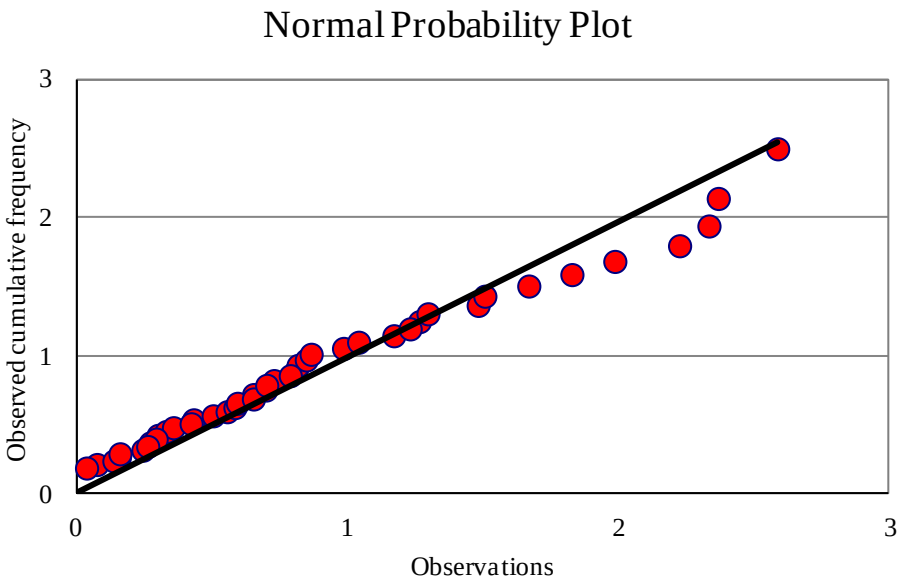

FIGURE 11: EXAMPLE OF A NORMAL PROBABILITY PLOT

Using the study of statistics some quantifiable measurements of the M&V process can be ascertained. This will furthermore make it possible to perform a comparative study of a before and after improved M&V process.

2.5. QUALITY STANDARDS AND COMPLIANCE

2.5.1. PREAMBLE

Quality management has become increasingly important in today's business environment (Priede, 2012). The ISO 9001:2008 quality standard is a facilitator of quality processes, products and continuous improvement (ISO, 2013).

2.5.2. PROCESS APPROACH AND QUALITY (ISO 9001)

One strategy to competitively meet ever-changing market requirements is to establish a company on a process approach to business (Psomas *et al.*, 2011). To improve upon a company's process orientation it is necessary to measure and manage processes that are defined and followed (McCormack *et al.*, 2009). Quality management systems (QMS) provide an organisation with procedures, processes and adequate resource allocation to provide a stable level of product or service quality (Rusjan & Alic, 2010). This can be accomplished through the management of processes. The ISO 9001:2008 is a standard that defines the requirements for QMS through a process approach (ISO, 2008). According to ISO (2013) the standard places considerable emphasis on processes. The process approach to QMS can be seen in Figure 12.

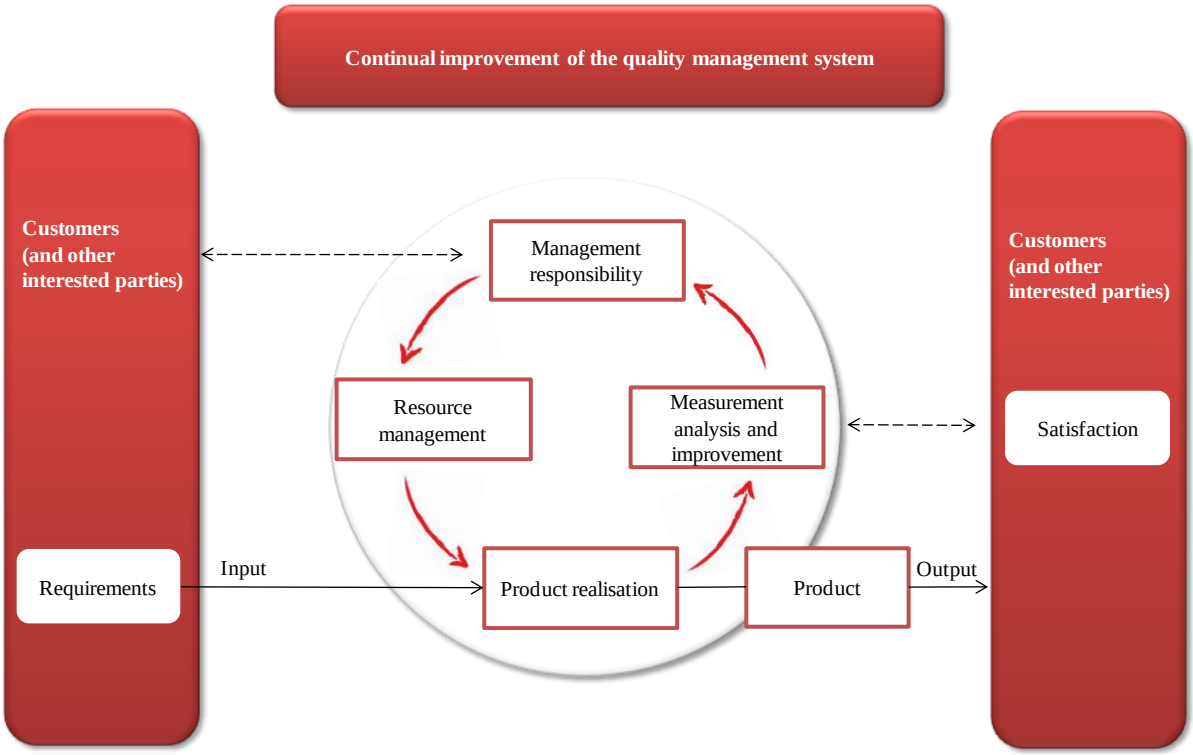

FIGURE 12: ISO 9000 PROCESS APPROACH TO QMS

2.5.3. BENEFITS OF THE ISO 9001 STANDARD

A number of benefits observed from ISO implementation are distinguished to support the necessity for ISO 9001:2008 with regard to the M&V process. Although the ISO standards show many other benefits, these may not be as appropriate to M&V. This of course by no means implies that M&V will not profit from the other benefits, it simply means that certain observed benefits are better suited and may provide the precise assistance the process requires.

According to Rusjan and Alic (2010) QMS controls an organisation's core business process, and those business processes supporting it, to deliver a product or service at a level of quality that rarely fluctuates. Research shows that ISO 9001-certified organisations have seen improvement in quality of both products and service (Awan & Bhatti, 2003; Magd & Curry, 2003). M&V is in essence a service providing stakeholders of energy-savings projects with correct, unbiased and verified savings. Improving the quality of the service and product (a measured baseline and savings) increases the quality at which the savings are reported and decreases the likelihood of reporting incorrect savings.

ISO 9001:2008 places considerable emphasis on correct and adequate documentation (ISO, 2008). Procedures supported by such documentation is clear, standardised and simplified (Magd & Curry, 2003; Valls & Vergueiro, 2006). Better documentation control enforced by a QMS makes for an administrative system that is free of unnecessary procedures and obstacles (Karapetrovic & Willborn, 2001; Awan & Bhatti, 2003). M&V is a process with an abundance of documentation such as scopes, plans, baselines and reports. A total of at least 60 documents can be present for one energy-savings project. This is assuming that a performance tracking report is sent out every month during the project period. M&V hopes to see great value in the improvement of the handling of documents and the records thereof.

Valls and Vergueiro (2006) noted that ISO 9001-certified organisations display strengthening in the leadership of managers. Consequently improvement can be seen in the planning of processes and utilisation of resources.

The skills, development and localisation (SD&L) programmes that aim to elevate the previously disadvantaged majority in South Africa are a high priority. Strengthening the leadership through the investment in SD&L can, apart from the benefit of improved planning, promote the public image of a South African ESCO.

Awan and Bhatti (2003) express that lead times are reduced and the chances of meeting deadlines are increased through ISO 9001 implementation. The ESCO industry in South Africa is occasionally placed under stress by Eskom to implement projects within a certain amount of time that is often shortened due to rising demand. Seeing that the timeframe for energy-savings projects is directly proportional to the time it takes to complete and agree on the baseline, it would be advantageous to reduce the lead times of the M&V process if possible.

Other benefits of implementing a QMS with the ISO 9001 standard include:

- Improving customer interactions (Karapetrovic & Willborn, 2001),
- Meeting customer's expectations (Fuentes *et al.*, 2003),
- Boosting company image through the standard of high quality products and/or services (Heras *et al.*, 2002; Ballantyne, 2005; Mathews, 2005),
- Enhancing employee morale as a result of each employee's contribution to the total process (Zhang, 2000),
- Communicating better internally (Awan & Bhatti, 2003), and

- Increasing job satisfaction amongst employees (Awan & Bhatti, 2003).

A QMS implemented through the ISO 9001:2008 requirements shows great promise to realise the abovementioned benefits. Although some benefits may be more suited to the M&V process than others, an organisation should strive to meet all the requirements and not only focus on those requirements enabling the benefits most fitting to a process.

2.6. INFORMATION SYSTEMS AND DATABASES SUPPORTING BUSINESS PROCESSES

2.6.1. PREAMBLE

Information systems are defined by Bentley *et al.* (2007) as "an arrangement of people, data, processes, and information technology (IT) that interact to collect, process, store, and provide as output the information needed to support the organisation". This definition implies that information systems use IT as building blocks. Since information systems are dependent on IT, any significant research findings regarding IT will extend to the information systems.

The advantages of using information systems to access and share relevant information from databases were highlighted by Bhatt and Stump (2001). They stated that, amongst other improvements, the use of information systems can aid in eliminating duplicate activities, prevent errors and reduce cycle times. A number of researchers later again supported this claim (Akhavan *et al.*, 2006; Hicks *et al.*, 2010; Ramirez *et al.*, 2010).

According to Akhavan *et al.* (2006) IT not only helps to automate activities, but it also helps to redesign and reshape business processes. In addition, these researchers claimed that IT provides consistent and quick information support throughout the organisation to respond to dynamic challenges. It is further stated that information systems aid an individual in performing a task (Petter *et al.*, 2008). Finally, internet-based networks help managers to effectively monitor the performance of their subordinates (Ramirez, *et al.*, 2010).

There is enough evidence in literature to suggest IT and information systems are in some way beneficial in the support of business processes.

2.6.2. TRENDS IN INFORMATION SYSTEMS

Van der Aalst (2009) engineers a concept surrounding modern information systems where the systems consist of layers. The centre is the operating system that makes the entire system work; the remaining layers are the applications that classify the system. As the science of computers evolves the different levels are continually expanding to absorb new functionality. Because of this phenomenon there is a shift from programming to assembling of complex software systems. An information system for the M&V process shall have to merge into existing management systems. The identification of appropriate software systems that can be assembled to adequately support the M&V process is therefore essential.

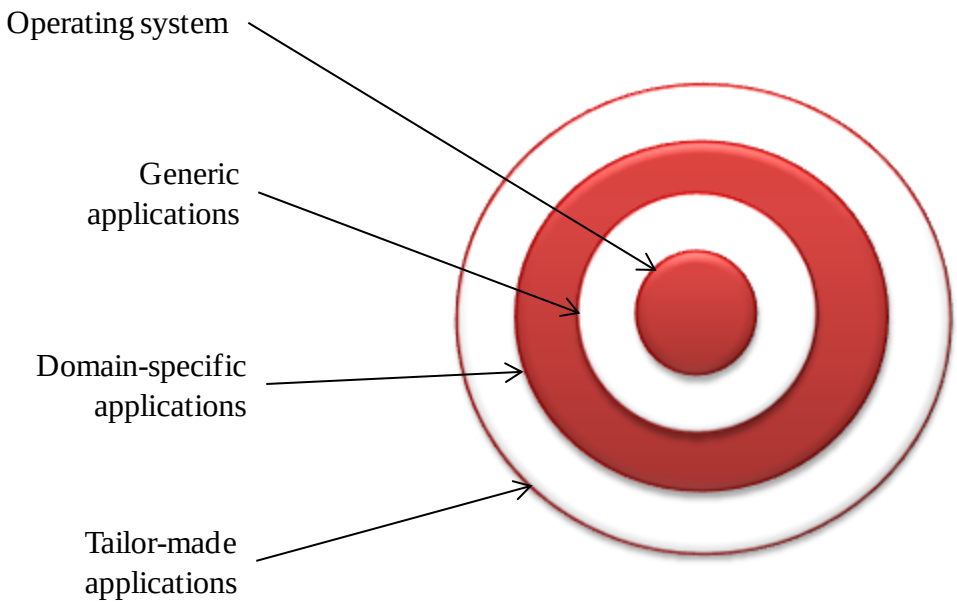

FIGURE 13: TRENDS IN INFORMATION SYSTEMS (VAN DER AALST, 2009)

THE CENTRE

On a basic level the operating system has two functions. The first function is to manage the hardware and software resources of the system; this signifies that an operating system ensures its applications receive enough resources to operate. The second function is to provide a stable and consistent application interface; this means that a software developer can be fairly certain an application written on one computer will work on another (Franklin & Coustan, 2000).

It is important to note that a multi-user operating system makes the resources of the computer available to many different users simultaneously (Franklin & Coustan, 2000). An M&V information system will have to deal with more than one user at a time.

GENERIC APPLICATIONS

Van der Aalst (2009) places database management systems in the second layer of the information systems construct. A database is defined as "any collection of data, or information, that is specifically organised for rapid search and retrieval by a computer" (Encyclopaedia Britannica, 2013). A relational database is the term used to signify a database in which data resides in a series of two-dimensional tables that "relate" to one another (Bentley *et al.*, 2007). Finally, a database management system (DBMS) is the software used to access and manage the data in a database (Valade, 2004).

Semantics of databases may be translated for ease of understanding in the following manner: *a DBMS handles data that is stored in a database*. In this definition the terms relational database and database is combined because most databases are relational (Valade, 2004).

MySQL is a DBMS that has the advantages of speed, ease of use and open-source availability (Valade, 2004). An important concept to reconcile with MySQL is the Structured Query Language (SQL). SQL is a universal language used to communicate with DBMS. The ease of using SQL is compared to that of MySQL because it is a nonprocedural language where a request is simply expressed in the semantics of SQL (Taylor, 2006).

Because of the advantages and availability of MySQL and SQL a database for the M&V process can easily be constructed.

DOMAIN-SPECIFIC APPLICATION

Van der Aalst (2009) uses decision-support systems as examples of domain-specific applications (the third layer). Decision-support systems are designed to support decision makers in solving structured, unstructured or semi-structured problems in organisations (Dong & Srinivasan, 2013). Van der Aalst (2009) further goes on to say that process-aware information systems (PAIS) can reside in this layer.

As the name suggests PAIS takes the science of traditional information systems and builds information systems on the basis of process models (Van der Aalst, 2009). This means a business process model is built in BPMN for example, and then transformed into executable code (Van der Aalst, 2009). This enables the PAIS to be flexible and adapt to changes within the process (Van der Aalst, 2009).

It is, however, possible for an information system to be process-aware without providing a generic approach to modelling and enactment of operational business processes (Van der Aalst, 2009). In other words, custom-made software can support business processes without transforming models into executable code.

The information system for M&V will not incorporate decision support or PAIS at this stage. The domain-specific application will more closely resemble a process-aware information system than a decision-support system. But to no extent will the graphical model of the process be translated into executable code; the model will merely be used as a guideline to understand what the process requires from an information system.

TAILOR-MADE APPLICATIONS

The DBMS (MySQL) found in the second layer now offers functionalities that can be used in tailor-made applications (Van der Aalst, 2009). Queries are requests that are built using SQL and sent to a MySQL DBMS (Valade, 2004). This query functionality enables a user to see information and data tailored to that specific user. To simplify; a system may display a summation of data from a database to a specific user; which means that a query was used to tailor a specific interface or assemble data for a specific user.

Where the M&V process is concerned the only tailor-made applications will be queries sent to the DBMS.

2.7. SYSTEMS ENGINEERING AND SYSTEMS THINKING

2.7.1. PREAMBLE

A system is viewed as a combination of elements that are interconnected. The elements influence each other as well as the whole system (Rapoport, 1986 cited in Schiuma, 2012). Systems thinking, in its broadest and simplest form, is an approach used on, or sometimes even by a system. People in business, amongst many others, are interested in systems thinking. This is not because systems thinking automatically solves problems it may experience, but because it presents a new perspective on the problem it is faced with; and also the solution that might emerge (Cabrera *et al*., 2008).

2.7.2. SYSTEMS THINKING

It is important to note that according to Cabrera *et al*. (2008) systems thinking is conceptual and patterned. There are four rules to conceptualise a system space: distinction, system, relationship and perspective. Applying each of these rules conceptualises a problem in a systematic manner by:

- Defining what the process is and what it is not (*distinction*),
- Looking at the process and its subprocesses in a larger context and to see the system of which it is part (*system*),
- Seeing the relationships between activities, outcomes and the space outside system boundaries (*relationship*), and
- Viewing the process from different perspectives (*perspective*).

The conceptualisation rules are used to bring to light the patterns that are ever present in all cognitive reasoning and analysis.

2.7.3. SYSTEMS ENGINEERING

Systems engineering is one of the many fields where systems thinking is applied. The function of systems engineering according to Kossiakoff *et al.* (2011) is "to guide the engineering of complex systems".

During the previous sections of this chapter a number of research topics were discussed. They covered a variety of engineering and business principles. The aim of systems engineering in this dissertation is to aid the practical application of these engineering and business principles to the M&V process of an ESCO.

Blanchard and Fabrycky (2011) proclaim that the actual implementation of systems engineering will vary from one system to the next. They further pose different process models that should be tailored to the specific system under focus.

The *Vee* process model is one such example upon which the analysis and improvement of the M&V process will be based.

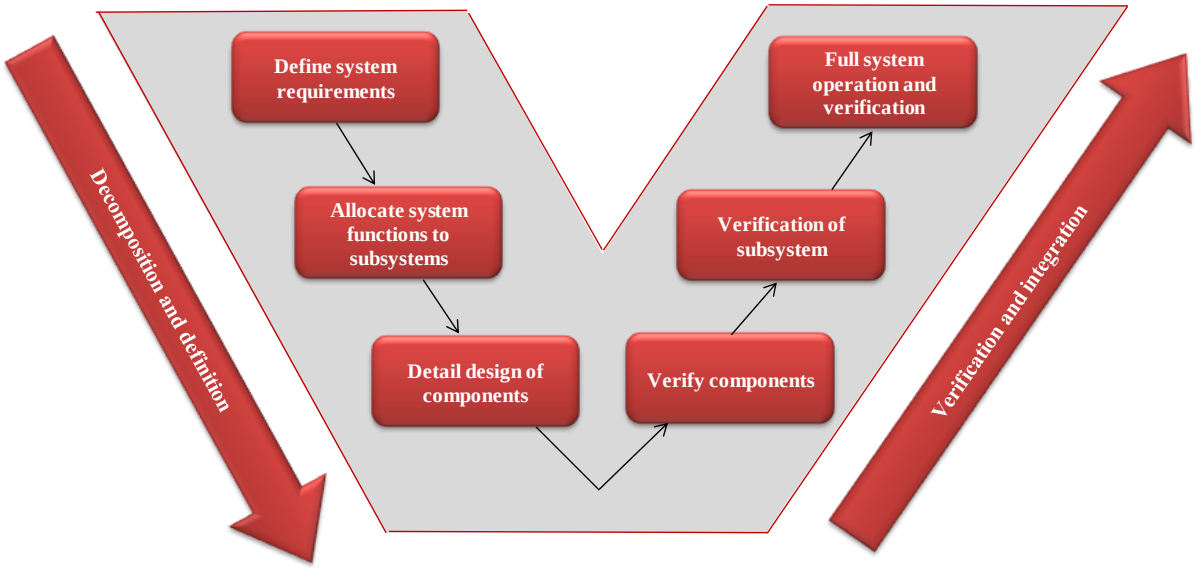

FIGURE 14: SYSTEMS ENGINEERING VEE DIAGRAM (BLANCHARD & FABRYCKY, 2011)

DEFINE SYSTEM REQUIREMENTS

Process knowledge gained and represented through business process modelling contributes first of all to the understanding of M&V. Furthermore, statistical analysis of the performance and efficiency highlights opportunities for improvement and in doing so defines system requirements.

ALLOCATE SYSTEM FUNCTIONS TO SUBSYSTEMS

Improvement opportunities that were identified are allocated to certain areas of the M&V process. They are classified according to their main focus of improvement.

DETAIL DESIGN OF COMPONENTS

Details on an information system that will support the M&V process are given.

VALIDATION OF COMPONENTS

Verification of components is tailored to the M&V process by validating that all requirements are met.

VERIFICATION OF SYSTEMS

A case study verifies that improvements for the M&V process were realised.

FULL SYSTEM OPERATION AND VERIFICATION

Full system operation is out of the scope of this dissertation. The scope includes two objectives. The first objective is to evaluate and improve the M&V processes. The second objective is to design an information system that will support the operation and management of the M&V process.

2.8. CONCLUSION

In this chapter various scientific principles pertaining to business processes and organisations as a whole were examined. Chapter 1 motivated the need for the evaluation and improvement of the M&V process. Chapter 2 transferred knowledge on the methods and trends in business process change. It also supported the endeavour to improve the M&V process of an ESCO because research indicates that improving business processes has a positive impact on the performance of organisations.

Before process change can be implemented and process improvement verified the process must be evaluated; for this reason evaluation tools and techniques were discussed. Design and quality consideration were raised and must be taken into account. This will assist in achieving the first aim of the research.

Finally, systems engineering is chosen to absorb and guide the application of all the topics covered in this chapter.

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CHAPTER 3: EVALUATION OF THE EXISTING M&V PROCESS OF AN ESCO

3.1. INTRODUCTION

3.1.1. PREAMBLE

In Chapter 1 the existing system was considered using the *PIECES* framework (Wetherbe & Vitalari, 1994). The outcome suggested that virtually nothing is known about the performance, information, economics, control, and efficiency of the M&V process. In Chapter 2 research was conducted on methods for evaluating business processes. In this chapter data is gathered and evaluated to measure the performance indicators of the M&V process.

The aim of this chapter is to evaluate the M&V process and provide some measurable performance indicators.

3.1.2. EMPIRICAL DATA

The data was gathered from a South African ESCO; in Chapter 5 the ESCO is discussed in more detail. The deliverables from historic projects comprise the data available for the M&V process.

There are six deliverables for the M&V process (Den Heijer, 2011):

- M&V scoping report;
- M&V plan;
- M&V baseline report;
- Post-implementation M&V report;
- Performance assessment report; and
- Performance tracking reports.

The lead time of the M&V process is assumed to be the workdays between the deliverables. More precisely, the scoping and baseline report. This is because the implementation of the project can be delayed until the baseline report is signed. A concern regarding this lead-time assumption is that a number of activities precede the M&V scoping report. Until the process is monitored more continuously, this is the only measure available. The data is verified through the knowledge that an external and impartial M&V team records the dates on which reports are issued.

3.1.3. PROCESS KNOWLEDGE

Evaluation of the M&V process is further promoted by the author's familiarity with its operation within an ESCO. Opportunities for improvement can be discerned by knowledge of activity and information flow. Graphically displaying the M&V process using process modelling is one method of conveying the author's knowledge.

3.2. GRAPHICAL MODELS OF THE EXISTING M&V PROCESS

3.2.1. PREAMBLE

BPMN is chosen to evaluate the process flow and activities. The visually represented models may also provide a distinction of the process. Distinction in systems thinking is part of differentiating what is part of the system and what is not. The M&V process for energy cost-

saving projects comprises tasks and activities that are modelled. Monsalve's model for modelling in levels of abstraction is used to represent the M&V process.

3.2.2. THE STRATEGIC LEVEL

One purpose of the strategic level of abstraction is to establish if the actual operation of the M&V process matches the strategic goals and objectives. Objectives that aim to reach certain goals of the process are shown in Table 2.

TABLE 2: M&V PROCESS GOALS AND OBJECTIVES

OBJECTIVE	GOAL
• Determine and ensure reliability of data-handling technologies • Provide independent M&V team with reliable data	Provide quality data to an independent M&V team so that they may determine the energy savings realised from energy-savings projects.
• Involve and inform independent party of project objectives • Ensure M&V team and ESCO collaboration	Partake in M&V activities to confirm and support the M&V performed by an independent party.
• Ascertain the model by which the project success will be measured	Measure energy savings against electricity consumption baseline.

The goals and objectives fully support the function of the M&V process. Energy savings can be independently verified by providing the M&V team with quality data. The goal to have the ESCO partake in the activities is, however, not in reality part of the function of M&V. It has nevertheless been believed to strengthen the correct verification of energy savings. This is because the ESCOs have more technical expertise than the M&V team when it comes to their projects.

The strategic level further aims to present the *big picture* of the M&V process. This model is set to communicate with management. It is the author's belief that the model mirrors management's perception of the M&V process. There are few elements displayed in this level, because too much information may result in interpretation errors.

The graphical model and description of the strategic level can be seen in Appendix B.

3.2.3. THE TACTICAL LEVEL

The task and activities of the strategic level is broken down to reveal more detail. An important feature of the tactical level is the use and allocation of resources (Monsalve *et al*, 2010). It is now essential to add more elements to the model to showcase the various roles of the resources. Conscious effort, however, is given to follow Mendling *et al*. (2010) other guidelines. Gateway conditions are specified, sequence flows connected and activities are labelled with verbs.

The external parties involved in the process are referred to as external participants while internal parties are referred to as resources. The M&V process has the following role players:

- Project manager,
- M&V manager,
- M&V consultant,
- Project engineer,
- Independent M&V team, and
- Eskom.

Resources

External participants

INTERNAL RESOURCES

Internal resources perform the M&V process tasks and activities. They obtain electricity consumption data together with independent variable data that may have an effect on the baseline. These activities directly support the M&V function as prescribed by Eskom's guideline as described in Chapter 1. Activities that indirectly support the M&V function of energy-savings projects are also performed by the internal resources. These include the duplication of the independent M&V team's activities for added confirmation.

The hierarchy of the process' internal resources starts with the project manager who identifies the opportunity for a project. The project engineer will perform an investigation to assess the feasibility of a project. The feasibility is entirely dependent on an electricity consumption

baseline compiled during investigation phases. The project engineer will continue to be a valuable resource for the M&V process.

The M&V consultant is an expert in the field of M&V. The consultant professionally advises the course of action, as well as the strategies and methods to determine and compile energy consumption baselines for projects. There is a possibility that an M&V consultant in some instances may also be the M&V manager. This, however, will result in only minor changes to the model as it is presented here. The M&V manager, as the title suggests, oversees all M&V activities and signs documents and procedures off.

EXTERNAL PARTICIPANTS

Eskom is the electricity utility of South Africa and the financial backers of energy cost-saving projects. The independent M&V team serves as an unbiased and impartial party that authenticates the savings measured and achieved by the ESCO.

THE MODEL

The purpose of the tactical abstraction level is to examine the utilisation of resources. To ease the understanding of the model it is divided into four phases. The directions of use for this model are the same as for the strategic model. The basic concept and roles of the various resources are highlighted. For more detail on the sequence flow and activity description see Appendix C.

3.2.4. ANALYSIS

Although the M&V process forms part of a larger energy-savings project, the process can be viewed on its own. This is obvious from the strategic model. The M&V process is therefore differentiated from energy-savings projects.

The purpose of the strategic model is to determine the alignment of operational activities to the goals and objectives of the M&V process. Project engineers inspect and select the data-handling technologies most suited to the project and ensure that reliable data can be obtained. The baseline development subprocess develops baselines upon which all stakeholders will agree with the use of reliable data. By reviewing all M&V documentation the same level of quality can be ensured. Throughout the strategic level model there is continuous

communication between the ESCO and independent M&V team as shown by the message flows between the pools.

Strategically the existing M&V process delivers on its objectives and goals. It is possible that, because it appears to be goal oriented, inefficiencies and errors within the process may have been overlooked. The tactical level that follows allow for the consideration of resource utilisation. More detail is given on activities as well as when and by whom they are performed.

The existing resource allocation has an effect on the performance, cost and efficiency of the process. Instead of solely advising project engineers on M&V related queries, the M&V consultant performs almost all of the cognitive reasoning for the process. When these activities are multiplied by the number of projects, a backlog on M&V deliverables are inevitable. An expert in the field may cost considerably more than a project engineer (this will be investigated in Section 3.4). Overall it is inefficient to use one expert to do the M&V for all projects; especially when a project engineer is allocated to a project in any case.

There is nothing in the model to indicate that any part of the process is standardised, except for the process itself. Den Heijer (2011) may give guidelines on the succession of M&V activities, but neglects to mention methods and practices to understand and perform these activities.

One of the most notable systems thinking relationships of the M&V process is shared with the project environment. Figure 15 graphically shows how the two influence one another.

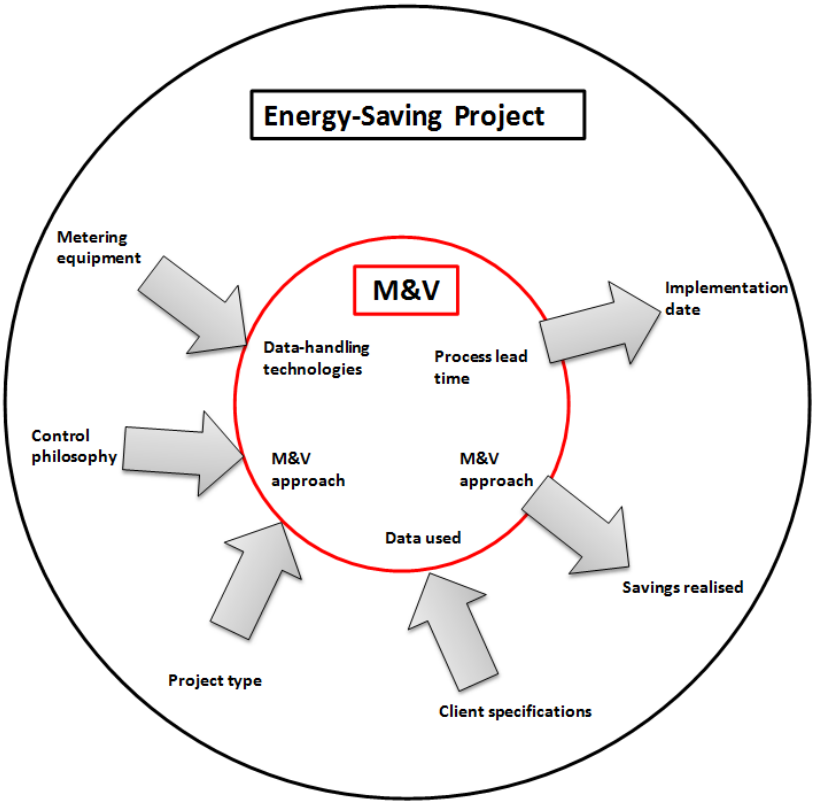

FIGURE 15: RELATIONSHIP BETWEEN M&V PROCESS AND PROJECT ENVIRONMENT

The site equipment determines the data-handling technologies while the project control philosophies dictate the M&V approach. An ESCO, for example, may identify an energy efficiency opportunity on a mine compressor system. It may then be determined that the mine has no measuring equipment installed on the system; at which point the ESCO will have to install electrical data-measuring instrumentation themselves. The ESCO then estimates a control philosophy where flow is used to reduce energy. Since the control philosophy has a direct impact on the energy, it must be integrated with the M&V approach.

Another factor influencing the M&V approach is project type. An energy efficiency project (as in the example above) has independent variables that may influence the energy consumption. Extra data must be obtained. The client specifications and requirements, if there are any, influence the data used to compile a baseline.

Influence also occurs in reverse order; a delay in the lead time of the process may cause a delay in the project implementation. Furthermore, as the control philosophy regulates the M&V approach; the approach influences the savings.

Following knowledge gained from the analyses of the process using process modelling, focus can shift to empirically measuring the performance, information, economics, control and efficiency of the process.

3.3. PERFORMANCE EVALUATION

3.3.1. PREAMBLE

The existing system data available is now assessed through various measuring and analysis techniques. Statistical distributions usually provide insights into sample data. When interpreted correctly the information obtained from statistical analysis can lead to making the right choices for the process.

3.3.2. DETERMINING DATA DISTRIBUTION

It is assumed that the probability distribution of the workdays taken to complete the M&V process is normal. This assumption is made because the workdays between scoping and baseline report can be seen as a measurement.

A normal probability plot is made using a regression model where the workdays are plotted against the observed cumulative frequency. According to Montgomery & Runger (2006) if the hypothesised distribution adequately describes the data, the plotted point will fall approximately along a straight line.

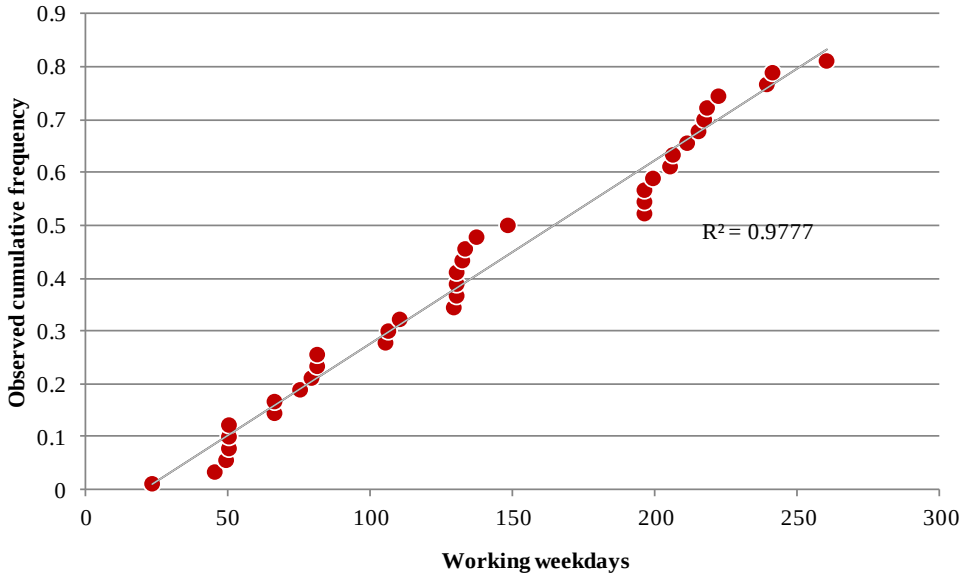

FIGURE 16: NORMAL PROBABILITY PLOT OF WORKING WEEKDAYS TO COMPLETE M&V PROCESS

In the case of Figure 16 the points do not deviate to the point of rejecting the hypothesis. It is therefore assumed that the sample data of workdays for the M&V process follows a normal distribution.

3.3.3. DESCRIPTIVE STATISTICS

Out of a history of 119 projects, 67 met the requirements of having at least one scoping and one baseline report. Workdays between the two dates were calculated and measurements were obtained through descriptive statistics.

SAMPLE DATASET 1

TABLE 3: DESCRIPTIVE STATISTICS (OUTLIERS INCLUDED)

DESCRIPTIVE STATISTICS: OUTLIERS EXCLUDED	
Mean	200
Standard Error	21
Median	196
Mode	1
Standard Deviation	169
Sample Variance	28 501
Kurtosis	1.24

DESCRIPTIVE STATISTICS: OUTLIERS EXCLUDED	
Skewness	1.24
Range	723
Minimum	1
Maximum	724
Sum	13 380
Count	67
Confidence Level (90.0%)	34

Table 3 shows the mean of the sample data, which is calculated as 200. The mean of sample data gives a measure of the centre of the data. It is calculated by adding all the values in the sample set and dividing by the number of data points; much like an average. The mode is the value that occurs with the highest frequency and also gives a measure of the centre of the data. In the case of the above sample data the mode is one.

For a normal distribution there are two parameters used to calculate the probability density function of a random variable x. The mean (μ) is the balancing point of the data where the probability of a random variable x having the value of the mean is 50%. The standard deviation (σ) indicates how much variation there is from the data points to the mean. To calculate the probability that a random variable will take on a given value, both the mean and standard deviation is required. Using the mean and standard deviation provided by applying descriptive statistics the probability density function is calculated and shown in Figure 17.

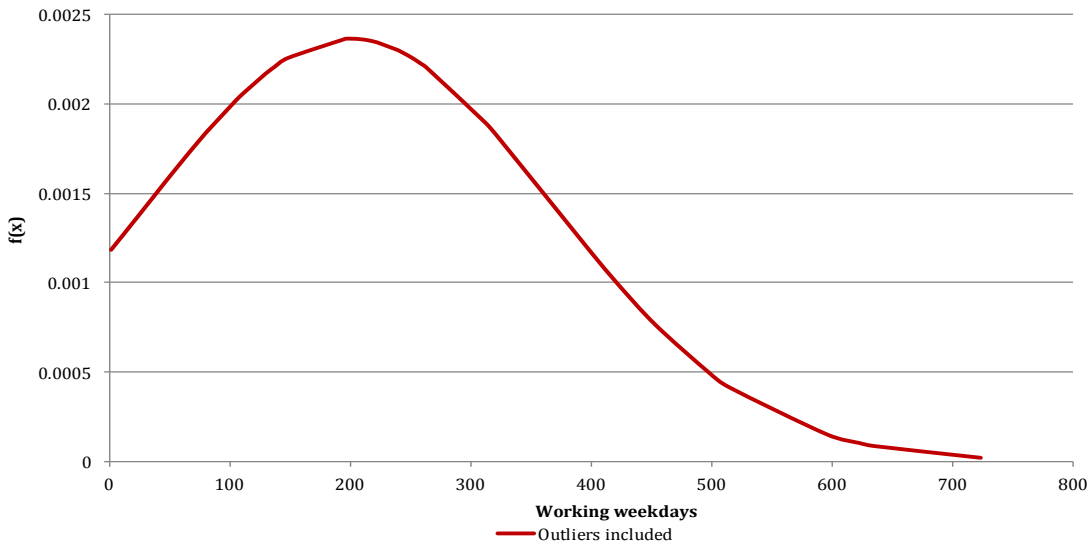

FIGURE 17: NORMAL DISTRIBUTION (PROBABILITY DENSITY) – OUTLIERS INCLUDED

The figure shows a one-sided tail for the distribution. The flatness of the distribution graph is an indication of the large standard deviation. Although the mean is the balancing point, the data points are not very close to the mean with a standard deviation of 169.

The model is cut off at 0 because the M&V process cannot be negative; it cannot take a negative amount of workdays to complete the process. It implies that the distribution should be truncated. Were it not for the fact that a negative number of workdays are impossible, the model would have followed a perfect bell curve. Figure 18 shows the truncated distribution ranging from -400 to 700.

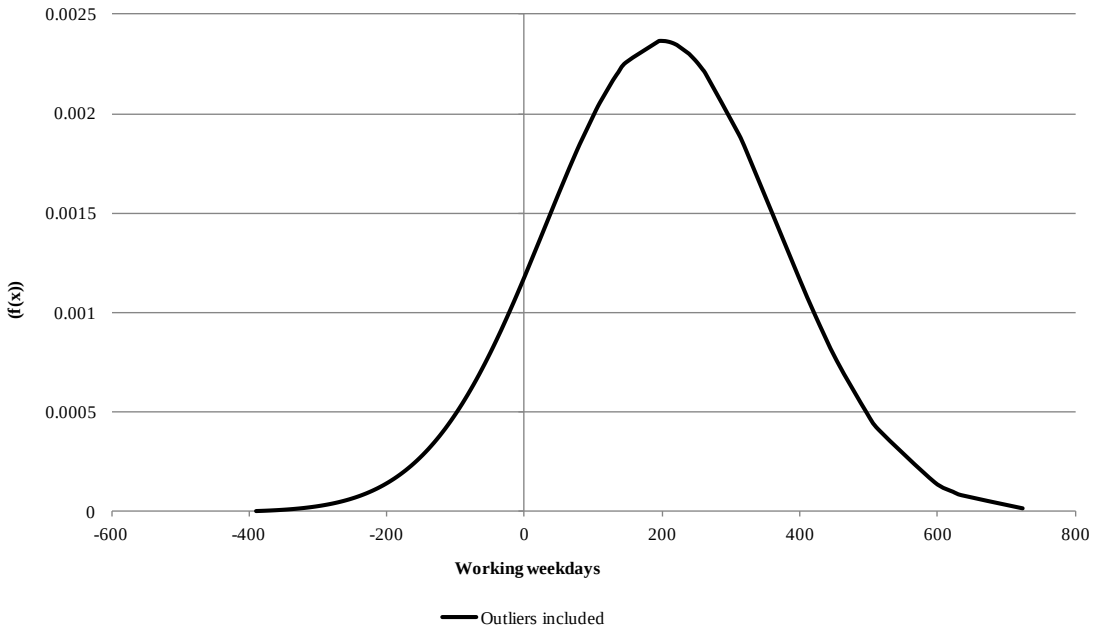

FIGURE 18: TRUNCATED NORMAL DISTRIBUTION OF SAMPLE DATASET 1

Taking truncation into consideration when calculating the probability density function is often complex and should be avoided, if possible.

It is curious that the mean ($\mu = 199$) and the mode ($\mathrm{M}o = 1$) of the sample data vary to such an extent, considering both are indications of the centre. This begs the question; how much is a mode equal to one affecting the mean and standard deviation? This question is explored and answered by removing all outlier values from the sample data.

SAMPLE DATASET 2

The range of Sample Dataset 2 is minimised to exclude any projects taking only one day, or longer than two years to complete. It is assumed that these projects were particular cases and

did not necessarily reflect a true situation of the process. The result was that the number of data points decreased from 67 to 56. Fortunately the drop in sample size is not large enough to cause concern. The results from the exclusion, however, are substantial. These results are shown in Table 4.

TABLE 4: DESCRIPTIVE STATISTICS: NETWORK DAYS (OUTLIERS EXCLUDED)

DESCRIPTIVE STATISTICS: OUTLIERS EXCLUDED	
Mean	184
Standard Error	15
Median	196
Mode	50
Standard Deviation	115
Sample Variance	13 266
Kurtosis	0.3
Skewness	0.8
Range	475
Minimum	23
Maximum	498
Sum	10 281
Count	56
Confidence Level (90.0%)	26

In Sample Dataset 2 the mean now drops from 199 to 184. The mode is much higher and the range is reduced. The standard deviation also drops to 115. The graph of the distribution is shown in Figure 19.

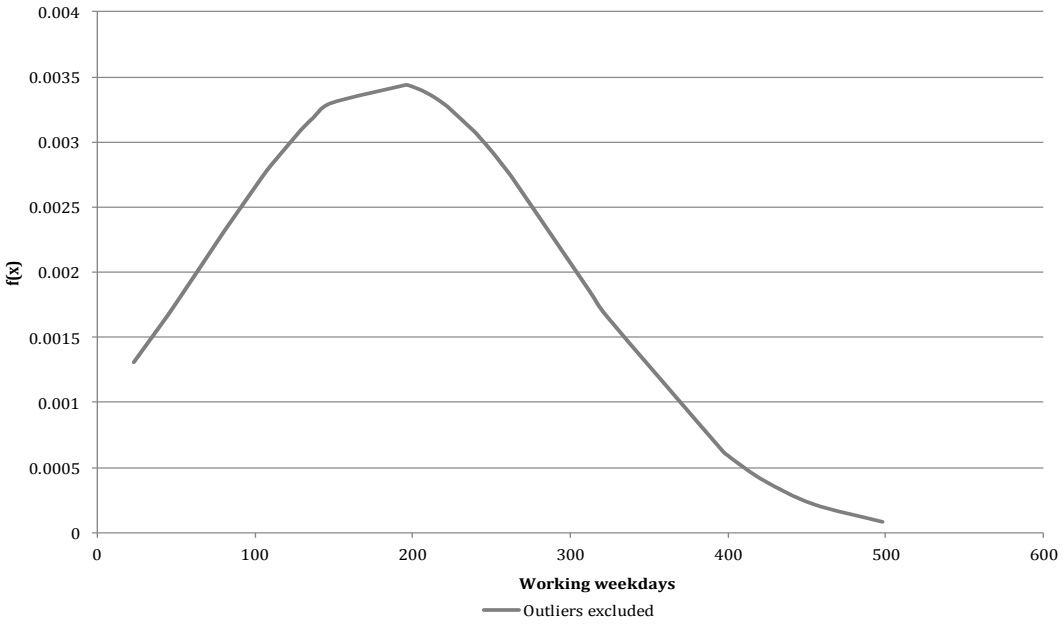

FIGURE 19: NORMAL DISTRIBUTION (PROBABILITY DENSITY) – OUTLIERS EXCLUDED

At first glance there is not much difference between Figure 17 and Figure 19. Both distributions reach the highest probability density at approximately 200 network days and both graphs are relatively flattened. It is only when the two graphs are plotted together that the differences are obvious; this can be seen in Figure 20.

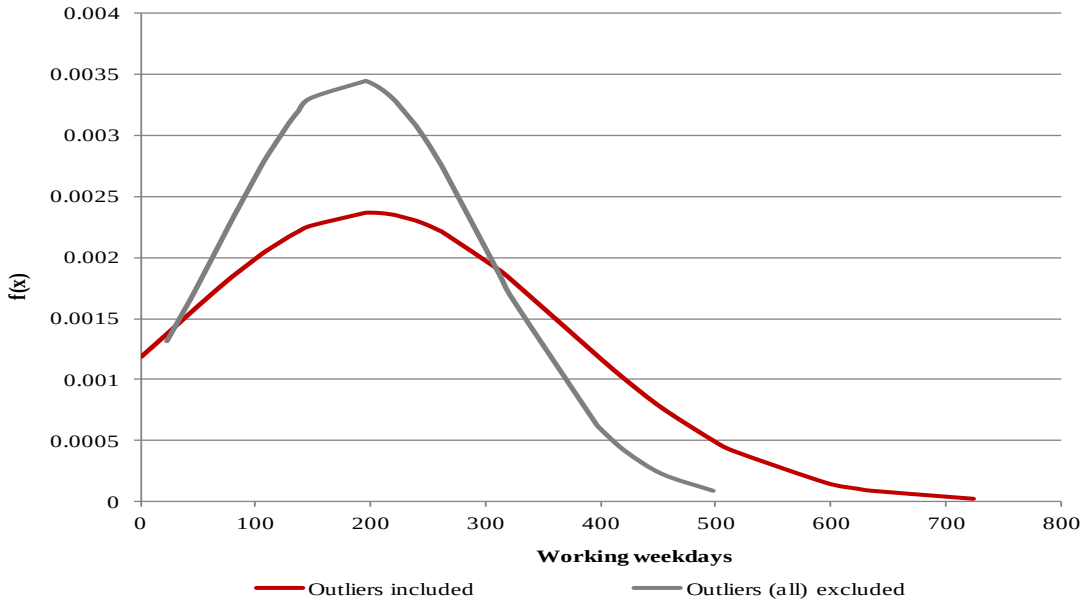

FIGURE 20: NORMAL DISTRIBUTION (PROBABILITY DENSITY) – COMBINED

The graph now highlights the differences between the sample datasets. The sample data where no outliers are excluded (green graph) shows a more flattened distribution. This is due

to the difference in standard deviation. The larger the standard deviation, the flatter the normal distribution graph will be.

The blue graph, which denotes the sample data where outliers are excluded, is sharp compared to the green graph. This is advantageous in many ways, the most important of which is the fact that truncation is not necessary for this distribution. Although negative values are not taken into account, the number of discarded data points is small enough to ignore.

The distribution allows us to measure the performance and efficiency of the process. The mean of workdays taken to complete the process is extremely high. This is not the desired performance of a business process. Furthermore, the high standard deviation divulges that many of the data points are not close to the mean. These parameters indicate that the process is extremely inefficient in producing timely results and it is also inconsistent in doing so.

Until now all 67 projects were measured under the same conditions. Descriptive statistics gives valuable information on the dataset, but without much consideration of the influence a project might have on the M&V process. Three project types are available to the ESCO model in South Africa: load shifting, peak clipping and energy efficiency. Despite perhaps logistical and socio-economic issues surrounding a project, these project types may have a notable influence on the M&V process.

The relationship between the M&V process and the energy-savings project environment has been previously mentioned. Project type is observed as an influential factor during the M&V process. If relationships are all interlinked within a system it could be beneficial to quantify the effect project type has on the performance of the M&V process.

Probability density functions are again used to display the normal distributions. A comparison of the project types' normal distributions is given.

FIGURE 21: NORMAL DISTRIBUTION OF PROJECT TYPES

Load-shifting and peak-clipping projects follow a very closely related normal distribution. The means are close to 200 and large standard deviations result in flattened graphs. On the other hand, energy efficiency projects have a slightly lower mean and significantly smaller standard deviation. This phenomenon may be attributed to the history of energy interventions. DSM projects in South Africa started with load-shifting projects and were later joined by energy efficiency initiatives.

It may have taken the M&V process some time to get off the ground. Over time as ESCOs and M&V teams became more accustomed to the process they became naturally more efficient. This, however, has no bearing on the fact that the process performance is still poor and requires attention.

3.4. M&V PROCESS ECONOMICS

3.4.1. PREAMBLE

The economics of the process is measured in two ways. The first quantification is the project delay cost. According to the NEC a signed copy of the baseline report is required before

implementation can commence. The second quantification is the costs of the resources allocated to the process.

3.4.2. PROJECT DELAY COSTS

The data used to quantify the project delay costs comes from the study of DSM projects. Firstly, the science of M&V is used to determine the possible electrical energy savings. The next step is to determine what the costs of both the present (before intervention) and proposed (after intervention) baselines would have been and will be, respectively. The savings are then considered for an entire year. Table 5 indicates the average savings per annum for each type of project.

NERSA allowed Eskom to apply an annual increase of 8% to electricity charges (Eskom, 2013). This increase per year is applied to the typical annual savings of each type of project.

TABLE 5: AVERAGE ANNUAL ENERGY SAVINGS PER PROJECT TYPE

	2013	2014	2015	2016	2017
Energy Efficiency (EE)	R5 263 712	R6 139 593	R7 734 119	R10 522 184	R15 460 540
Load Shifting (LS)	R1 840 590	R2 146 864	R2 704 431	R3 679 348	R5 406 169
Peak Clipping (PC)	R4 766 432	R5 559 566	R7 003 452	R9 528 120	R13 999 934

The cost savings listed in Table 5 cannot be achieved unless the project is implemented and the intervention proved successful by the performance assessment. It therefore stands to reason that if a project is delayed there are potential cost savings being lost. The M&V process is supposed to aid the stakeholders in determining the true success of an energy intervention. The process should not stand in the way of implementing the interventions.

A concern of this take on the M&V process project delay costs is that the M&V process may not be the only cause of delay. A second major cause of project delay is the Eskom processes. This is, however, not applicable to the M&V process of an ESCO.

This data should be viewed in the context in which it is meant; merely as approximated costs if M&V was the only delay in the project lifecycle. Figure 22 graphically displays the possible savings by project type that could have been realised.

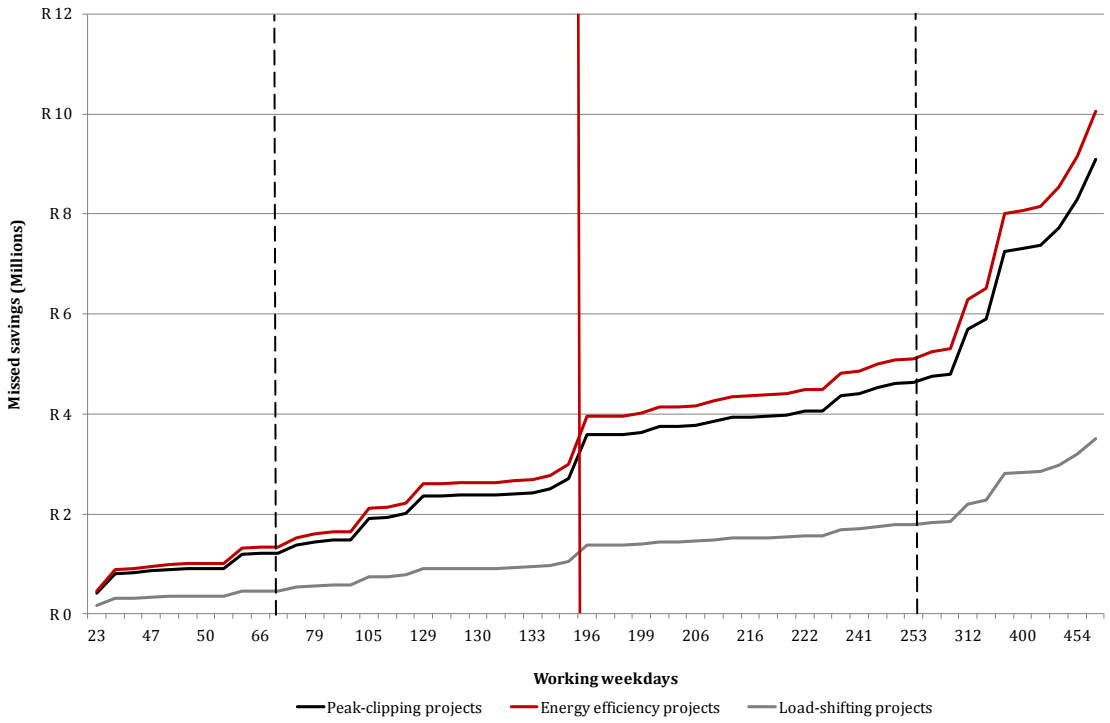

FIGURE 22: MONETARY EFFECT OF DELAY ON PROJECT TYPE

The red vertical line is situated approximately at the mean of the data. The dashed black vertical lines are situated in the regions of one standard deviation from the mean. To quantify what this means probability calculations are performed on the data. There is a 34% probability that energy efficiency projects have missed cost savings of between R4m and R5.8m. Furthermore, there is a 25% probability[1] that the projects took longer than one year and missed an entire year's savings.

The impact of missed cost savings can be further quantified by the following bubble graphs.

[1] Calculated from normal distribution probability density function from Section 3.3.

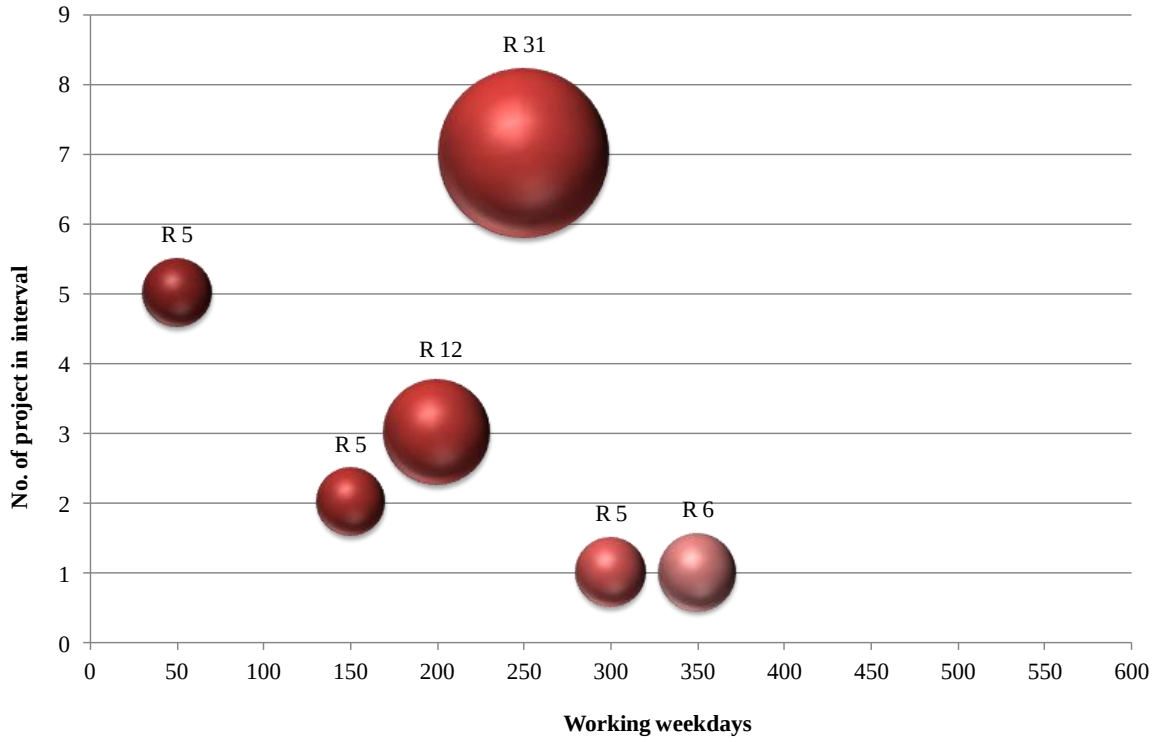

FIGURE 23: SUMMATION OF PROJECTS' DELAY COST (IN MILLIONS): ENERGY EFFICIENCY

R31-million cost savings could have been realised if seven energy efficiency (EE) projects were not delayed for approximately 250 workdays (Figure 23).

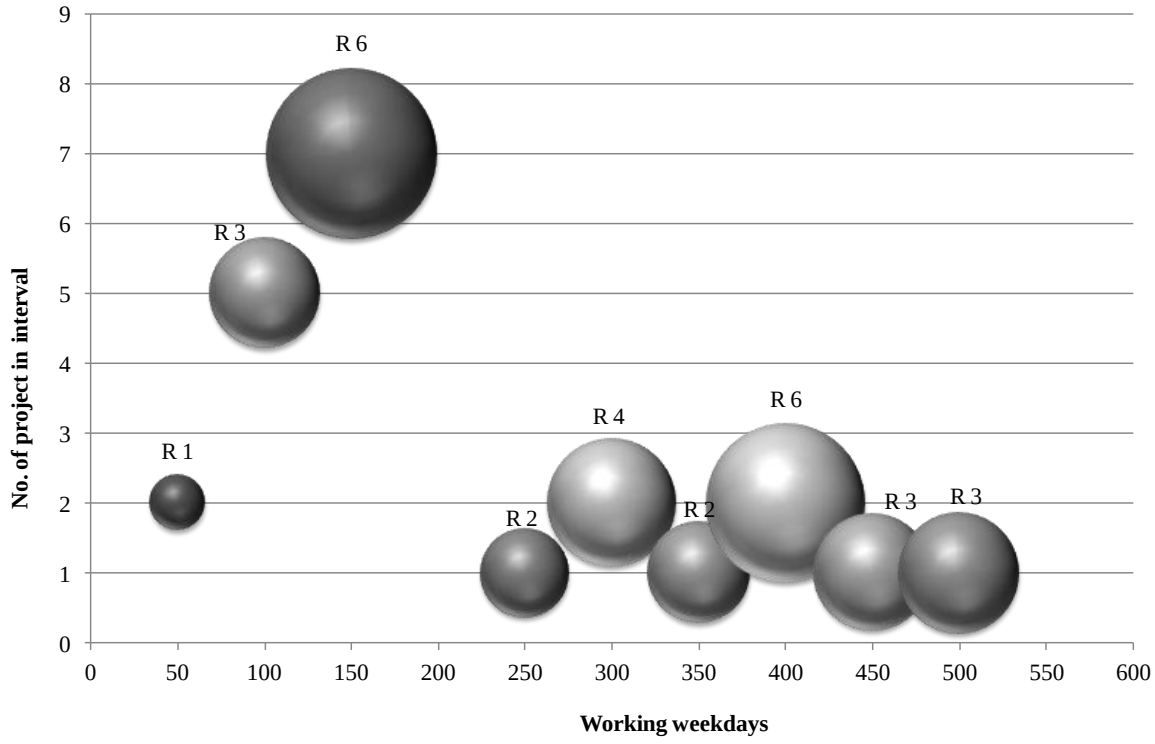

FIGURE 24: SUMMATION OF PROJECTS' DELAY COST (IN MILLIONS): LOAD SHIFTING

The load-shifting projects are a bit more scattered (Figure 24).

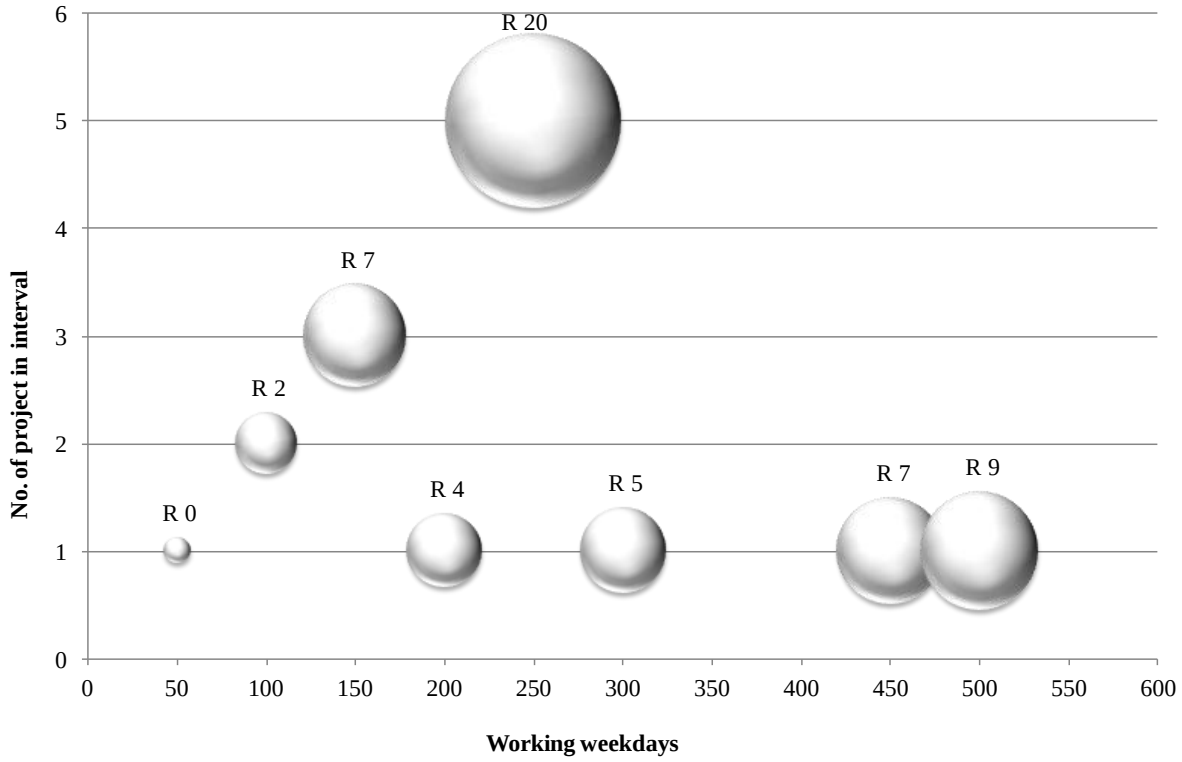

FIGURE 25: SUMMATION OF PROJECTS' DELAY COST (IN MILLIONS): PEAK CLIPPING

The peak-clipping projects follow more or less the same cause-and-effect model as energy efficiency projects. Five of these projects were delayed for almost 250 workdays to result in accumulated missed cost savings of R20 million (Figure 25).

3.4.3. RESOURCE UTILISATION COSTS

The resources with the most responsibility within the M&V process are the consultant and project engineers. An hourly rate is obtained for the two resources based on experience, expertise and accountability. The notification of indicative time-based fee rates from the Engineering Council of South Africa is used (RSA, 2011).

TABLE 6: RESOURCE COST SPECIFICATIONS

RESOURCE	EXPERIENCE (YEARS)	QUALIFICATION	HOURLY RATE
M&V consultant	7 +	Post-graduate	R1 800
Project engineer	1-2	Graduate	R 780

The most time spent on the M&V process is associated with the activities up until the development of the baseline. All cognitive and speciality skills come into play during this phase of the M&V process. Based on the theoretical modelling of the M&V process the activities allocated to the two resources were identified.

The number of hours spent on M&V activities is subjective. For example, a certain project may have an extremely complex control philosophy. As it was discovered, project control philosophy has a direct impact on the complexity of M&V approach. This project may then require more time to complete M&V activities. It is therefore necessary to employ a different strategy to determine the costs of resources for the M&V process.

The example above clarifies that time spent on M&V is dependent on at least one factor. Factors influencing M&V man-hours can be one or many; as a result it is difficult to standardise what the time spent on M&V will be. The only reasonable conclusion to make is that time spent on M&V should be a variable. The time variable can be multiplied by the hourly rate of the resource.

The next step is to consider the distribution of activities between resources. This is for one of two instances: either the number of hours used to complete M&V is unknown; or only the total time is known. In these cases the theoretical M&V process model can be used as a guidance mechanism. This is to say a percentage of activities performed by the two resources can be computed.

TABLE 7: ACTIVITIES ALLOCATED TO RESOURCES (BEFORE IMPROVEMENT)

ACTIVITY	RESPONSIBLE RESOURCE
Determine available DHT	Project engineer
Pre-implementation site visit	M&V consultant
Determine DHT plan	M&V consultant
Determine M&V approach	M&V consultant
Execute DHT plan	Project engineer
Obtain data	Project engineer
Develop baseline	M&V consultant
Review documentation	M&V consultant
M&V consultant (5/8)	63%
Project engineer (3/8)	37%

The above considerations resulted in the following equation:

$$\boldsymbol{x(0.63)(R\ 1\ 780) + y(0.37)(R\ 780) + c = Cost}$$

EQUATION 3.4-1

Where x and y is the number of man-hours spent on M&V activities by the consultant and the project engineer respectively. Multiplying x and y with the distribution percentages as well as the hourly rate gives an estimate of resource costs for the M&V process. The value c is representative of overhead costs for the M&V process and is assumed to be a constant value.

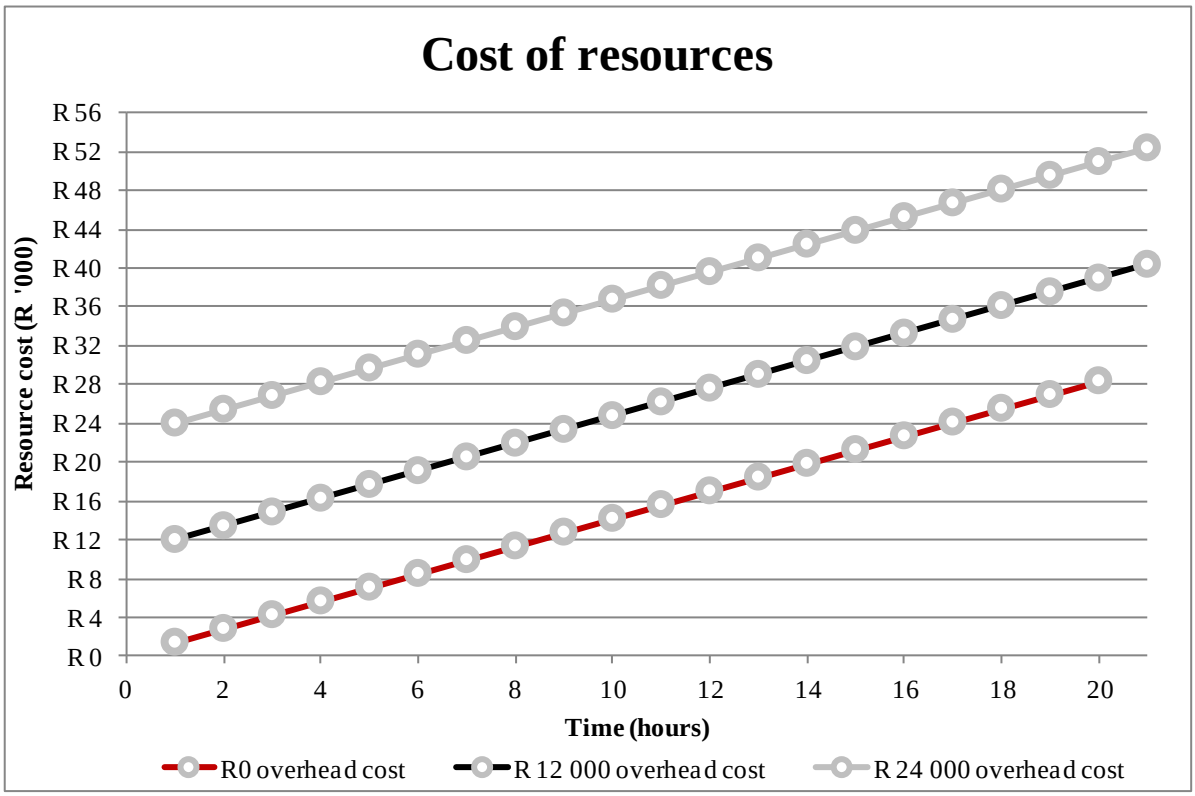

FIGURE 26: CORRELATION BETWEEN RESOURCE COSTS AND TIME SPENT ON M&V

Equation 3.4-1 gives a linear model that shows how costs and time correlate. This correlation is better depicted in Figure 26. The overhead costs (c) will change the offset of the graph. For illustration purposes three separate overhead cost examples are displayed in the graph.

3.5. M&V PROCESS EFFICIENCY

3.5.1. PREAMBLE

Efficiency is a broad term used in a variety of engineering principles. In the ESCO industry it is used to describe how much energy is used to produce a certain output. An energy efficiency project will, for instance, permanently reduce the overall energy consumption of a system while maintaining production.

3.5.2. MEASURING M&V EFFICIENCY

This perception of efficiency is extended to the M&V process. Certain resources are used to produce the output of the process. The M&V consultant and project engineers use their specialised skills to reason and calculate an energy consumption baseline for the projects. It should be noted that project engineers are also qualified and capable to perform M&V activities.

Taking the values from Table 6 and Table 7 the efficiency of the M&V process can be measured in the following manner:

- A consultant performs 63% of M&V activities at an hourly rate of R1 800
- Project engineers perform 37% of M&V activities at an hourly rate of R780

This is the equivalent of supplying 3 MW of energy for a certain amount of production, while 1.5 MW would have sufficed.

3.6. INFORMATION OF THE M&V PROCESS

3.6.1. PREAMBLE

Information is the input and output data of the process. An important aspect about the information of a process or system is documentation and file storage. The service of a process or system is the measure of consistency and reliability of results.

3.6.2. SYSTEM INFORMATION AND DATA

The data available for the evaluation of the M&V process was said to be the deliverables of the M&V process: six stage reports compiled by the M&V team with the assistance from the ESCO.

Although the data was found to be incomplete, certain valuable deductions can be drawn from the reports that are at hand. At least one report of all historical projects is available and a report may be part of an individual deliverable; such as the scoping, M&V plan and

baseline report. Alternatively, it can be a report from a set of deliverables; such as one of many performance assessment or tracking reports. A single tracking report, for example, indicates that a project did or does exist; but it also points to the absence of other reports.

In Chapter 1 it was established that there is no existing centralised database for M&V deliverables. The deliverable reports can nevertheless be located. A catalogue of reports is examined to determine which reports are available and which are missing.

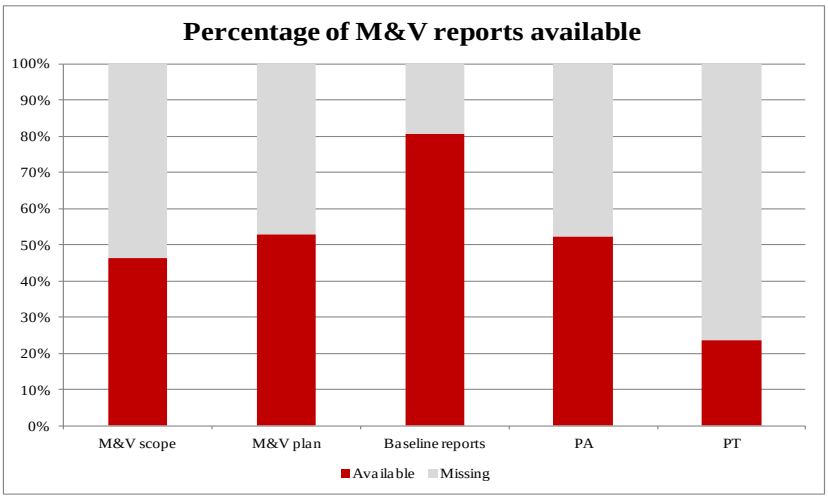

FIGURE 27: PERCENTAGE OF M&V REPORTS AVAILABLE AND MISSING

Results from evaluating the M&V catalogue indicate an inconsistency of report availability. The catalogue is 31% complete. This percentage is most notably affected by the number of performance tracking reports available. Although 80% of historical baseline reports are accessible the catalogue is deemed incomplete.

3.7. CONCLUSION

To rectify the lack of cognisance of the M&V process it is evaluated. Using an outline similar to the *PIECES* framework problems and opportunities regarding the M&V process are identified.

Certain problems are identified through the evaluation of the M&V process. Elongated performance and lead time of the process causes a delay on the savings possible from energy

cost-saving projects. Inefficiency and incorrect utilisation of resources further cause the costs of performing the process from the ESCO's side to be unnecessarily excessive.

Along with the identification of problems comes the opportunity for improvement. The most important opportunity for improvement is the allocation of resources. The performance and lead time of the process may very well be shortened by removing activities from the M&V consultant and reallocating them to the project engineer. Furthermore, the economics (costs) of the process can be lowered and the efficiency increased.

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CHAPTER 4: DEVELOPMENT OF AN IMPROVED M&V PROCESS

4.1. INTRODUCTION

In Chapter 3 evaluation of the M&V process highlighted areas that require attention. Two objectives are approached simultaneously in Chapter 4. The first objective is to develop an improved M&V process based on the discoveries from the previous chapter. The second objective is to design an information system that will support the M&V process and help manage M&V activities.

Quality considerations under the ISO 9001:2008 standard were discussed in Chapter 2. The main consideration applicable to the M&V process is documentation control. In addition, the trends in information systems and the construction of systems were discussed in Chapter 2. In this chapter the knowledge gained on documentation control and information system design is used to improve the M&V process. Systems engineering assigns two areas to the design of high level and detail requirements. This chapter now employs this part of systems engineering to develop and put into service the opportunities for improvement.

The opportunities for improvement can be categorised into focus areas. *Process resources* is the category that targets the most efficient use of M&V process resources, in particular the human resources. *Standardisation* is an area of improvement that focuses on establishing criteria and work procedures for the M&V process. Requirements for an information system are distinguished and designed on high as well as detail level in the improvement category

information system. Finally the *quality* improvement area focuses on how the ISO 9001:2008 quality standards are applicable and beneficial to the M&V process.

4.2. FUNCTIONAL REQUIREMENTS

Functional requirements are those that define the function of a system. Bentley *et al.* (2007) stated functional requirements as "A description of activities and services a system must provide". The systems engineering approach has a step where functions are designated to subsystems. Functional requirements for the improvement focus areas are drawn up. The requirements aid the implementation and management of the solutions to the critical areas identified.

4.2.1. RESOURCE ALLOCATION

As a result of analysis, a restructuring of resource allocation is required. The project engineers must be given more responsibility of a project's M&V. This may, however, cause the consultant to lose sight of M&V groundwork. The system must therefore also assist the consultant in the management of resources and their M&V activities. To summarise the requirements for resource allocation:

- Reallocate a number of M&V activities to project engineers, and
- Ensure the M&V consultant is kept up to date on all the M&V activities of project engineers.

4.2.2. STANDARDISATION

According to recent research, standardisation of business processes holds great promise to make processes more manageable, less clouded and helps better process performance (Münsermann *et al.*, 2010). These benefits of standardisation may be especially useful since most of the M&V responsibility is handed over to people who have limited experience or knowledge concerning the M&V process. Given that senior project engineers perform the

pre-improved M&V process their transfer of knowledge to junior personnel is limited as well. Standardisation is one solution to address a requirement for better process understanding from project engineers:

- Standardise procedures and templates.

4.2.3. INFORMATION SYSTEM

Documentation control is the main feature of the ISO 9001:2008 standard as far as the M&V process is concerned. As part of this quality consideration a database of M&V documentation must form part of the information system for the M&V process. The M&V process adheres to the requirements to form a relational database because files and documentation for the M&V process are interconnected.

Another requirement for a practical information system is applications specifically designed for the M&V domain. An application that can automate certain tasks or activities is therefore a requirement for the M&V process. Some of the abovementioned functional requirements can be integrated with an automation application; for example, the task of allocating a project engineer and notifying said engineer can be automated.

The functional requirements for the information system can be described by the following:

- Design relational database to store M&V files and documentation, and
- Design domain and tailor-made applications to manage M&V activities.

4.2.4. CONTROL AND QUALITY

The resource allocation shift resulted in a final functional requirement for the system: to monitor the quality of M&V outputs and the activities of project engineers. The control and quality of the M&V process is directly affected by the information system supporting it.

Together, the above requirements form the high level purpose of the system; a system that will store quality data and information on a centralised database, with the help of correct resource allocation, standardisation and a bit of automation.

4.3. DETAIL DESIGN OF COMPONENTS

The functional requirements aided the coordination of improvement initiatives into specific focus areas. The detail design of components proceeds to identify means by which the functional requirements can be met.

The measurement and verification information system will henceforth be referred to by its acronym, MAVIS. The design parameters that will incorporate the functional requirements identified into MAVIS are detailed.

4.3.1. RESOURCES ALLOCATION

A need to relocate some of the activities has been identified. The project engineer should be responsible for devising an M&V approach and constructing the project baseline. The management of the process will become important when the consultant no longer performs the activities; the consultant must have a holistic view of all M&V activities. As a management information system, MAVIS must assist the consultant with the holistic view.

The graphical model that demonstrates the resource allocation can be seen in Appendix D.

4.3.2. STANDARDISATION

Aspects to be standardised are shown in Figure 28; the figure is used for demonstration purposes only. Four activities that take place before the implementation of the project are either given standardised templates or are being standardised according to criteria.

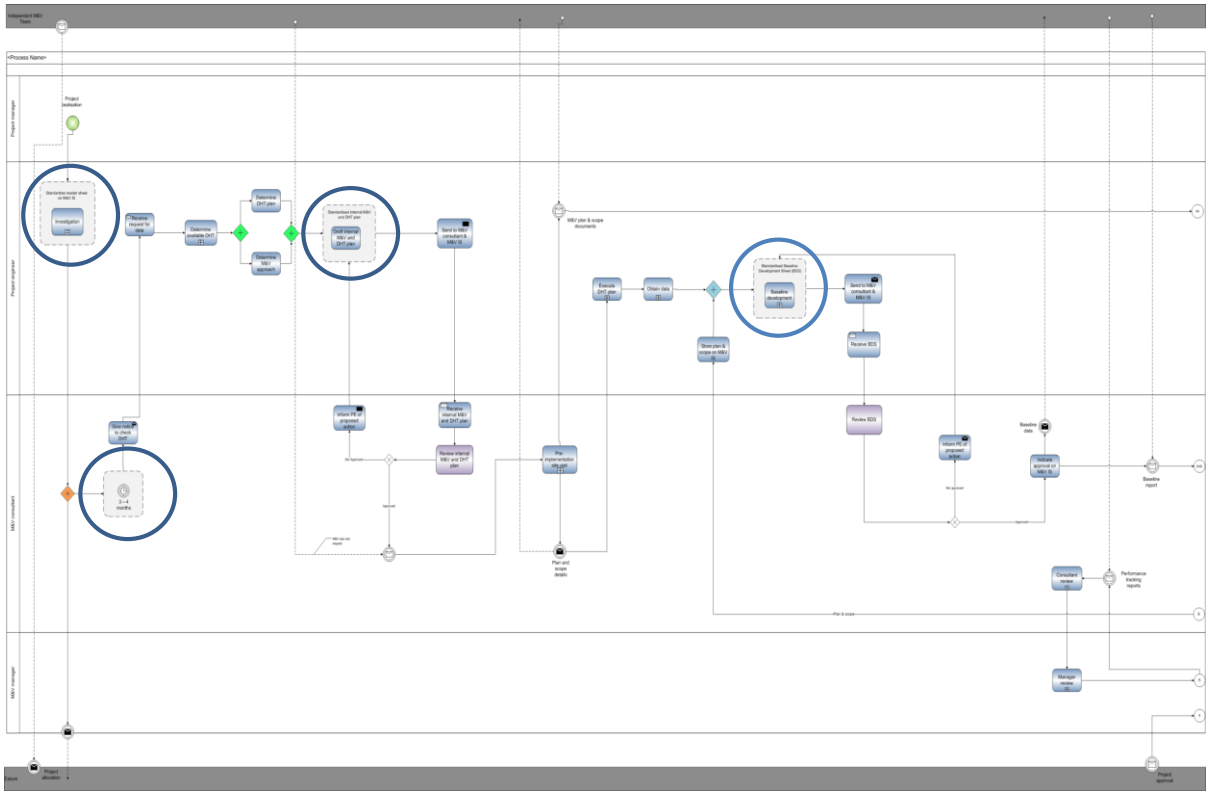

FIGURE 28: GRAPHICAL M&V PROCESS BUSINESS PROCESS MODEL WITH STANDARDISATION AREAS

INVESTIGATION FINDINGS

To simplify the process of writing project proposals for Eskom, the investigation findings are summarised in what is called a master sheet. In the master sheet, the first baseline for the project is given. It is upon this baseline that a conclusion will be drawn as to the potential for an energy-savings project. Standardising the documentation for investigation findings aids the consultant and management by giving historic data and origin of the baseline and potential.

PROJECT-DEPENDENT TIMEFRAME

The model of existing process indicated that there was no standardised method of determining when to start the process of determining M&V approach and researching DHT that are available. A standard waiting period can assist the project engineer to take a considered approach to M&V.

M&V APPROACH AND DATA LOGISTICS

Standardise the recording of M&V approach and acquiring data. The M&V consultant oversees a number of projects. This standardisation will allow him to keep a holistic view of

all projects and their M&V activities. Furthermore, if a new project has similar constraints or characteristics of a previous project, facts from the previous projects can be valuable to the new project. Standardising the requirement to draw up an approach to M&V will force the project engineer to contemplate the correct approach. This facilitates the cognitive process of understanding M&V as well as the performance of the process itself.

BASELINE DEVELOPMENT

The baseline development is probably the single most important activity of the M&V process. If the baseline is not properly constructed, the savings of the project could be negatively affected. A baseline that does not take into account the effect project variables may have on the savings can hinder project success. Again mentioned here is the fact that the consultant has to oversee many projects and a standardised method of presenting the project engineer's findings on baseline calculations can assist the consultant.

Demonstrated in Figure 29 is a Venn diagram of the standardisation actions and the business areas that may benefit from it.

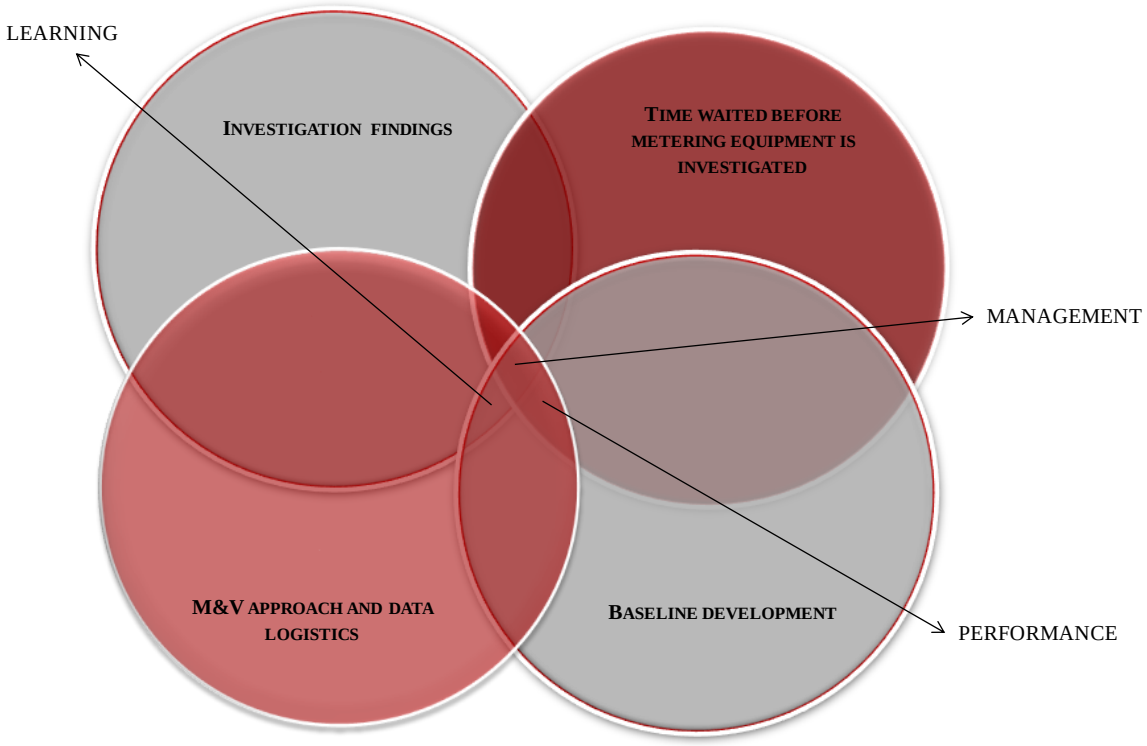

FIGURE 29: VENN DIAGRAM – BENEFITS OF M&V PROCESS STANDARDISATION

Management and the consultant benefit from all the new standardisation actions. The performance benefits from all save the investigation findings, and learning benefits from all

save the timing actions. MAVIS must hold standardised templates, information and calculate timeframes.

4.3.3. INFORMATION SYSTEM

A relational database for the M&V process will contain files and documentation connected by project details, project engineers and M&V teams. The database should store project details, project data (such as baseline data), baseline documentation (scope, plan and baseline reports) along with the performance assessment and performance tracking reports.

Most of the automation will be used to notify participants of occurring activities and uploading or downloading of necessary files. The automation of tasks aims to assist the implementation and management of the other requirements. This is done, for example, by automatically sending a notification via email to the project engineer stating that it is time to construct the baseline and attaching the baseline development template.

4.3.4. CONTROL AND QUALITY

Chapter 2 mentions that QMS and the ISO standards have been successful in improving the quality of a process output. Following this logic it is reasonable to assume that by making an effort to be ISO compliant, the quality of the process will improve. If the quality does not improve initially the policy is to keep on trying. This is the foundation of all ISO standards as well as the study of quality management: plan to improve, examine improvement, confirm improvement and proceed to take action to implement the improvement.

Keeping record of previous revision comments holds certain advantages; a concise record of notes, comments and additions made to a certain project's M&V documentation can be referred to when the same M&V team is assigned to a new project. If a number of comments are repeated often it is possible to avoid the same mistakes by taking preventative action and addressing the concerns beforehand.

The shift of resource responsibility described in Section 4.3.1 holds a project engineer responsible for the M&V process of the project. The M&V consultant is responsible for the management of the process and must therefore have a holistic view of activities. This is done

once again through the information system's relational database. The system should be designed to ensure the M&V consultant is constantly up to date with M&V activities and has access to all documentation.

4.4. SYSTEM DESIGN

4.4.1. PREAMBLE

During the course of this chapter the M&V process is improved and four areas are used to focus and guide improvement initiatives. In the *information system* focus area the improvement initiatives define the function of a system that support and manage the M&V process.

Following the function specification the system itself is designed. To coordinate the design of MAVIS in a methodical manner the systems thinking approach is used. The preliminary system design shows, on a high level, the interaction of the role players with MAVIS. The detail system design builds upon Van der Aalst's (2009) view of trends in information systems.

4.4.2. PRELIMINARY SYSTEM DESIGN

The four rules of systems thinking as described in Chapter 2 are used to aid the conceptualisation of a system space. First the system is categorised into smaller and more manageable subsystems. The subsystems that constitute MAVIS are structured according to similarities in information, data and stages of the M&V process.

The first subsystem, *project details*, coincides with the investigation stage of the project. The second subsystem is *project data*; the activities related to identifying and collecting of data, followed by the construction of the power consumption baseline. The third subsystem, *baseline documentation*, is vital to the M&V process; scoping reports, M&V plans and baseline reports are received and reviewed during this stage.

The fourth and fifth subsystems are *performance assessment* and *performance tracking* respectively. These subsystems directly correlate to the M&V stages of the project.

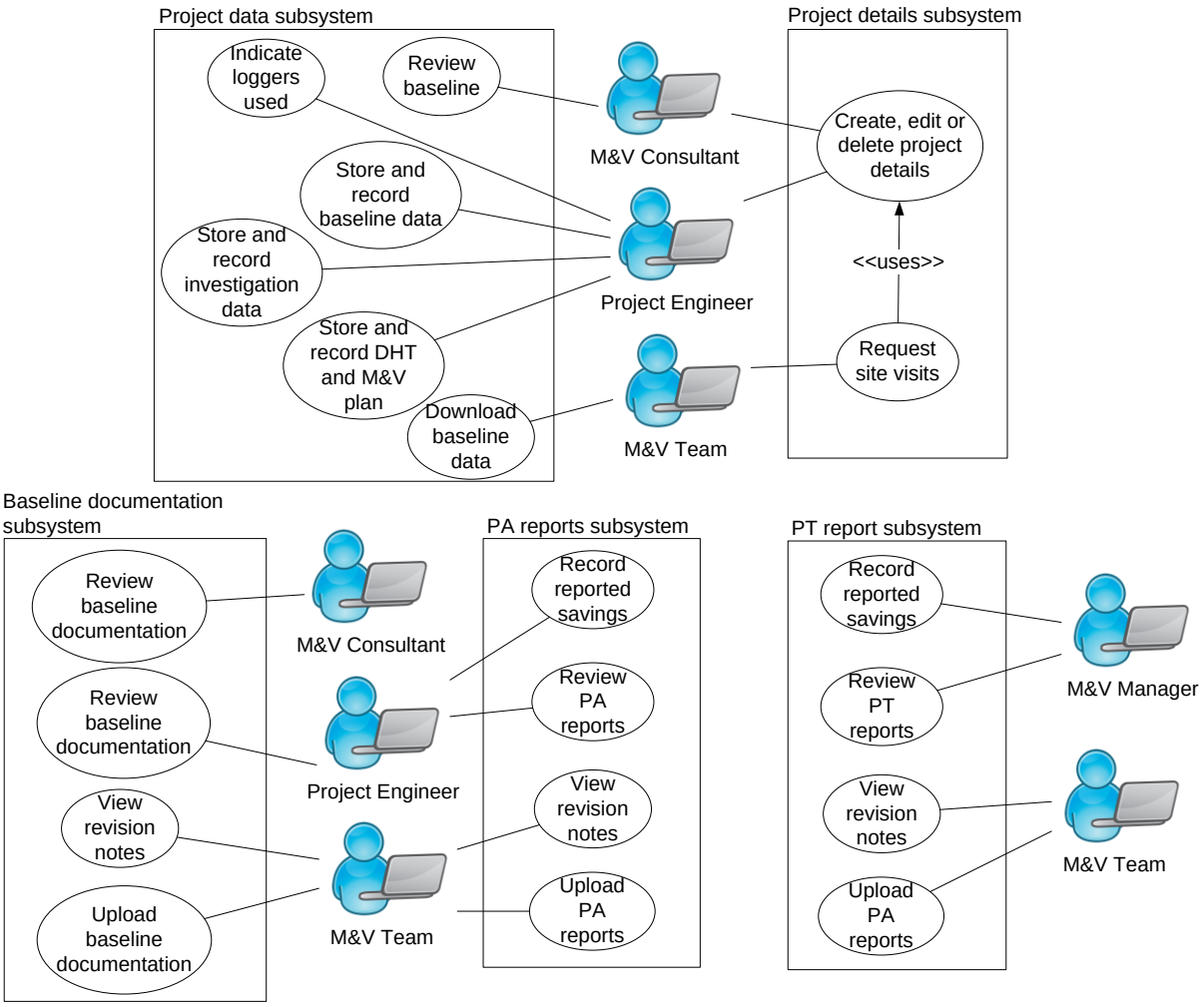

FIGURE 30: USE CASE DIAGRAM OF ROLE PLAYERS' INTERACTION WITH MAVIS

The use case diagram in Figure 30 shows how the different users interact with MAVIS. Furthermore, the perspectives of role players can be deduced from the use case diagram. The main form of interaction between the users and the system is information management; users manage information and data through the system. Role players see interfaces customised to display the information relevant to their participation in the M&V process.

The relationships between subsystems are basic: *project details* is the foundation to which all other subsystems are linked. There is, however, a reverse connection as well; as the remaining subsystems are updated, *project details* is likewise updated. Figure 31 graphically represents the relationships between the subsystems of MAVIS.

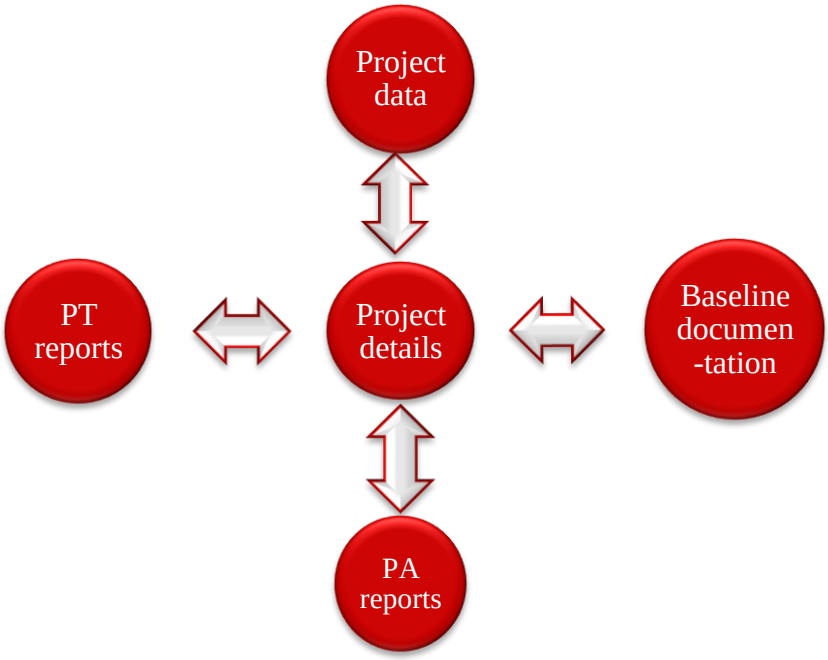

FIGURE 31: SYSTEMS THINKING RELATIONSHIPS BETWEEN SUBSYSTEMS OF MAVIS

4.4.3. DETAIL SYSTEM DESIGN

To provide a detailed description of the mechanisms of MAVIS the layers upon which information systems are built is revisited.

The functionality to allow data communication and multi-user access are the basic requirements for an operating system for MAVIS. Generic application, as specified in Chapter 2, is a DBMS where the subsystems of MAVIS constitute the storage units on the database. Domain-specific applications are a set of notification emails and automation of response-time calculations. Notification emails are sent out when triggered by another action and response-time calculations help inform participants when tasks or activities are to be executed. Tailor-made applications are queries sent to the RDMS that present the correct information to the correct resources or role players.

Appendix D can be examined for detail on the functional specification of MAVIS. Great detail is given on the flow of data in and out of MAVIS; the capabilities of the storage units that will hold the data are specified. Finally, the notification triggers and messages as well as explanation on the response-time calculation can be seen in Appendix D.

4.5. CONCLUSION

Improvements suggested in this chapter were acquired as a result of careful evaluation followed by a systematic methodology to categorise and develop improvement initiatives. Firstly, initiatives to better the M&V process are applied to focus areas of improvement. Secondly, suggested tasks, activities and standardised protocols are prepared for each of the focus areas.

A conceptual systems design communicates the functions of each subsystem of MAVIS as well as interaction between the system and its users. Operational specifications for MAVIS are put forth during a discussion on the detail design of the system.

To test the validity of the improvements a case study of the implemented suggestions is discussed in the next chapter.

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CHAPTER 5: FINDINGS AND DISCUSSIONS

5.1 INTRODUCTION

This chapter describes and discusses the findings of a case study where the suggested changes to the M&V process were implemented. The case study follows the framework of Chapter 3: data on the performance, efficiency, and costs of the process will be collected to determine the value of changes brought to the process.

First, the *to-be* process is modelled to showcase the activity and information flow modifications, followed by a comparison of the MAVIS design and the requirements of the improved process. The performance of the improved process is then measured by evaluating the data available; workdays between receiving a scoping report and signing the baseline report. The costs of placing the consultant responsibility role on project engineers are calculated along with the savings not yet realised (if M&V is the sole contributor to implementation delay). Finally, the efficiency of the process is measured.

The data was gathered by performing a case study on a South African ESCO. The ESCO under consideration is an ESCO specialising in energy-savings projects in the mining sector. The ESCO has implemented over 100 DSM projects and employs over 50 project engineers. Two employees focus on M&V: the M&V manager and the M&V consultant. Data for the empirical verification of the process can be seen in Appendix F.

5.2 NEW PROCESS MODEL AND MAVIS

The graphical model of the M&V process is altered to incorporate changes to resource allocation, standardisation and control and quality. In addition the support provided by the subsystems of MAVIS is indicated on the improved graphical model. The model indicating verification of the MAVIS design to M&V process requirements can be found in Appendix F.

Table 8 indicates the verification of the requirements for an improved M&V process within an ESCO.

TABLE 8: VERIFICATION OF IMPROVED PROCESS REQUIREMENTS

REQUIREMENT	VERIFICATION
Manage and allocate resources effectively	1. The *project details* subsystem allows the consultant to redistribute M&V activities to the project engineer responsible, and 2. The system informs and updates the consultant on ongoing M&V activities through notification and monitoring.
Standardise M&V process protocol	1. Investigation of findings template standardised and uploaded to MAVIS, 2. Calculation of timeframes for M&V data measurement commencement and requests for required performance tracking reports, 3. Control of record keeping and document revisions, and 4. Automation of notifications.
Information system design	1. A relational database for M&V data, documentation and reports is a fundamental part of MAVIS. 2. Automatic notifications are sent to all entities informing them of system additions relevant to their participation in the M&V process.

REQUIREMENT	VERIFICATION
Control and quality	1. Quality and control is ensured by the notification and monitoring of timely activities. 2. The MAVIS relational database aids the implementation of documentation control.

Opportunities for improvement were identified through the evaluation of the before-improvement M&V process. These improvement opportunities were categorised into focus areas, and functional requirements were developed to host M&V process improvements. Table 8 shows that functional requirements satisfy the improvement focus areas.

5.3 IMPROVED PROCESS PERFORMANCE

A lack of performance indicators for the M&V process was one motivation for research into the process. Moreover, evaluation of the M&V process indicated that it is an inefficient process. Response time is a performance indicator that can now be measured to determine inefficiencies. Measuring the response times will also aid the validation as to how successful the improvements to the process were.

Two projects that occurred during the case study timeframe were investigated to measure M&V process performance and efficiency. Table 9 summarises the results from measuring the response times of the M&V team and ESCO during the M&V process.

TABLE 9: AVERAGE RESPONSE TIMES DURING M&V PROCESS FOR M&V TEAM AND ESCO

	PROJECT 1	PROJECT 2
M&V team	10.40	10.67
ESCO	12.20	8.75

Project 1's performance data displays that the ESCO had an average response time of 12.2 days. The M&V team, however, on average responded within 10.40 days. In the

evaluation phase the working weekdays were taken from the date of the scoping report until the baseline report. These measurements are more detailed, because more project detail is available. This is due to the improved monitoring of the M&V process.

Where the M&V team responded quicker than the ESCO during Project 1, the tables have shifted in Project 2. The ESCO responded earlier during Project 2, but with an average not too far away from the M&V team's average response time.

To quantify the performance improvement between the before- and after-implementation M&V process the working weekdays between scoping and baseline report dates are used. Although more detailed performance and response times can now be measured and compared, for the purpose of showing improvement, performance measurement must have the same unit detail. Eight more projects could be added to the after-improvement indicators when measured according to the research evaluation criteria.

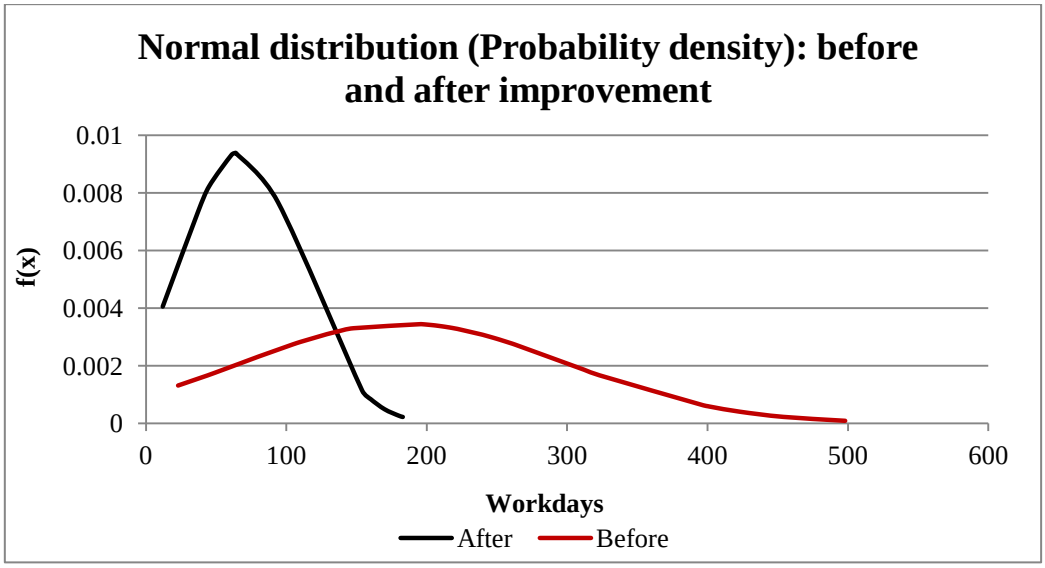

FIGURE 32: NORMAL DISTRIBUTION COMPARISON BEFORE AND AFTER M&V PROCESS IMPROVEMENT

The quantified results showed the following change. The mean of the after-improvement M&V process is 67 working weekdays, which is a 117 working weekday improvement in M&V process performance. The standard deviation of the after graph is still relatively close to the mean at 42.

5.4 COST CALCULATIONS OF IMPROVED PROCESS

Results show that improvements applied to the M&V process have a significant impact on the measured performance. The next step is to determine if reallocated resources have an effect on resource costs. Table 10 lists the activities of the after-improvement M&V process, along with appointed resources.

TABLE 10: ACTIVITIES ALLOCATED TO RESOURCES (AFTER IMPROVEMENT)

DETERMINE AVAILABLE DHT	PROJECT ENGINEER
Pre-implementation site visit	M&V consultant
Determine DHT plan	Project engineer
Determine M&V approach	Project engineer
Draft internal DHT & M&V plan	Project engineer
Review internal DHT & M&V plan	M&V consultant
Execute DHT plan	Project engineer
Obtain data	Project engineer
Baseline development	Project engineer
Review baseline	M&V consultant
Review documentation	Project engineer
Review feedback	M&V consultant
M&V consultant	33%
Project engineer	67%

Estimating the resource apportioning from the above table gives a 33% and 67% split. Cost- and time correlation of the after-improvement M&V process can be compared to the before-improvement situation.

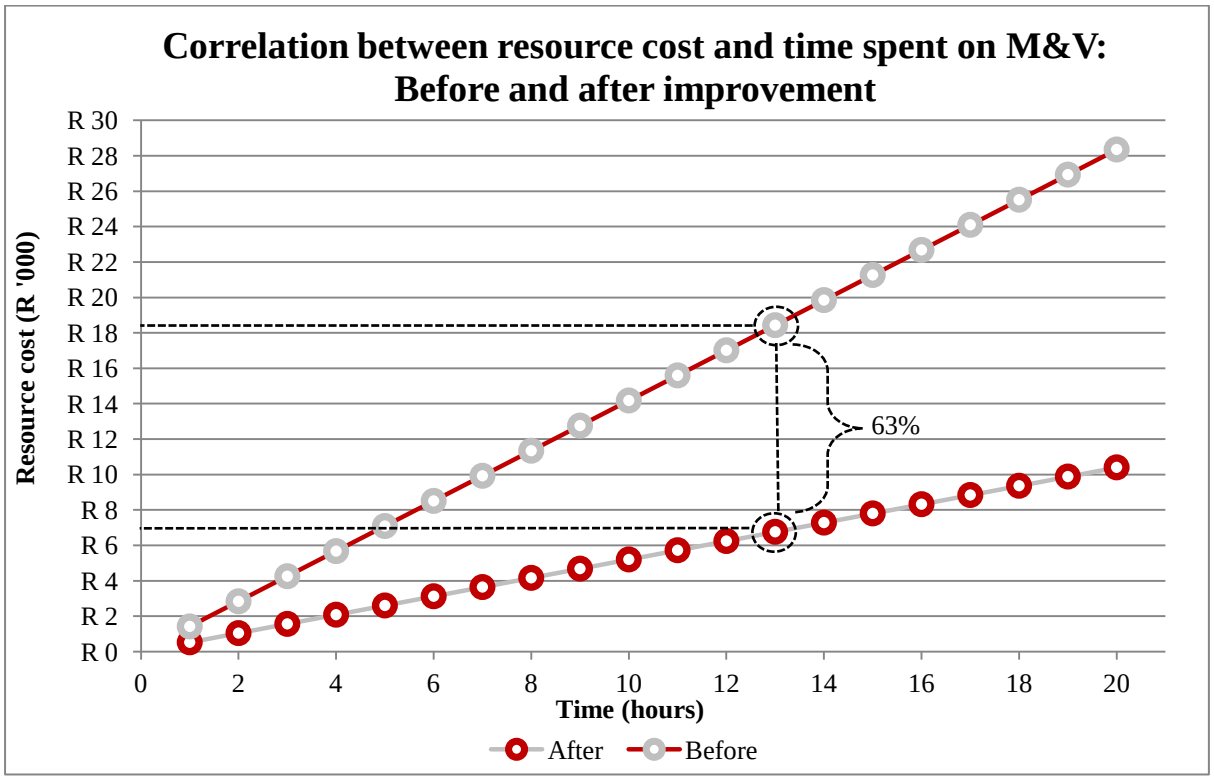

FIGURE 33: CORRELATION BETWEEN COST OF RESOURCES AND TIME SPENT ON M&V (BEFORE AND AFTER M&V PROCESS IMPROVEMENT)

The reallocation of resources results in a 63% improvement in resource costs.

5.5 EFFICIENCY OF IMPROVED PROCESS

The resource allocation improvements resulted in subsequent efficiency improvements; there is an unmistakeable reversal in efficiency. Before improvement the consultant performed 63% of the activities, whereas it now reversed to 33%. Project engineers were responsible for 37% of the M&V process and are now accountable for 67%.

5.6 CONCLUSION

Improvements developed in Chapter 4, excluding the design of MAVIS, were implemented in a South African ESCO. The majority of performance indicators that were quantified in Chapter 3 were used as a benchmark to determine the success of improvements. The case study results show a definite upgrade in the performance indicators of the M&V process internally performed by an ESCO.

There are, however, some limitations to the results obtained. Sample space for the improved M&V process is significantly smaller than the sample space used in Chapter 3 and understandably influences the performance indicator (response time). A comparison of the before- and after-improvement project delay costs is superfluous to this study; seeing as the costs are directly proportionate to the response time of the process it is self-explanatory that the costs will fluctuate together with the response time. Lastly, the value of an information system for the M&V process cannot yet be realised as the system has not been put into operation.

Despite the limitations the case study proved successful in quantifying improvements in performance indicators of the M&V process. What is more the case study demonstrates that changes brought on by individual improvements resulted in an overall improved M&V process.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. FINAL CONCLUSION

The M&V process is essential to determine accurate savings of energy cost-saving projects. In addition, depending on the funding model, the accuracy of the savings either has a direct or indirect impact on the financial prospects of the ESCO. The focus of this study was therefore the internal M&V process of an ESCO. The first consideration was the importance of M&V to the success of the ESCOs initiatives and financial implications.

A brief analysis based on a framework that aids the identification of problems and opportunities revealed that virtually nothing is known about the M&V process. The analysis further helped to identify problems that may occur as a result of poor performance. The second consideration was therefore to provide quantification of performance indicators and establish the validity of hypothesised problems.

Objectives for the study were formed based on the aforementioned considerations. Firstly, evaluate the M&V process for problems and opportunities. In addition, quantify performance indicators to show if speculated problems in fact do occur. If opportunities for improvement are evident improve the M&V process of an ESCO.

To start with, research revealed positive impacts as well as numerous approaches associated with the improvement of business processes. Amongst these approaches is business process modelling that graphically transfers knowledge of process tasks, activities and flow. This was

followed by a study in the collection, analysis and presentation of data. The field of statistics was used as one method to represent data gathered from a South African ESCO. Other performance indicators were measured according to the same framework used to support the need to evaluate the M&V process. Discoveries made through evaluation include:

- Lack of standardisation causes confusion amongst resources and a lack of understanding,
- Incorrect resource allocation causes inefficiency of the process,
- Prolonged response times has financial implications, and
- Deficiency of a concrete database results in inadequate documentation control.

Just as the evaluation validated the hypothesised problems it also introduced opportunities for improvement. Opportunities were categorised into focus areas of improvement, and functional requirements for the opportunities in each area were constructed. After assigning function to each improvement area, an operational strategy to implement improvements was presented. The development of an improved M&V process ends with the preliminary and detail design of an information system that supports the M&V process and assists the management of resources and activities.

The suggested improvements, save for the information system, was implemented in a South African ESCO. The results were compared to the performance indicators quantified in the evaluation of the M&V process. The following results were obtained:

- The performance in terms of response time decreased by 117 working weekdays,
- The reallocation of resources resulted in a 63% improvement in resource costs, and
- The efficiency improved.

The various outcomes of evaluation, development and implementation were examined and the study can forthwith be concluded: all three of the study's intended objectives for the internal M&V process of an ESCO were reached successfully.

6.2. RECOMMENDATIONS

Although there was a significant improvement in the M&V process and the objectives of the study were achieved there are nevertheless some limitations. Fortunately the limitations provide possibilities to foster the investigation and improvement of the M&V process of ESCOs specifically and ultimately all M&V processes of energy cost-saving projects.

A limitation on the performance measure for the case study regarding response time is the relatively small sample space. Because there are only a finite number of projects performed over the course of year, and consequently a finite number of M&V processes, this limitation is fixed. This means that the long-term effects are still unknown. This presents an opportunity to continuously measure and monitor the performance indicators of the process.

The benefits of a supporting information system are excluded because it was not specified as an objective for this study. The objective put forward was to develop a system based on observation, investigation and knowledge gained on the M&V process of an ESCO. It is suggested that MAVIS be built and tested. The suggestion can be extended to include the M&V team, not only as users on the ESCOs M&V information system, but as administrators on an information system for external M&V teams.

APPENDIX A: M&V PROCESS DATA

PRE-IMPROVED M&V DATA

	Network days (outliers excluded)	f(x)
1	23	0.001357
2	45	0.001703
3	49	0.001768
4	50	0.001785
5	50	0.001785
6	50	0.001785
7	66	0.002051
8	66	0.002051
9	75	0.0022
10	79	0.002266
11	81	0.002299
12	81	0.002299
13	105	0.002672
14	106	0.002687
15	110	0.002743
16	129	0.002985
17	130	0.002996
18	130	0.002996
19	130	0.002996
20	132	0.003018
21	133	0.003029
22	137	0.00307
23	148	0.003168
24	196	0.003295
25	196	0.003295
26	196	0.003295
27	199	0.003286
28	205	0.003262
29	206	0.003257
30	211	0.00323
31	215	0.003204
32	217	0.00319
33	218	0.003182
34	222	0.003151

	Network days (outliers included)	f(x)
1	1	0.001222985
2	1	0.001222985
3	1	0.001222985
4	1	0.001222985
5	1	0.001222985
6	1	0.001222985
7	23	0.001398654
8	45	0.001574091
9	49	0.001605506
10	50	0.001613324
11	50	0.001613324
12	50	0.001613324
13	66	0.001735863
14	66	0.001735863
15	75	0.001802103
16	79	0.00183077
17	81	0.001844907
18	81	0.001844907
19	105	0.002002488
20	106	0.002008506
21	110	0.002032084
22	129	0.002132413
23	130	0.00213712
24	130	0.00213712
25	130	0.00213712
26	132	0.002146352
27	133	0.002150875
28	137	0.002168346
29	148	0.002211071
30	196	0.002297158
31	196	0.002297158
32	196	0.002297158
33	199	0.002296816
34	205	0.002294076

35	239	0.002983
36	241	0.00296
37	260	0.002713
38	263	0.00267
39	312	0.001882
40	397	0.000693
41	400	0.000663
42	404	0.000624
43	423	0.000462
44	454	0.000268
45	498	0.000111

35	206	0.002293353
36	211	0.002288606
37	215	0.002283452
38	217	0.002280425
39	218	0.0022788
40	222	0.002271558
41	239	0.002227812
42	241	0.002221322
43	260	0.002146352
44	263	0.002132413
45	312	0.001837856
46	397	0.001175749
47	400	0.001152304
48	404	0.001121249
49	423	0.000977679
50	454	0.000761988
51	498	0.000506462
52	515	0.000425147
53	623	0.000111808
54	635	9.41136E-05
55	724	2.25955E-05

MISSED SAVINGS

Working weekdays	Peak clipping (PC)	Energy efficiency (EE)	Load shifting (LS)
23	R 420 030.41	R 463 851.98	R 162 197.59
44	R 803 536.43	R 887 369.00	R 310 291.04
45	R 821 798.62	R 907 536.48	R 317 343.10
47	R 858 323.00	R 947 871.43	R 331 447.24
49	R 894 847.39	R 988 206.39	R 345 551.38
50	R 913 109.58	R 1 008 373.86	R 352 603.45
50	R 913 109.58	R 1 008 373.86	R 352 603.45
50	R 913 109.58	R 1 008 373.86	R 352 603.45
65	R 1 187 042.45	R 1 310 886.02	R 458 384.48
66	R 1 205 304.64	R 1 331 053.50	R 465 436.55
66	R 1 205 304.64	R 1 331 053.50	R 465 436.55
75	R 1 369 664.37	R 1 512 560.80	R 528 905.17
79	R 1 442 713.13	R 1 593 230.71	R 557 113.45
81	R 1 479 237.52	R 1 633 565.66	R 571 217.59
81	R 1 479 237.52	R 1 633 565.66	R 571 217.59
105	R 1 917 530.11	R 2 117 585.11	R 740 467.24
106	R 1 935 792.31	R 2 137 752.59	R 747 519.31
110	R 2 008 841.07	R 2 218 422.50	R 775 727.59
129	R 2 355 822.71	R 2 601 604.57	R 909 716.90
129	R 2 355 822.71	R 2 601 604.57	R 909 716.90
130	R 2 374 084.90	R 2 621 772.05	R 916 768.97
132	R 2 410 609.29	R 2 662 107.00	R 930 873.11
133	R 2 428 871.48	R 2 682 274.48	R 937 925.17
137	R 2 501 920.25	R 2 762 944.39	R 966 133.45
148	R 2 702 804.35	R 2 984 786.64	R 1 043 706.21
196	R 3 579 389.55	R 3 952 825.55	R 1 382 205.52
196	R 3 579 389.55	R 3 952 825.55	R 1 382 205.52
196	R 3 579 389.55	R 3 952 825.55	R 1 382 205.52
199	R 3 634 176.12	R 4 013 327.98	R 1 403 361.73
205	R 3 743 749.27	R 4 134 332.84	R 1 445 674.14
205	R 3 743 749.27	R 4 134 332.84	R 1 445 674.14
206	R 3 762 011.46	R 4 154 500.32	R 1 452 726.21

Working weekdays	Peak clipping (PC)	Energy efficiency (EE)	Load shifting (LS)
211	R 3 853 322.42	R 4 255 337.71	R 1 487 986.56
215	R 3 926 371.19	R 4 336 007.62	R 1 516 194.83
216	R 3 944 633.38	R 4 356 175.09	R 1 523 246.90
217	R 3 962 895.57	R 4 376 342.57	R 1 530 298.97
218	R 3 981 157.76	R 4 396 510.05	R 1 537 351.04
222	R 4 054 206.53	R 4 477 179.96	R 1 565 559.31
222	R 4 054 206.53	R 4 477 179.96	R 1 565 559.31
239	R 4 364 663.79	R 4 820 027.07	R 1 685 444.49
241	R 4 401 188.17	R 4 860 362.03	R 1 699 548.62
248	R 4 529 023.51	R 5 001 534.37	R 1 748 913.11
252	R 4 602 072.28	R 5 082 204.28	R 1 777 121.38
253	R 4 620 334.47	R 5 102 371.75	R 1 784 173.45
260	R 4 748 169.81	R 5 243 544.09	R 1 833 537.94
263	R 4 802 956.38	R 5 304 046.53	R 1 854 694.14
312	R 5 697 803.77	R 6 292 252.91	R 2 200 245.52
323	R 5 898 687.88	R 6 514 095.16	R 2 277 818.28
397	R 7 250 090.05	R 8 006 488.48	R 2 799 671.39
400	R 7 304 876.63	R 8 066 990.91	R 2 820 827.59
404	R 7 377 925.39	R 8 147 660.82	R 2 849 035.87
423	R 7 724 907.03	R 8 530 842.89	R 2 983 025.18
454	R 8 291 034.97	R 9 156 034.69	R 3 201 639.32
498	R 9 094 571.40	R 10 043 403.69	R 3 511 930.35

APPENDIX B: M&V STRATEGIC LEVEL MODEL

The model is partitioned into three phases to facilitate the understanding and illustration thereof. The phases are set up as a road map; each phase ends with a reference that continues in the next phase. The first phase is displayed in Figure 34.

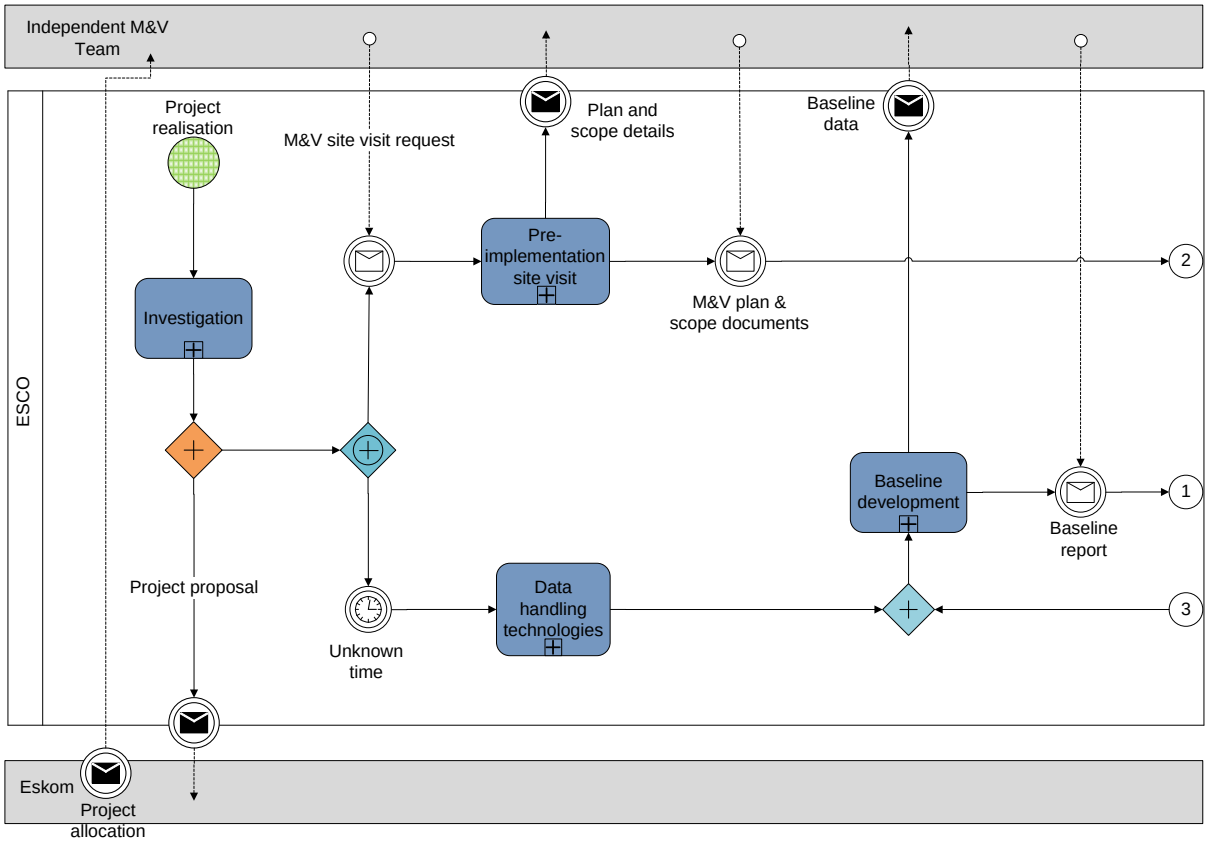

FIGURE 34: STRATEGIC LEVEL MODEL: PHASE 1

There are three pools in this level: the independent M&V team, the ESCO and Eskom. Although Chapter 1 indicates four stakeholders the M&V process model recognises only three. This is because Eskom IDM and EA can be seen as one stakeholder: Eskom. All M&V tasks and activities up to developing the baseline are displayed. The phase ends with the ESCO sending baseline data to the M&V team. Operation sequence of the process continues in the phase displayed in Figure 35.

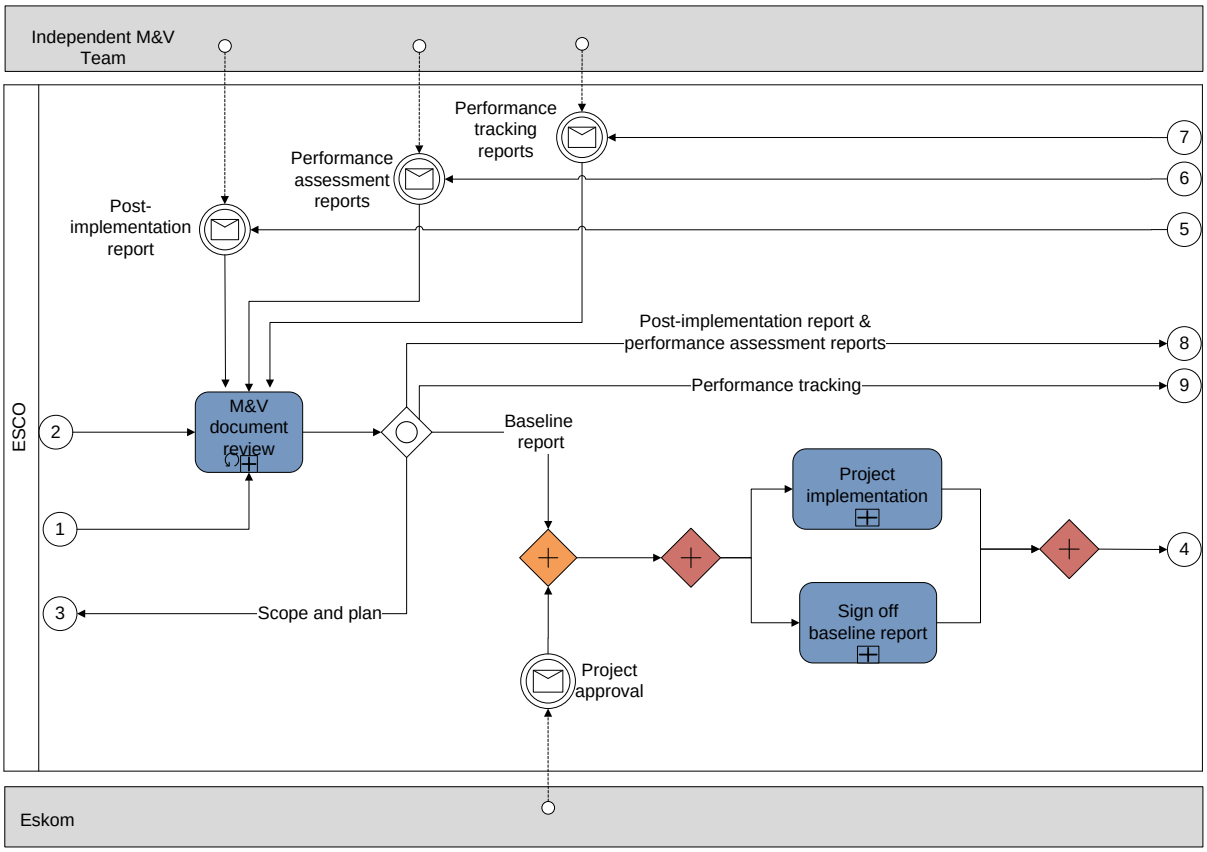

FIGURE 35: STRATEGIC LEVEL MODEL: PHASE 2

During this phase all documentation received from the M&V is reviewed. An elaborate looping sequence signifies that a document is received, reviewed and either accepted or sent back to be adjusted. Also included is the implementation of the project and the signing off of the baseline. The project cannot be implemented if the baseline is not signed.

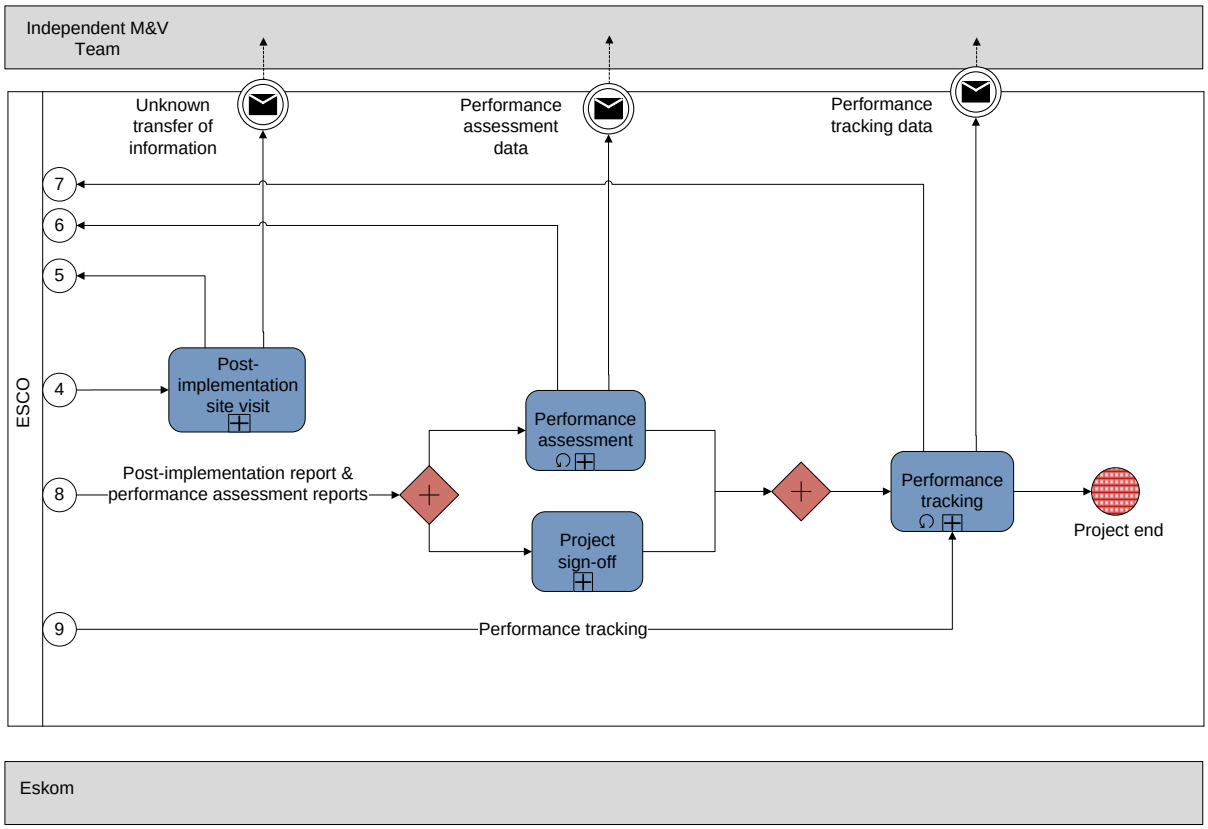

FIGURE 36: STRATEGIC LEVEL MODEL: PHASE 3

After the project is implemented the M&V performs another site visit and compiles another report. Afterwards the project enters the performance assessment and tracking stages before the project ends.

APPENDIX C: M&V TACTICAL LEVEL MODEL

PHASE 1

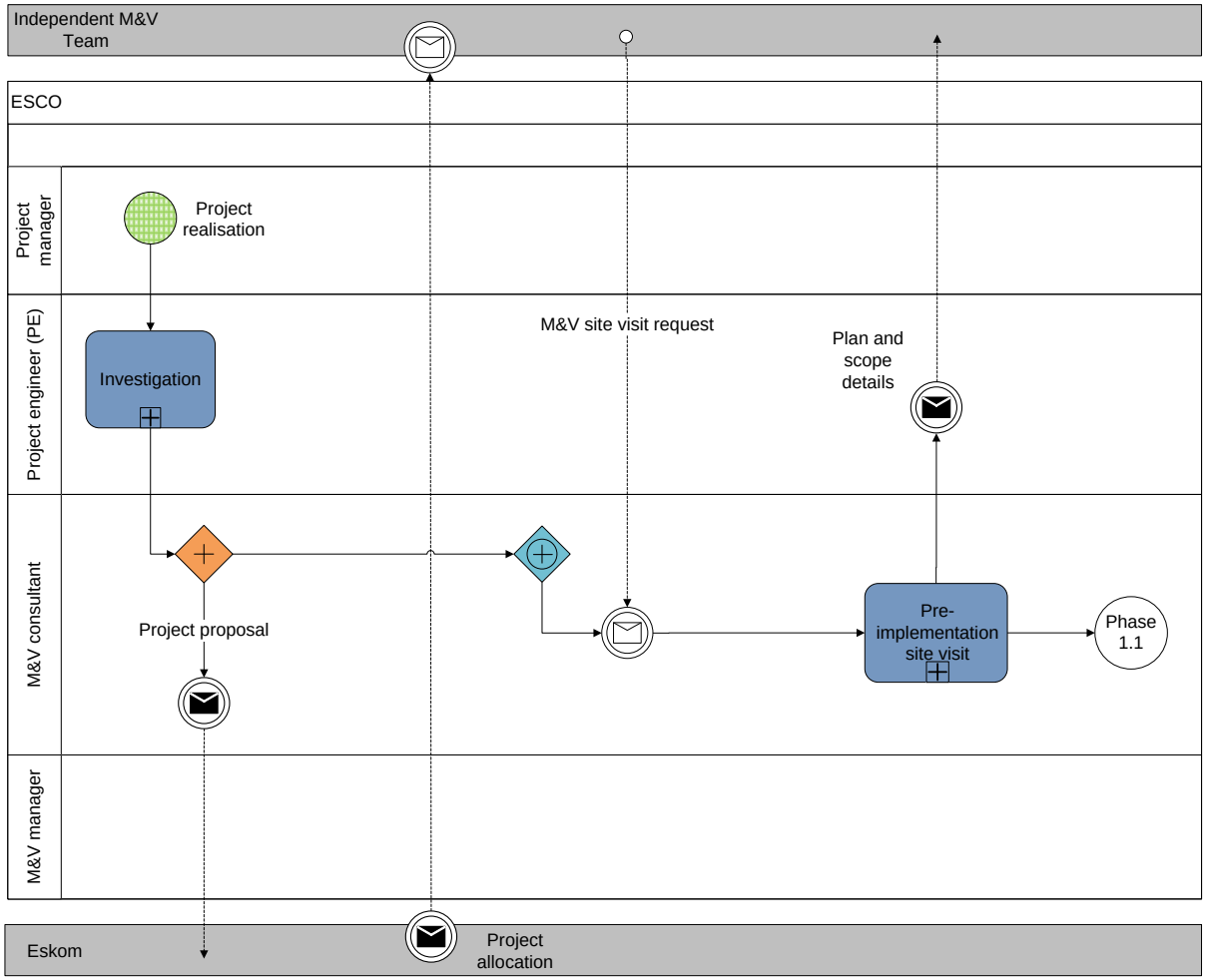

FIGURE 37: TACTICAL LEVEL MODEL: PHASE 1

In Phase 1 of the tactical level the project manager realises an opportunity for a project. The project engineer investigates the opportunity. A proposal is written and submitted to Eskom if the project engineer finds the project to be feasible. Eskom allocates an M&V team and they request a pre-implementation site visit. The M&V consultant acts as liaison between Eskom and the ESCO.

PHASE 2

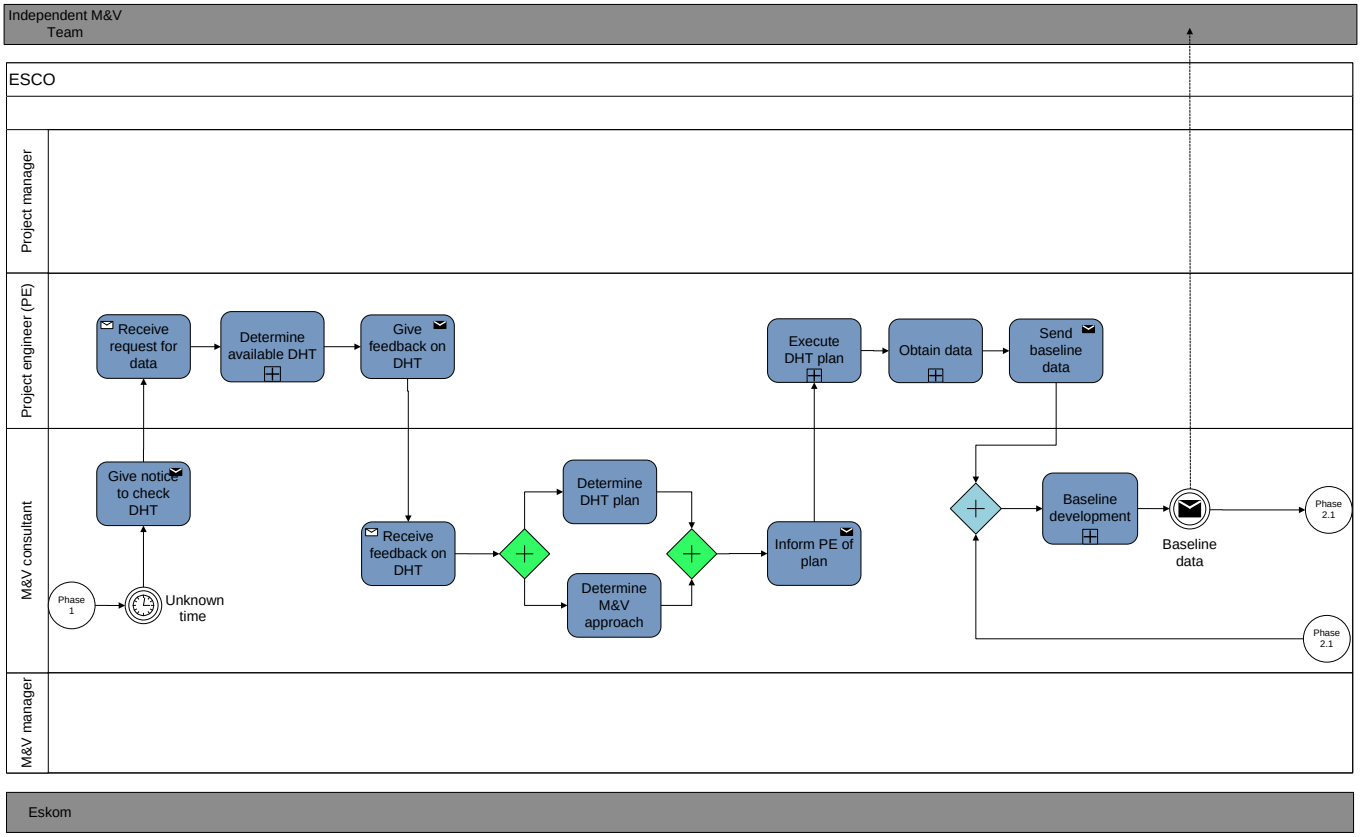

FIGURE 38: TACTICAL LEVEL MODEL: PHASE 2

In parallel with the M&V site visit the baseline can be developed. In this phase most of the responsibility and time-consuming activities fall on the M&V consultant. The project engineer will do the legwork to obtain data for the baseline. It is the M&V consultant who will determine the M&V approach and ascertain the baseline.

PHASE X.I

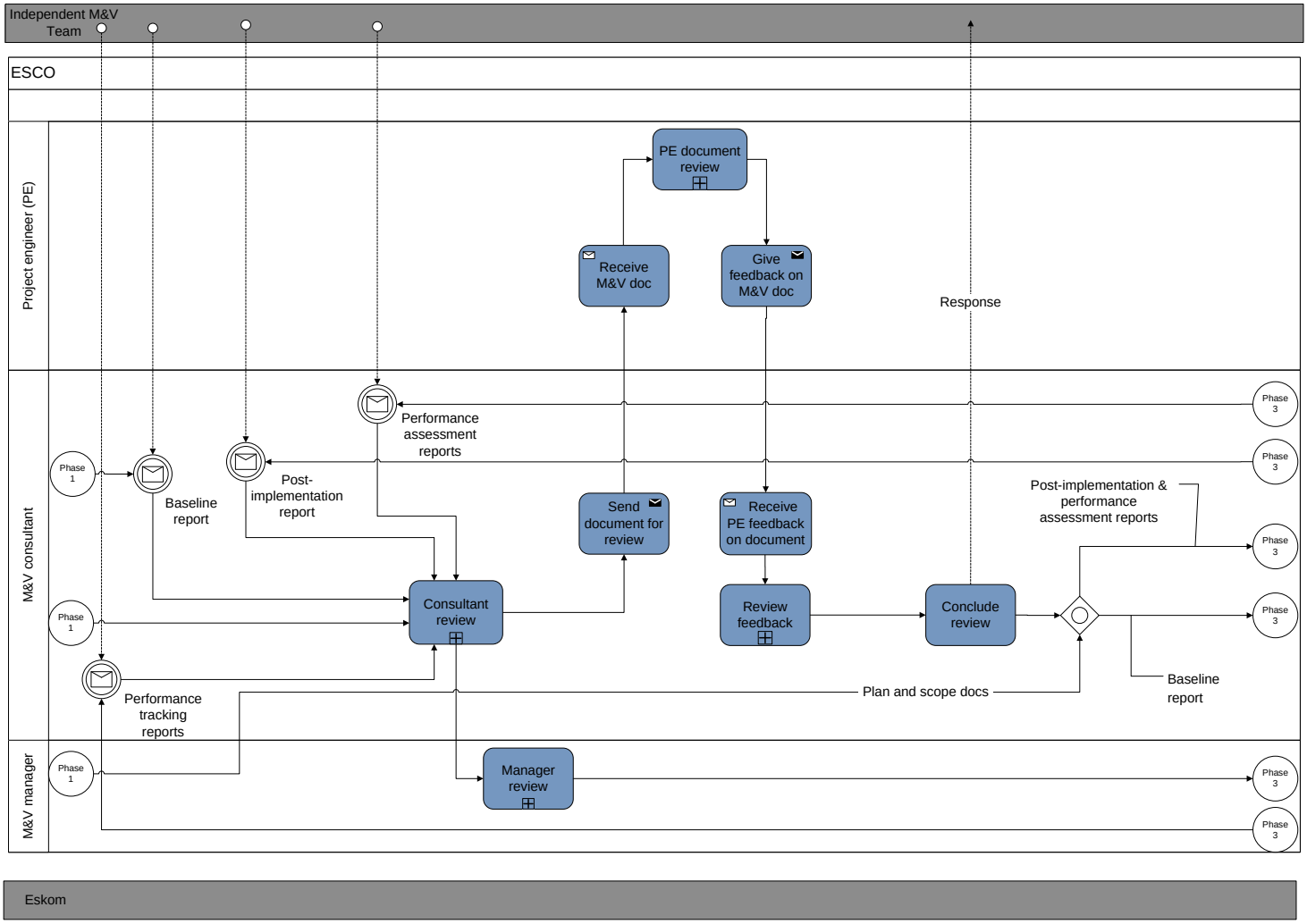

FIGURE 39: TACTICAL LEVEL MODEL: PHASE X.I

Phase X.I is the iteration of the activities related to document review. Each document compiled by the M&V team is received, reviewed and either accepted or sent back to M&V for editing. Specific documents dictate if the phase is exited by going back to Phase 1 or forward to Phase 3. The M&V consultant continues to act as liaison between the ESCO and the M&V team.

PHASE 3

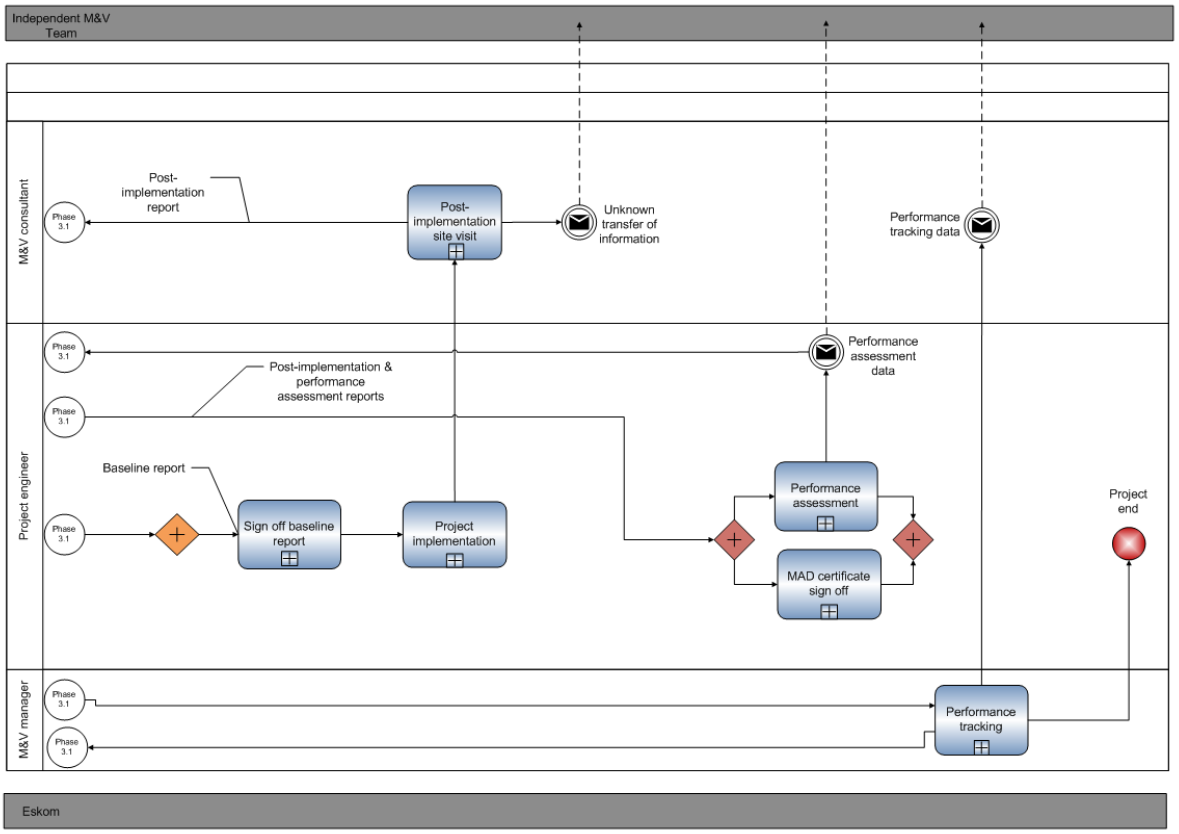

FIGURE 40: TACTICAL LEVEL MODEL: PHASE 3

Most of the responsibility in final phase is shifted to the project engineer. The technicalities of the M&V process are now completed and the M&V consultant will only step in to assist if discrepancies arise and to check the progress. Once in performance tracking the M&V manager will assist with administering the process.

APPENDIX D: IMPROVED M&V PROCESS MODELS

RESOURCE ALLOCATION IMPROVEMENTS

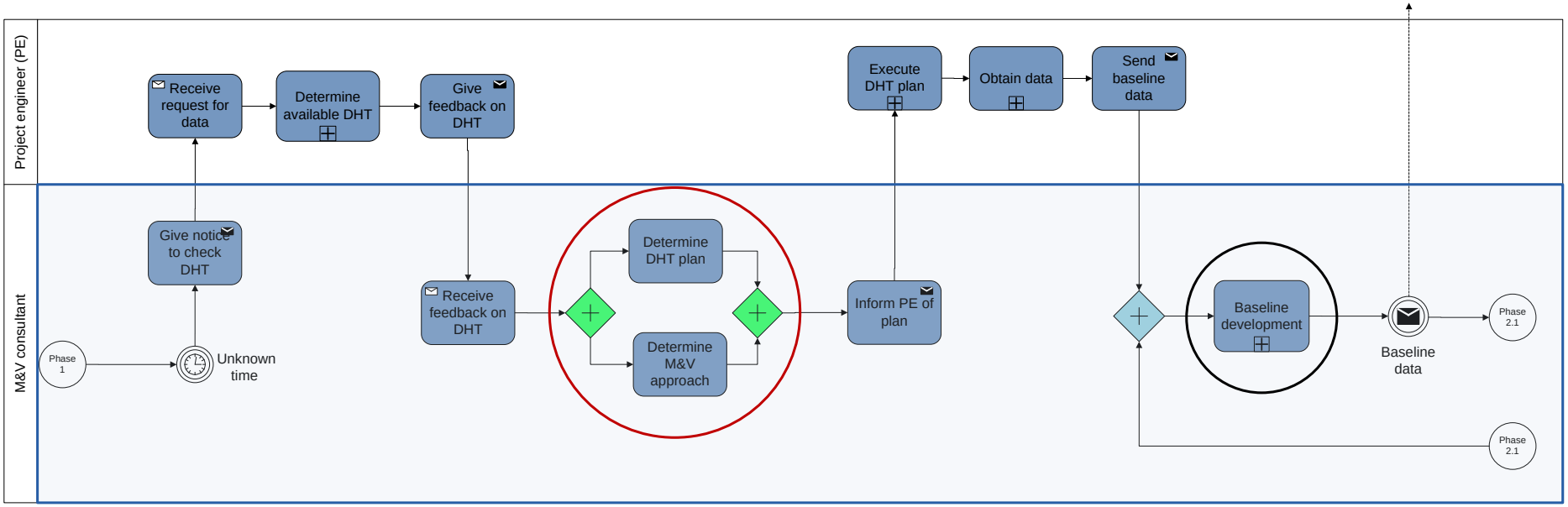

FIGURE 41: GRAPHICAL MODEL SHOWING BEFORE-IMPROVEMENT RESOURCE ALLOCATION

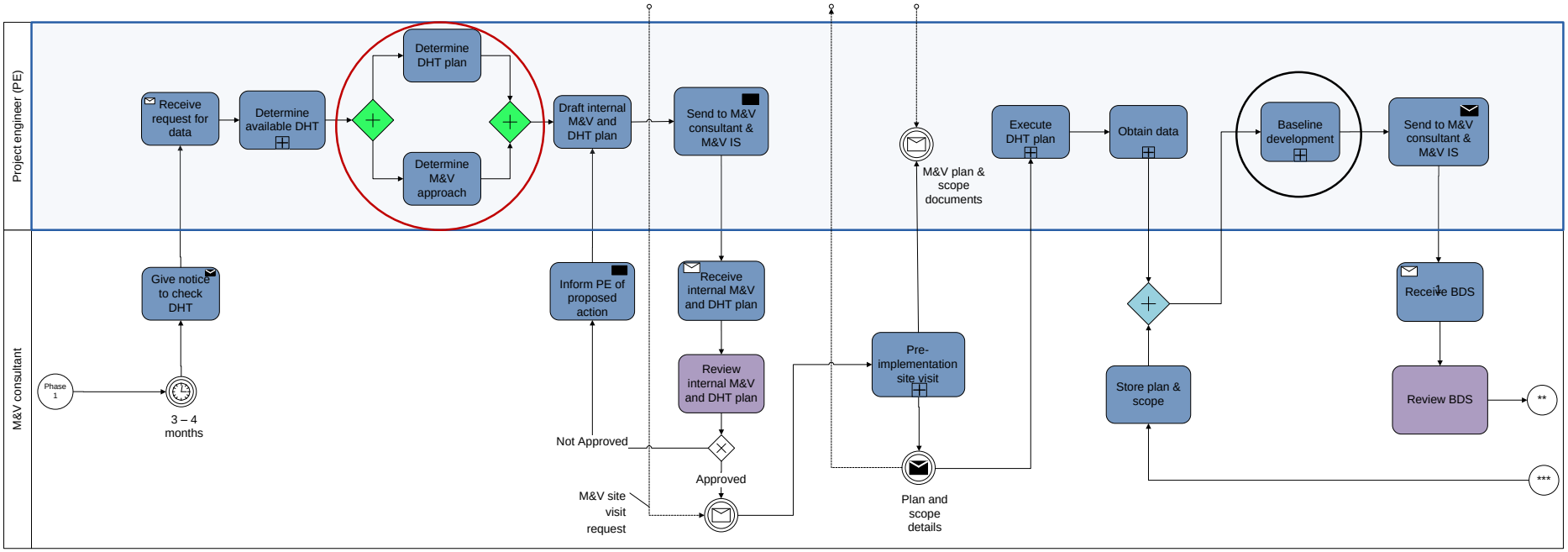

FIGURE 42: GRAPHICAL MODEL SHOWING AFTER-IMPROVEMENT RESOURCE ALLOCATION

FUNCTIONAL SPECIFICATIONS OF MAVIS

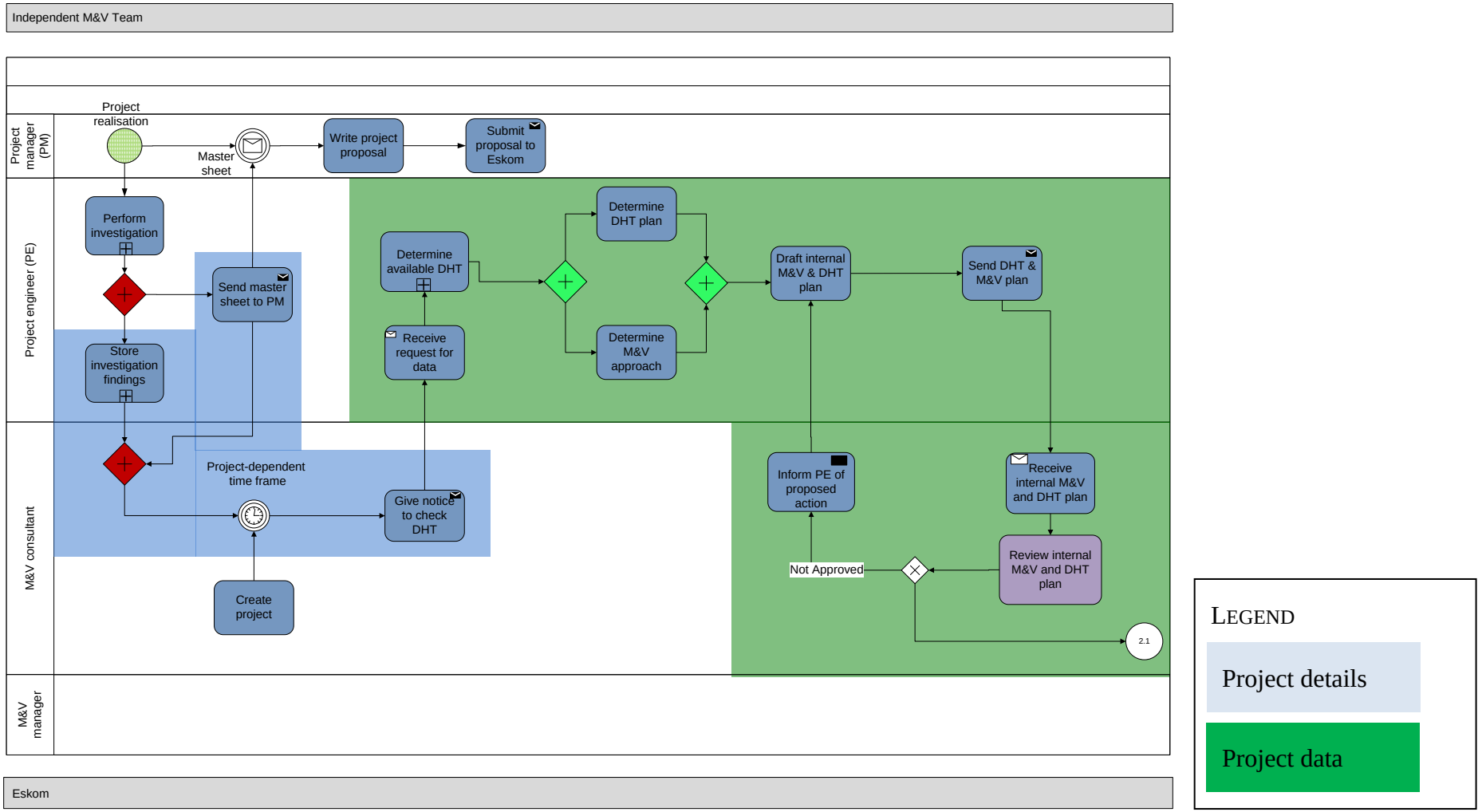

FIGURE 43: GRAPHICAL MODEL DEPICTING DETAIL ON THE FUNCTIONAL SPECIFICATION OF MAVIS – PHASE 1

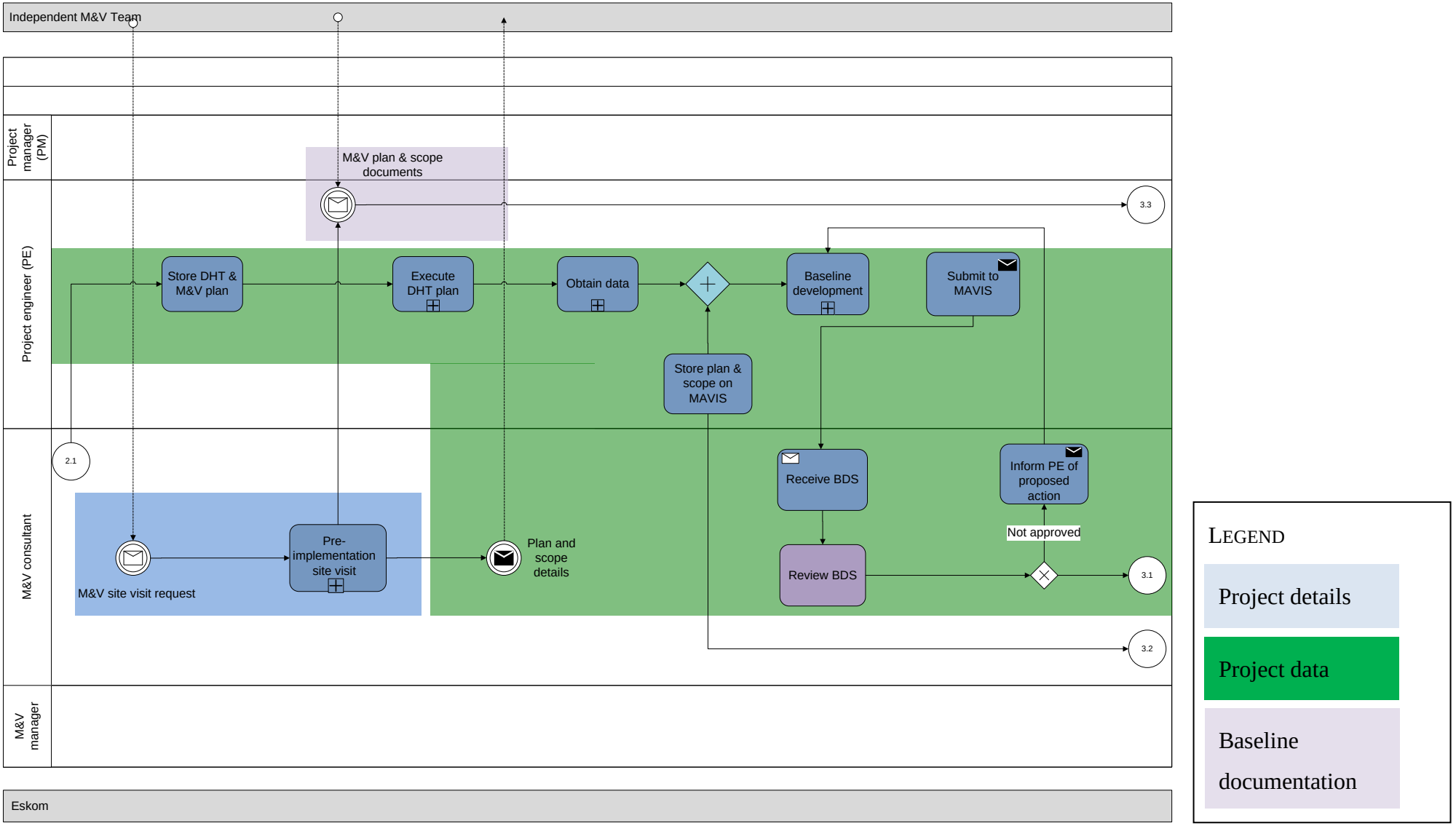

FIGURE 44: GRAPHICAL MODEL DEPICTING DETAIL ON THE FUNCTIONAL SPECIFICATION OF MAVIS – PHASE 2

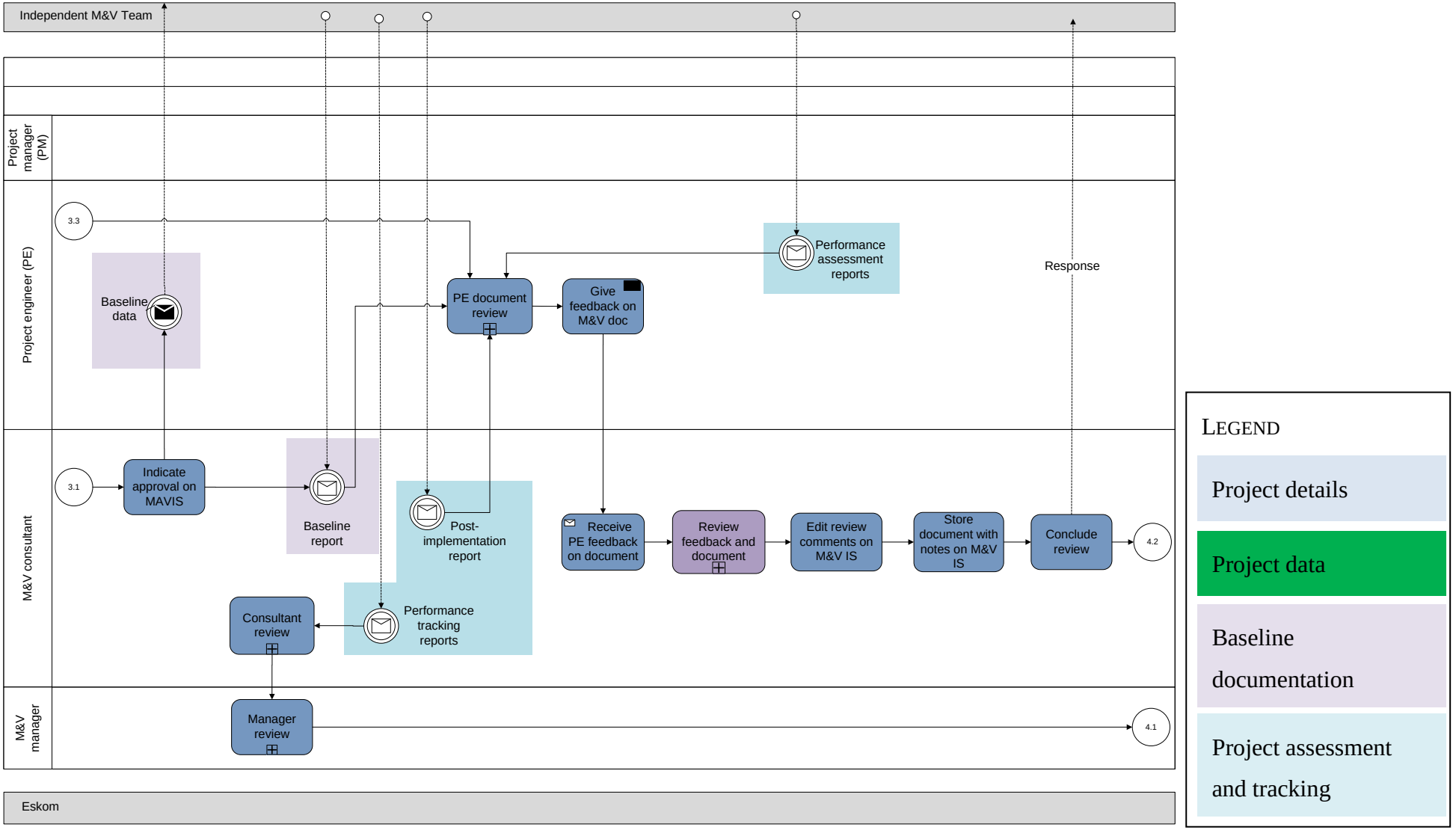

FIGURE 45: GRAPHICAL MODEL DEPICTING DETAIL ON THE FUNCTIONAL SPECIFICATION OF MAVIS – PHASE 3

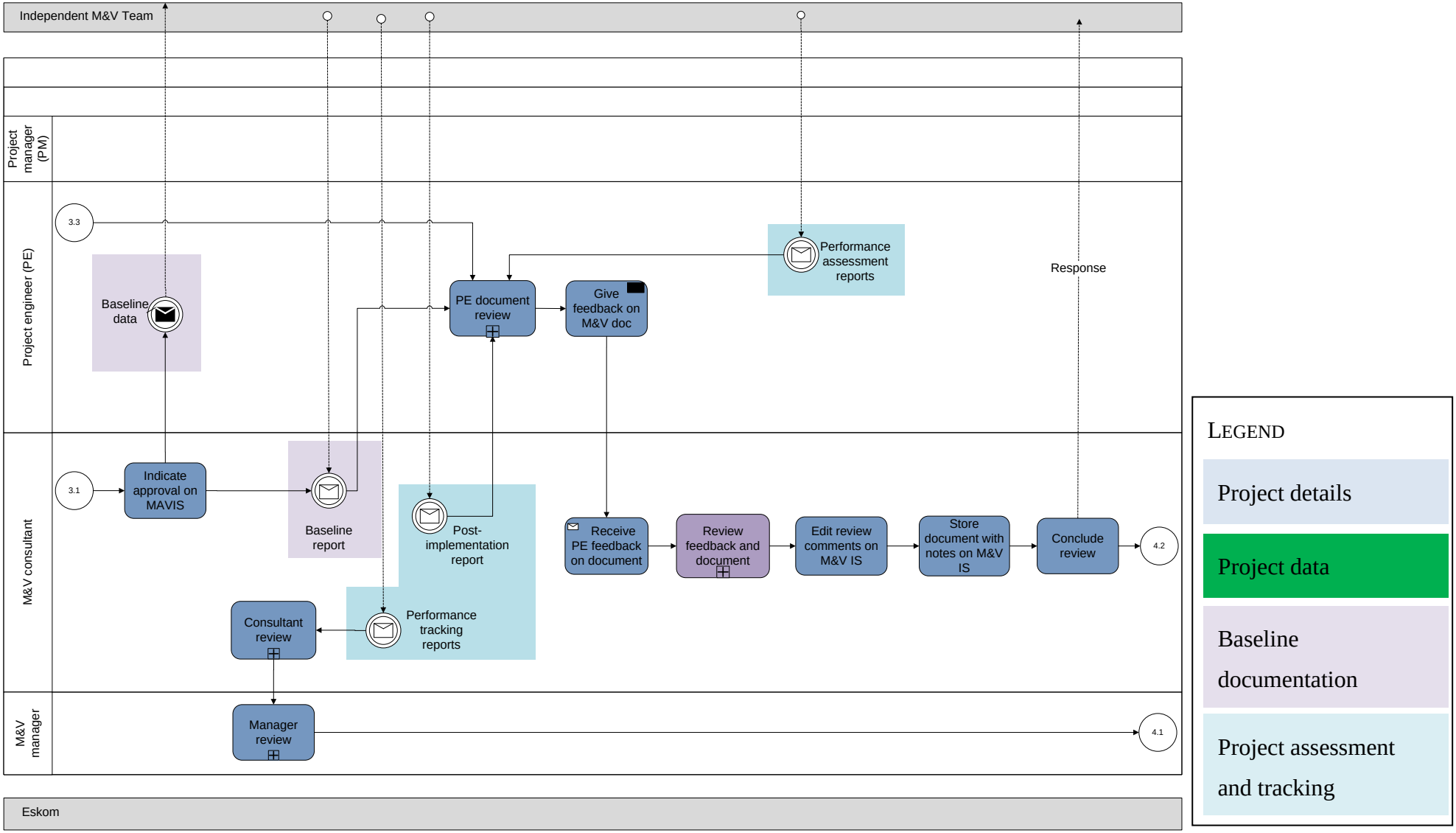

FIGURE 46: GRAPHICAL MODEL DEPICTING DETAIL ON THE FUNCTIONAL SPECIFICATION OF MAVIS – PHASE 4

APPENDIX E: ARCHITECTURE

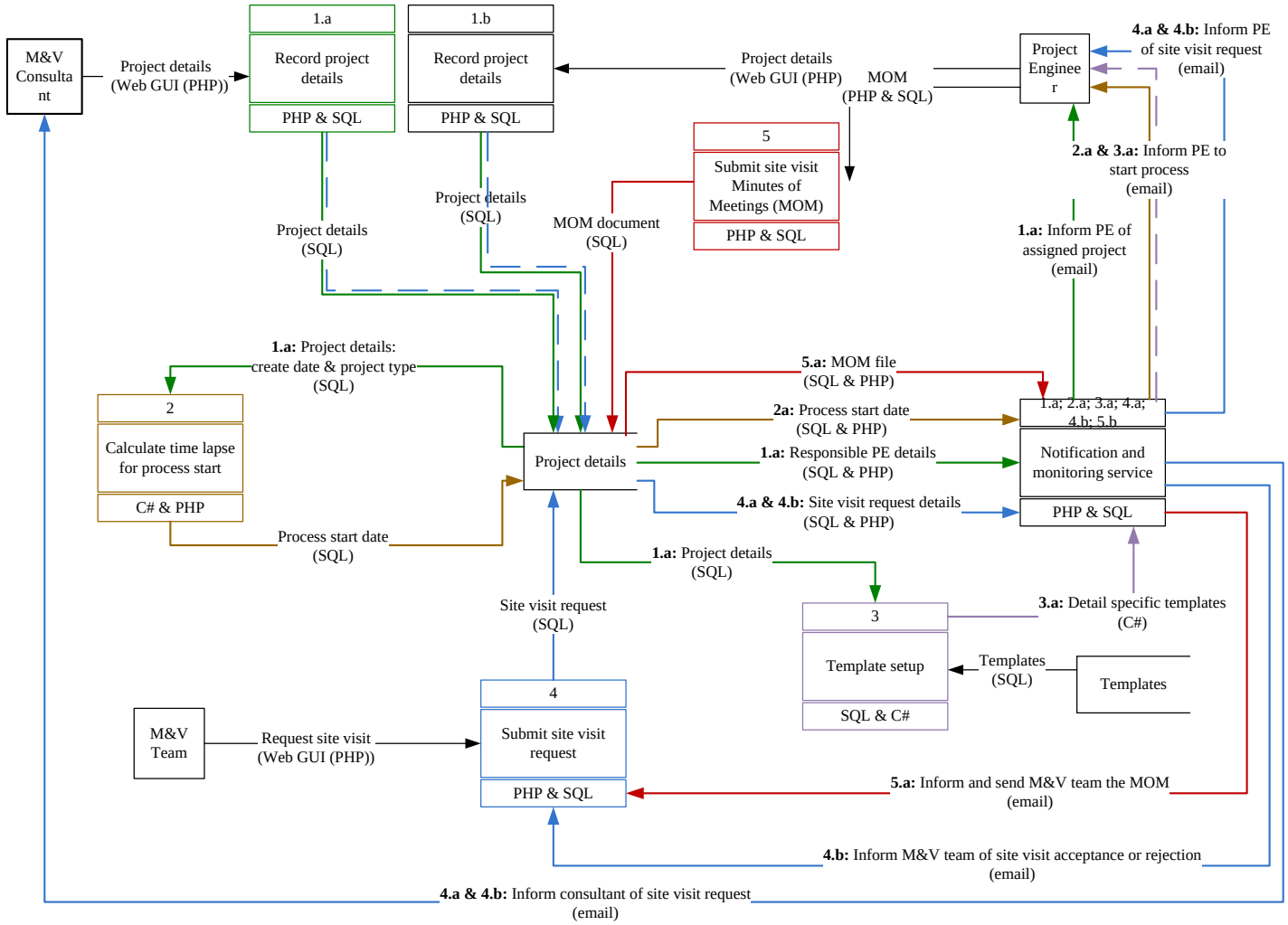

FIGURE 47: MAVIS PHYSICAL DATA FLOW DIAGRAM: PROJECT DETAILS

PROJECT DETAILS

Project details is a physical data store that forms part of the MAVIS database; it is also the primary physical data store and subsystem. All subsequent data stores and subsystems have relationships with *project details*.

1. a. Record project details

The M&V consultant interacts with MAVIS via a internet based graphical user interface (GUI). The function records the details of the project about to be created. Project details include; project name, DSM number (if applicable), project type, project target, M&V team (if applicable), responsible project engineer(s), their contact details and the project manager. The function sends the data to the SQL database under the project details physical data store. Information can be entered, altered or deleted at any time.

1. b. Record project details

The project engineer has the ability to add or edit project details, but not delete them. These details are handled in the same way as Function 1.a.

2. Calculate waiting timeframe

The system calculates the waiting timeframe before M&V activities can begin. This is done using the date on which the project was created and adding a number of days depending on project type: LS = 40 workdays; PC = 30 workdays and EE = 30 workdays. The system adds the calculated date to the *project details* physical data store.

2. a. Notification message

MAVIS sends a notification message on the date calculated in Function 2. This message indicates that the M&V activities can begin.

1. a. Notification message

The system recognises that the project engineer slot is no longer empty and sends the notification to the project engineer. The notification contains a message that states a project is created for which the project engineer is responsible.

3. Templates setup

The system populates two templates with existing details of the project; the DHT and M&V plan as well as a baseline development sheet (BDS).

3. a. Notification message

On the date calculated in Function 2 the system sends the notification message (Function 2. a.) with the templates attached.

4. M&V team site visit request

Once the M&V team knows they are assigned to a project they can access the system and find the project. The team submits a request (with date, time and place) for a site visit. The team also indicates the name and contact details of the M&V project engineer responsible. This request will be stored on the project details physical data store.

4. a. & 4. b Site visit request notification

The system again recognises that the site visit request slot is no longer empty and sends a notification messages to both M&V consultant and project engineer. The project engineer and M&V consultant accepts or changes the site visit request by Function 1.a and Function 1.b. The M&V team will also receive a notification message. If the meeting request was changed, the M&V team must log into the system again to accept or once more change meeting details.

5. Site visit Minutes of Meeting

After the M&V site visit a minutes of meeting (MOM) is compiled by the project engineer. The project engineer and consultant will review and iterate the minutes of the site visit meeting internally and without the assistance of MAVIS. When the consultant is satisfied with the draft, the project engineer submits the MOM document to the system.

5. a. Notification message

A notification message is sent to the M&V team with the MOM document attached. If the M&V team is satisfied with the document they can log onto the system and indicate MOM acceptance.

5. MOM approval or rejection

If the M&V team has not indicated either acceptance or rejection of MOM within one week since submission, the system changes status of MOM to accepted.

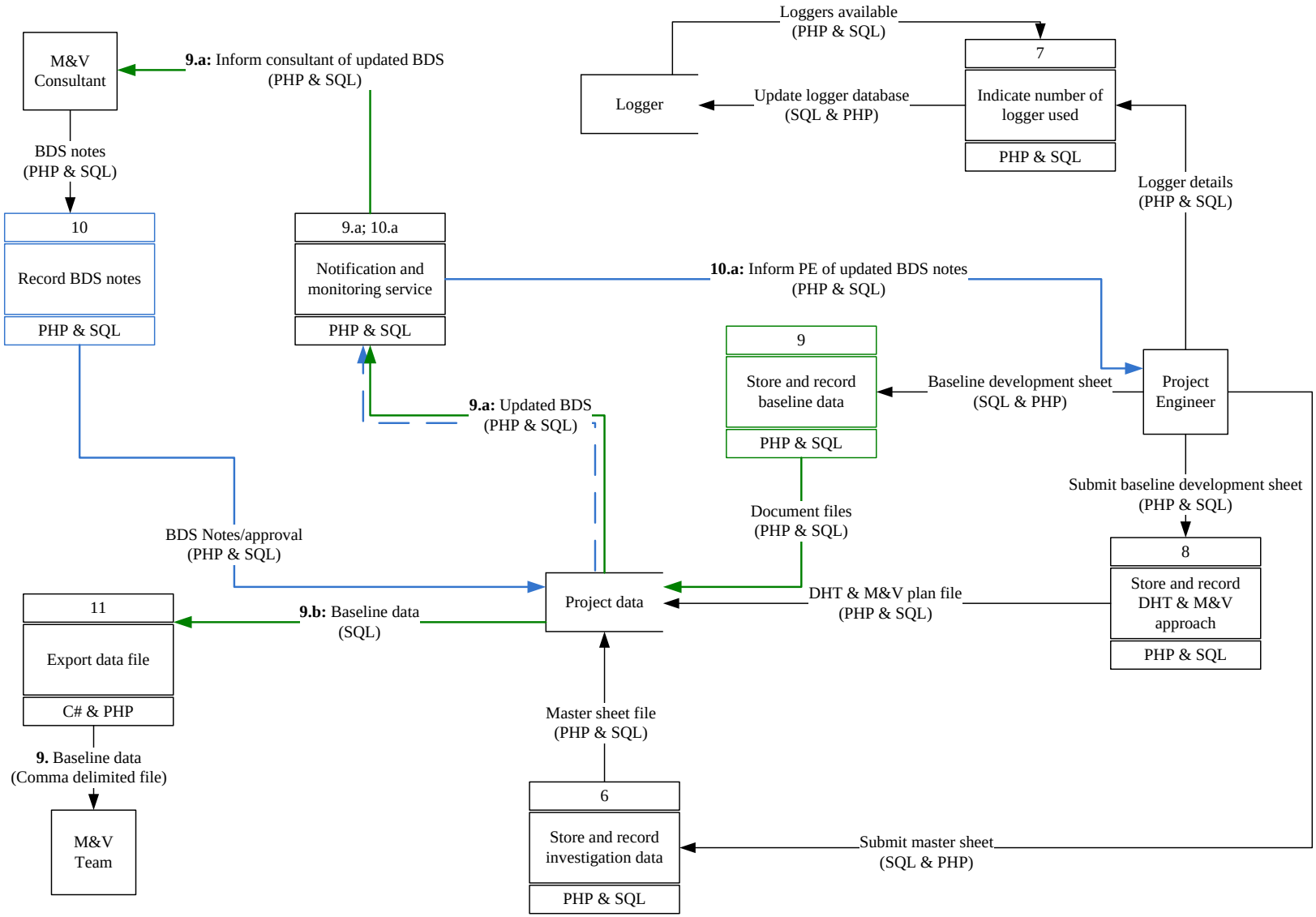

FIGURE 48: MAVIS PHYSICAL DATA FLOW DIAGRAM: PROJECT DATA

PROJECT DATA

6. Store and record investigation data

A Microsoft® Excel workbook (called a master sheet) holds all the summarised details of the project. The purpose of the master sheet is to convey enough information that a clear proposal can be written; this includes the baseline that determines if there are energy-saving opportunities. The project engineer submits the master sheet to the project data physical data store.

7. Log out DENT logger

Electricity loggers are one option of DHT and they are the property of the ESCO. The project engineer indicates if DENT loggers were used for data acquisition in Function 7.

8. Store and record DHT and M&V plan

The DHT and M&V plan template is attached to the notification messages of Function 2.a. and Function 3.a. The project engineer and M&V consultant review the plan outside the system. The document is uploaded and stored on MAVIS if the consultant has approved the plan.

9. Store and record baseline data

The project engineer uploads the BDS to the system.

9.a. Notification message

A notification message is sent to the M&V consultant indicating that a BDS has been uploaded to MAVIS.

10. Record BDS review notes

The consultant either adds revision notes or approves the BDS. Revision notes are made onto the system and stored on the project data physical data store. An approval box is ticked for the approval of the BDS.

10. a. Notification message

The project engineer receives a notification message detailing that the consultant has made suggestions to the BDS. The project engineer then proceeds to repeat Function 9.

11. Export data file

The system recognises that the approval box was ticked. It attaches a specified sheet of the BDS file as a *.csv file to a notification message and sends it to the M&V team.

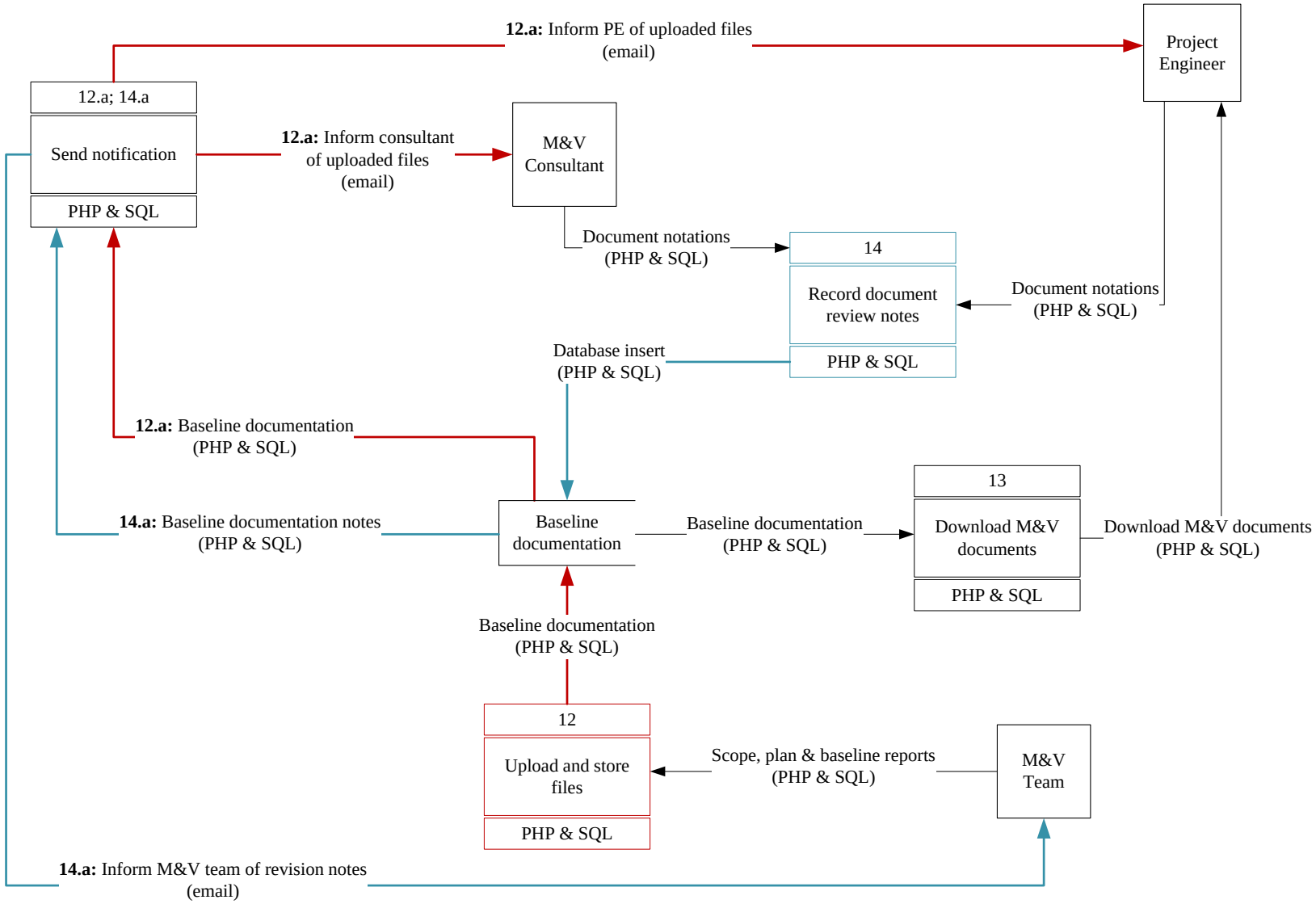

FIGURE 49: MAVIS PHYSICAL DATA FLOW DIAGRAM: BASELINE DOCUMENTATION

BASELINE DOCUMENTATION

12. Upload and store files

The M&V team uploads one or all of the baseline documents. These are: a scoping report, a M&V plan and a baseline report. The system stores the files on the baseline documentation physical data store.

12. a. Notification message

The system recognises the uploaded files and sends a notification message to both project engineer and M&V consultant.

13. Download or view M&V documents

The project engineer can view the documents on the system or download it from the database.

14. Record document review notes

The project engineer and M&V consultant can add review notes for the documents directly onto the system. The consultant alone, however, can indicate if a document is signed by all parties (client, M&V team and ESCO).

14. a. Notification message

The system recognises the review notes of the documents. The notification message copies the review notes and sends it to the M&V team.

Continuous improvement

Every six months the system should calculate the workdays of projects. This is added to the distribution sheet for quality checking.

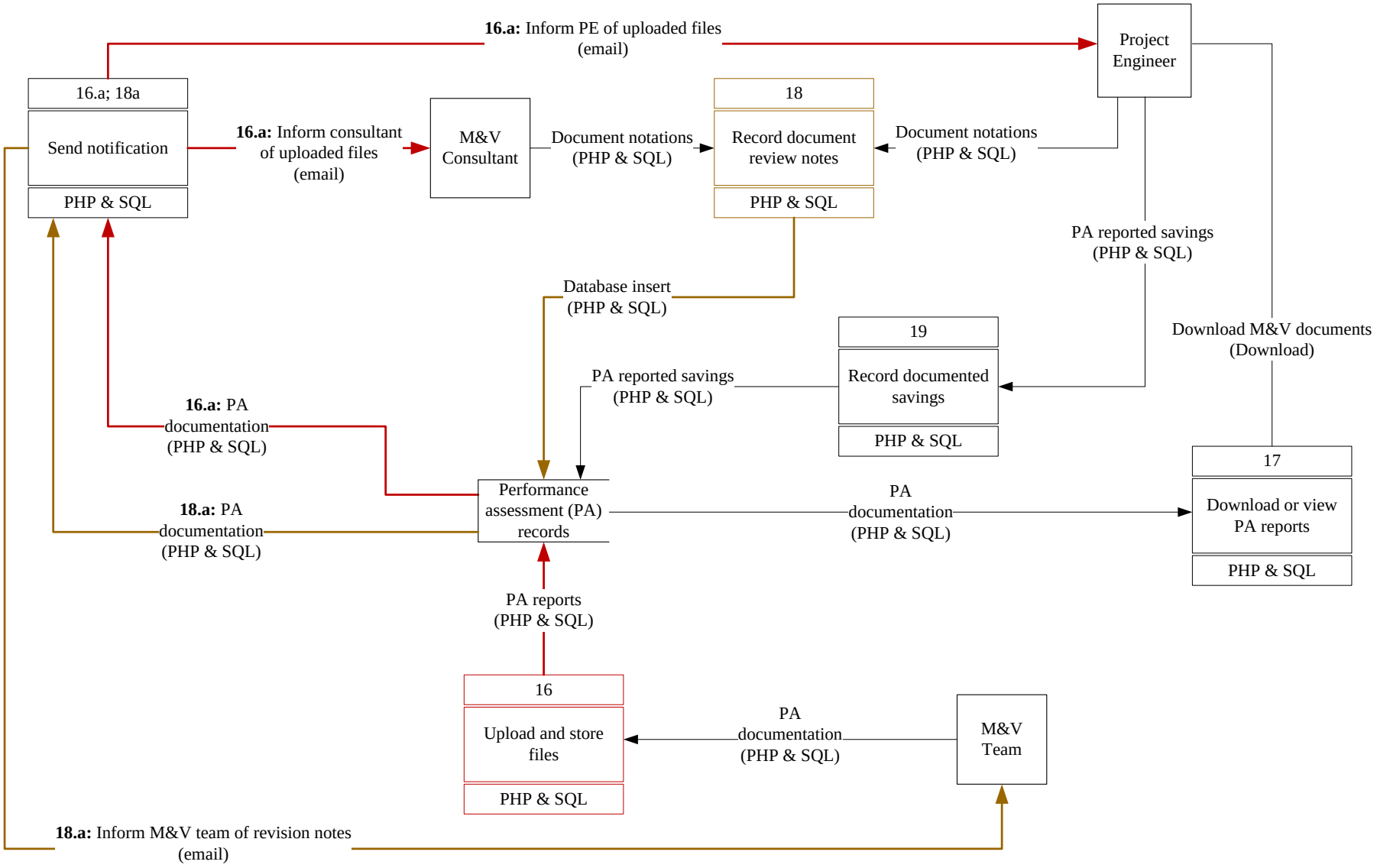

FIGURE 50: MAVIS PHYSICAL DATA FLOW DIAGRAM: PERFORMANCE ASSESSMENT RECORDS

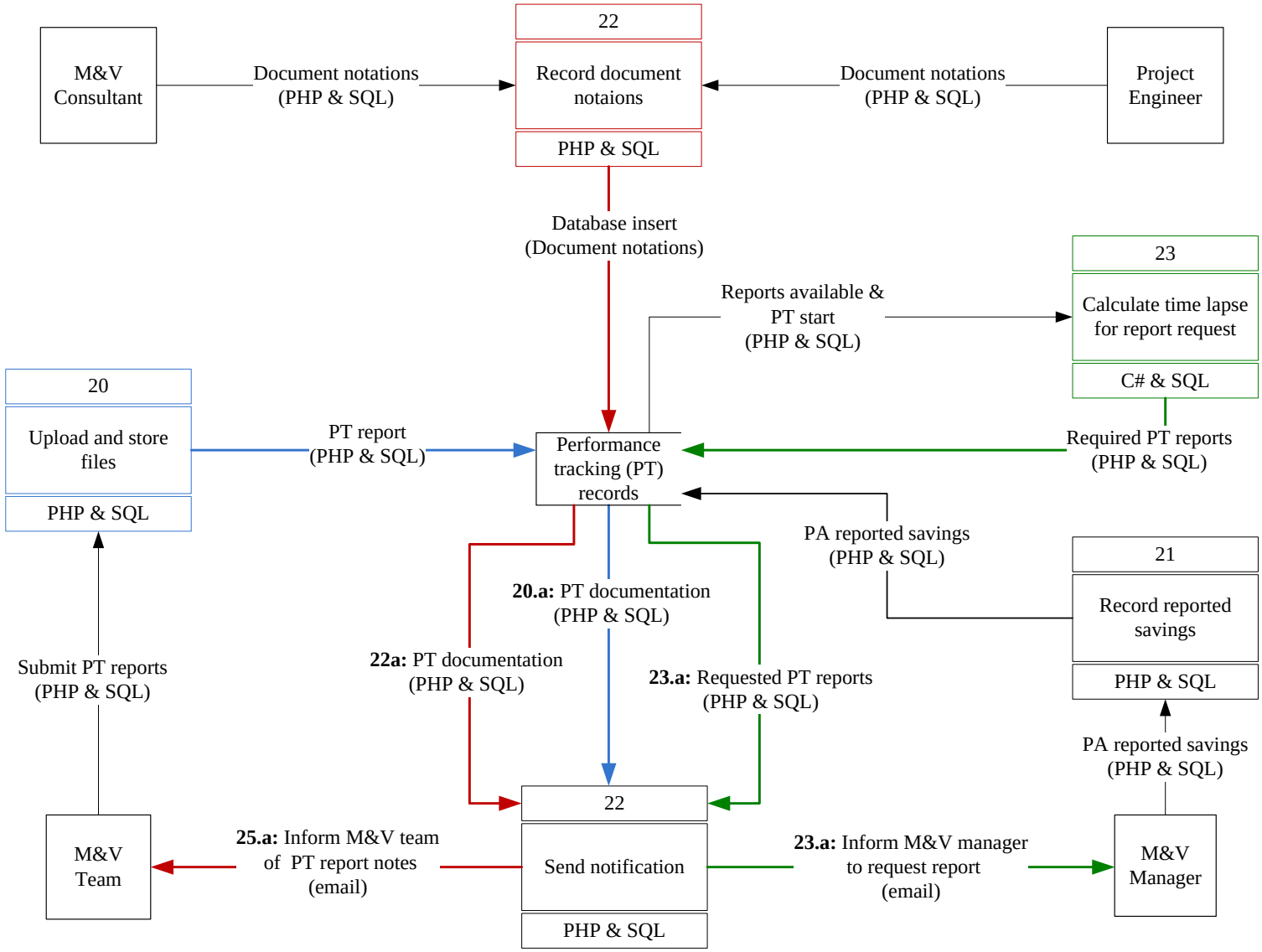

FIGURE 51: MAVIS PHYSICAL DATA FLOW DIAGRAM: PERFORMANCE TRACKING RECORDS

PERFORMANCE ASSESSMENT RECORDS

15. – 18. Upload, download, record, and notify

All processing and uploading tasks from the baseline documentation section are repeated here with the addition of Function 19.

19. Record documented savings

The project engineer extracts the reported savings by reading the report (either by viewing or downloading the report) and manually adding it to the system.

PERFORMANCE TRACKING RECORDS

20. Upload and store files

The M&V team uploads performance tracking reports. They have the choice to upload one or multiple reports at a time; depending on the backlog of project reports. When a report is uploaded the reporting date is added as to avoid confusion.

20. a. Notification message

The M&V manager receives a notification message stating the project name and reporting date.

21. Record reported savings

The M&V manager extracts the reported savings by reading the report (either by viewing or downloading the report) and manually adding it to the system.

22. Record document notations

The project engineer and M&V consultant both have the options to record notes on a specific performance tracking report. This option is for in case anything out of the ordinary happened to the savings, project or client site.

22. a. Notification message

An optional notification message copying the recorded notes can be sent to the M&V team if required.

23. Calculate waiting timeframe

The system runs an algorithm once a month. The logic of the algorithm is as follows:

- The system looks at the reporting date of the last report uploaded to the database.
- *If* the current date minus the last reporting date is greater than 60 workdays:
    - The system sends a notification message to the M&V manager, who then takes the matter up with the M&V team or the consultant.
- *Else* the algorithm exists and then runs again in one month's time.

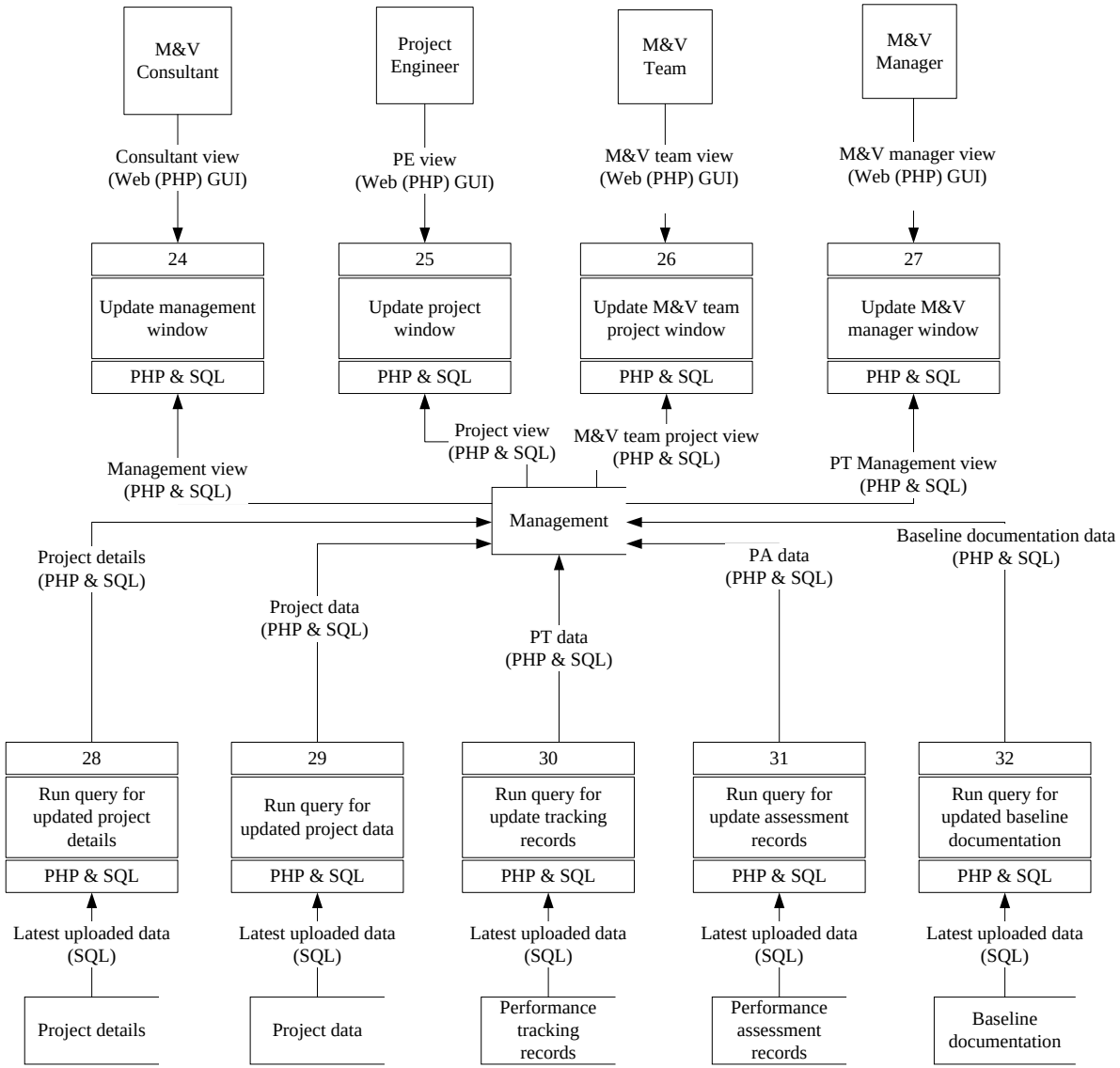

FIGURE 52: MAVIS PHYSICAL DATA FLOW DIAGRAM: MANAGEMENT RECORDS

MANAGEMENT

The management physical data store is a table within the database that runs queries to display the information particular to the entity accessing the system.

24. Update management window

The consultant has a GUI showing all M&V activities. The first interface shows a list of all the projects busy with M&V activities; from investigation up to performance tracking. The consultant has the authority to view GUIs for all the other entities.

25. Update project window

The project engineer views a GUI showing all M&V activities of the projects the engineer is responsible for.

26. Update M&V team project window

The M&V team views the same type of GUI as the project engineer. Details of the projects the M&V team are responsible for appears on the interface.

27. Update M&V manager window

The M&V manager views a GUI showing all projects in performance tracking. The first interface shows a list of the projects with the number of reports required for that specific project as well as the number of reports available.

APPENDIX F: CASE STUDY DATA

TABLE 11: PROJECT 1 PERFORMANCE MONITORING

PROJECT 1				
	Activity	**Date of response**	**ESCO response (days)**	**M&V response (days)**
1	M&V requests site visit	2013/02/20		
2	ESCO responds	2013/04/29	49	
3	M&V team gives available dates	2013/04/29		0
4	ESCO confirms client and own availability	2013/05/02	4	
5	Site visit is performed	2013/05/14		
6	ESCO sends scope of project and electricity tariffs	2013/05/15	2	
7	ESCO requests progress of baseline documentation development	2013/06/25		30
8	M&V team sends baseline documentation	2013/07/01		5
9	ESCO gives feedback on reviews of documentation	2013/07/04	4	
10	M&V team replies with queries and comments	2013/07/10		5
11	ESCO responds to queries and comments	2013/07/10	0	
12	M&V team sends updated baseline documentation	2013/07/23		10
13	ESCO request further updates to the baseline report	2013/07/24	2	
14	M&V team responds with updated baseline report	2013/07/25		2
15	Baseline report signed	2013/09/06		
		Average response time	**12.20**	**10.40**

TABLE 12: PROJECT 2 PERFORMANCE MONITORING

PROJECT 2				
	Activity	**Date of response**	**ESCO response (days)**	**M&V response (days)**
1	M&V requests site visit	2013/03/07		
2	ESCO responds	2013/03/07	0	
3	M&V team gives available dates	2013/03/07		0
4	ESCO confirms client and own availability	2013/03/07	0	
5	Site visit is performed	2013/03/15		
6	MOM is sent out	2013/03/20	4	
7	ESCO send scope of project and electricity tariffs	2013/03/26	8	
8	M&V team sends baseline documentation (scoping and plan)	2013/04/23		21
9	ESCO gives feedback on reviews of documentation	2013/05/07	11	
10	M&V team sends baseline documentation (scoping and plan)	2013/05/13		5
11	ESCO sends baseline data	2013/05/28	12	
12	ESCO requests baseline report	2013/05/30		
13	M&V team send baseline report	2013/06/06		6
14	Baseline report signed	2013/06/12		
		Average response time	**8.75**	**10.67**