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# **DEVELOPMENT OF A LIFE CYCLE COST MODEL AS A DECISION SUPPORT TOOL**

**By**

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## **Executive Summary**

This report presents an abrupt outcome of Life Cycle Cost (LCC) analysis, in particular LCC analysis in the Defence industry, which is based on a detailed literature study, internet web browsing and interviews with experts such as Defence Analysts. The main objective of the LCC analysis is to appraise the total cost of ownership of a product throughout its full life cycle which includes research and development, construction, operation and maintenance and disposal.

The estimated LCC is useful for decision making in scheduled maintenance or in planning upgrading. This report presents a LCC procedure which consists of six steps which are "Problem Definition", "Cost Elements Definition", "System Modelling", "Data Collection", "Cost Profile Development" and "Evaluation" [12].

This report will also present a conclusion and recommendations as it will be conducted over a period of ten months.

The implementation of this model will benefit Armscor by:

- Identifying the most cost effective alternative for that application (This is generally the application with the lowest LCC).

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## 1. Introduction and background

The Defence Institute is a division of ARMSCOR Business (Pty) LTD and its primary function is to provide support to the staff officers of the South African National Defence Force (SANDF). It is a division with more than 20 years experience in military decision support with a comprehensive team of scientist, engineers and operational specialists. The company is divided into three main divisions as seen in the figure below:

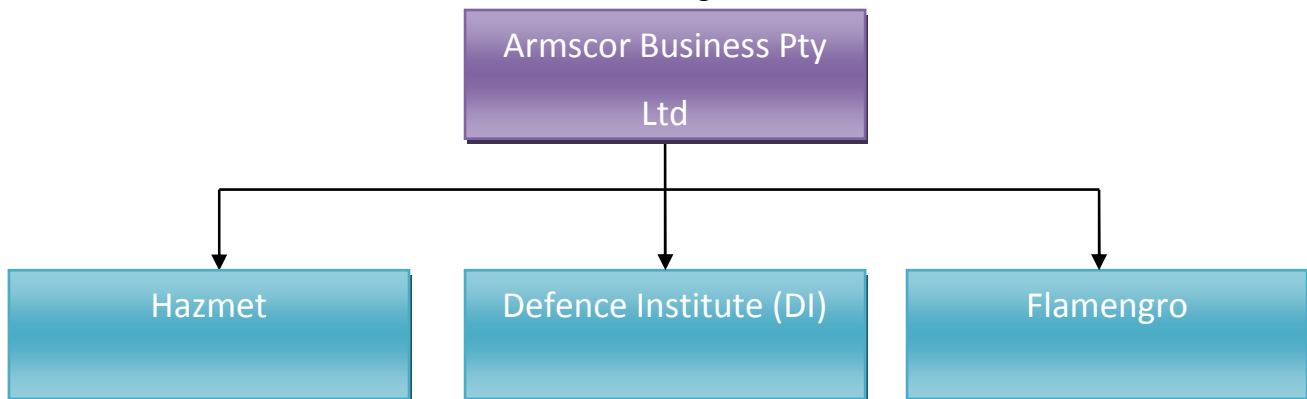


Figure 1: Divisions within Armcor Business Pty Ltd

Defence Institute is focused to assist the defence community in developing insight, solutions and knowledge to decision making scenarios and problems over the full life cycle of defence capabilities and systems. During the financial year 2009/2010, the Defence Institute was tasked by ARMSCOR to investigate the life cycle cost the of the product system (Malibongwe).

The staff target for the Project Malibongwe defines the project as follows:

“Project Malibongwe is the acquisition programme for the provisioning of standardised and cost effective transportable and mounted power source, which must provide reliable, uninterrupted, high quality power under all operational conditions to enable the user to operate weapons systems and supporting equipment at the mobile and tactical level of deployment.”

### 1.1 System Description

The boundaries of the Product System (Malibongwe) are graphically represented in figure 2 and appendix D.

#### 1.1.1 Organisational Boundaries

All mobile and mounted power generation requirements within the military environment at the tactical levels of operational deployment are included in Project Malibongwe. This

includes the requirements for the current equipment which is in operation within the military environment i.e.:

- South African Army (SA Army)
- South African Air Force (SAAF)
- South African Military Health Services
- Special Forces

### **1.1.2 Mounted Power Sources**

Malibongwe is restricted to only those power sources of which the intent and installation of the power generating equipment in such a way that it can be moved to provide the function of power to more than one location.

Certain installations such as fixed installation for emergency purposes in buildings (such as in hospitals) are excluded.

### **1.1.3 Systems**

Combat System

Included in Malibongwe is the provision of a mounted power generators for the following:

- Vehicle Support System
- On Ground Support System

### **1.1.4 Supporting Systems**

Included in Malibongwe is the provision of a mounted power generator for the following elements at the tactical levels as indicated in the figure 2.

- Defence Information Infrastructure
- Headquarter Infrastructure
- Accommodation Facilities
- Preparation of meals in facilities
- Workshops

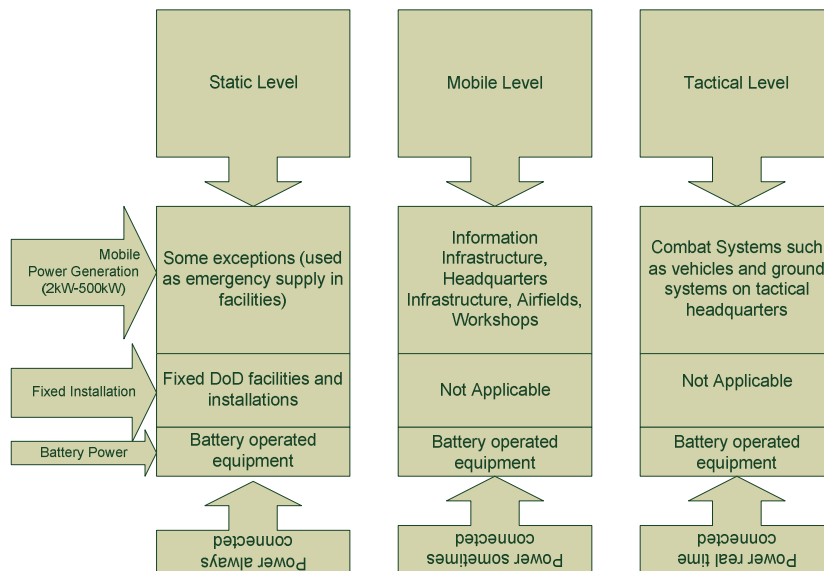
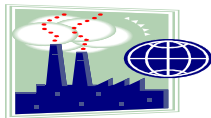


**Figure 2: Mobile and Tactical Power Generation Products System Boundaries**

### 1.1.5 Tactical Levels of Deployment

Project Malibongwe should only be restricted to the tactical levels of operational deployment. The definition of static, mobile and tactical levels of operational deployment for Project Malibongwe shall be the same as that of the acquisition projects. These definitions are:

- Static Level: The power of the generator is always connected.



- Mobile Level: The power of the generator is sometimes connected.



- Tactical Level: The power of the generator is real time connected (The power generator must meet the power requirements in the battle).



**Note. Tactical Levels for Project Malibongwe are in general the one that will be focused on.**

### **1.1.6 Capacity Boundaries**

Historically the power capacity boundary of 50 kVa existed between the command and management information system (CMIS) and the other deployment boundaries. CMIS is responsible for generators having a capacity of lower than 50 kVa while the other deployment boundaries have a responsibility for generators having a capacity of greater than 50 kVa.

Project Malibongwe should cover the total Defence Force requirement for the mounted power generators in the tactical environment and it should not be bounded by the capacity of the generator. It should also provide mounted power generators to all Divisions and Arms of Service within the Defence Force to both the command and management information system (CMIS) and other deployment boundaries on their requirements.

### **1.1.7 Battery Power**

This project will exclude the acquisition of batteries required to man power radios and other equipment carried by personnel and or installed on platforms requiring a battery source of power. The project does however include the generators (within the boundaries of the project as defined in this report) to charge those batteries.

### **1.1.8 System Breakdown Structure**

The organisation will provide the Defence Force with a level 5 Product System. The system will be designed to allow and enable the end user to implement a level 6 User System. A system breakdown structure applicable to the organisation is provided in appendix D.

## **2. Problem description**

A Request for Information (RFI) was issued to the suppliers listed in appendix A. These suppliers were obtained from the Armscor list of accredited suppliers in the field of power generation and distribution.

The aim of the RFI was to obtain technical information in order to make a buy or development decision, as well as to determine the most cost-effective technical concept to satisfy the User Requirements (Appendix B). The RFI process had no intention of narrowing down potential suppliers. The companies that received the RFI (refer to appendix A) had approximately three months to respond. Three companies responded to the RFI and presented several product options to the Project Team. The companies and their options are presented in appendix C.

Lastly this project explores the different data that is needed to analyse the Life Cycle Cost (LCC) for Project Malibongwe. The first objective aims at a structural overview of existing economic methods for LCC analyses and their advantages and disadvantages. The second objective is to point out the main data which are required to carry out a LCC analyses. The last objective is to move away from the limited application of LCC to a position where LCC can properly inform the early stage of decision making.

Armcor management then required a LCC analysis which will enhance and help them decide which option between the fixed speed and the variable speed generators (refer to appendix C) that will inform them about the technical information in order to make a buy or development decision as well as to determine the most cost-effective technical concept to satisfy the User Requirement.

### **3. Project aim**

The aim of the project is to identify, formulate and define a LCC Model to form the basis of predicting the life cycle costs for each of the concept options identified during the project study of Project Malibongwe.

## **4. Project scope**

### **4.1 The target**

The beneficiaries and stakeholders of this project are listed below:

- The Project Malibongwe team
- Defence Institute (Armcor Division)
- Armcor employees involved in the project
- The South African National Defence Force (SANDF)
- Department Of Defence (DoD)
- The University of Pretoria
- Mondli Ngwane

## **4.2 Project considerations that would influence the final decision**

The current considerations that should be taken into consideration when carrying out the required LCC Analysis as well as the effectiveness of the system concept include the following:

- **Function Performance**

- i. Power Generation Performance
- ii. Power Reticulation Performance
- iii. Power Sustainability

- **Operability**

- i. System Mobility
- ii. System Deployability
- iii. Human Factors
- iv. Training

- **Environmental Capability**

- i. Climatic Environment (Africa and Coastal)
- ii. Transportation Handling and Storage induced Environment
- iii. Operations induced Environment
- iv. Lightning

- **Maintenance (See literature study)**

### 4.3 Intermediate objectives (IO)

The intermediate objectives to come to a final conclusion are mentioned below:

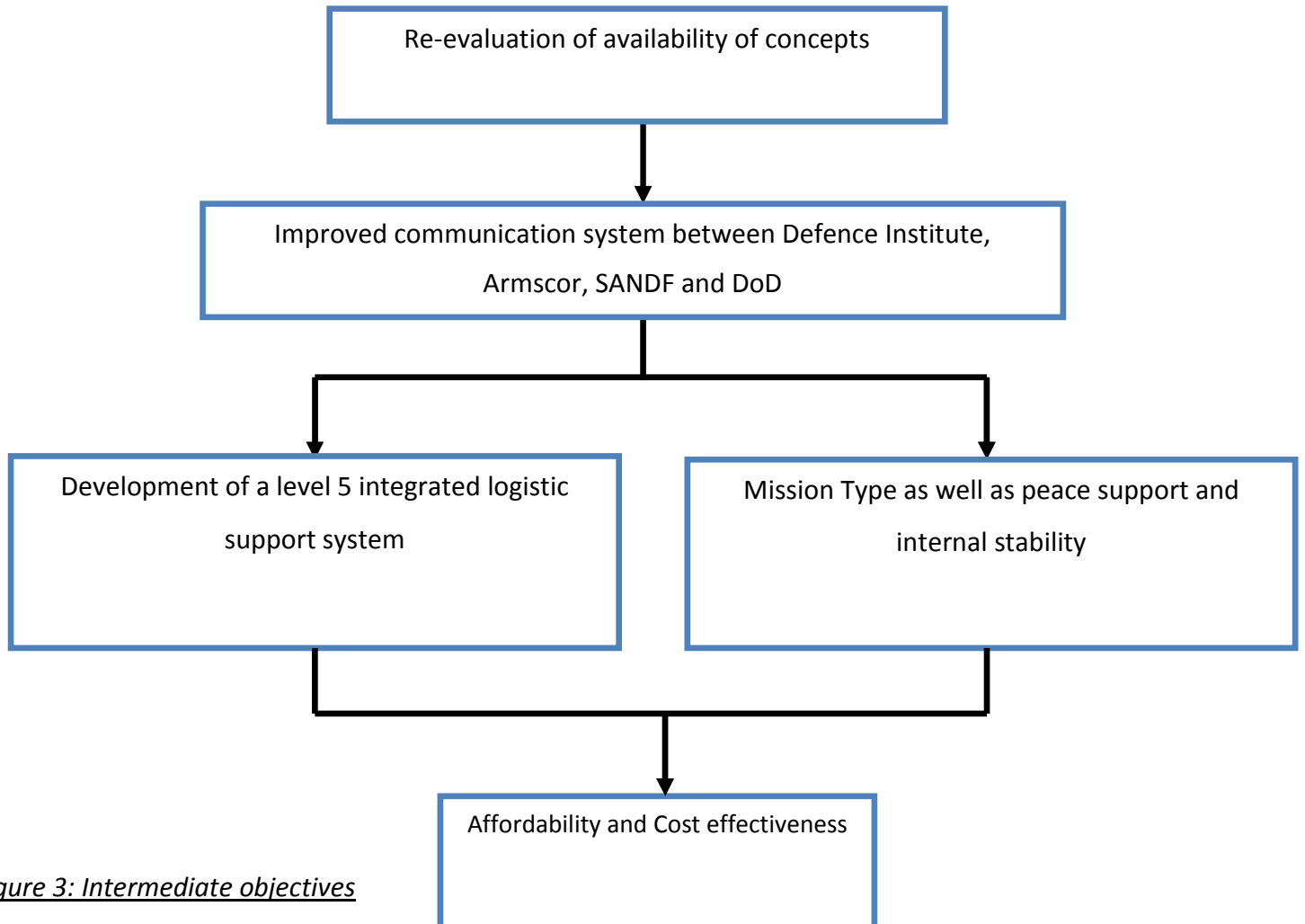


Figure 3: Intermediate objectives

#### 4.4 Tasks/Criteria that need to be completed in order to achieve the IO's

| Criteria                           | Fixed Speed System Concept                                                                                                                              | Variable Speed System Concept                                                                                                                      |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <u>Fuel Economy</u>                | High fuel consumption, directly related to power output, due to fixed speed operation and the need for dummy loads.                                     | Low fuel consumption, directly related to power output, due to variable speed operation and the need for dummy loads.                              |
| <u>Engine Longevity</u>            | Significantly less engine life with light load operation which causes oil dilution, cylinder glazing and carbon build up in fixed speed generator sets. | Significantly longer engine by preventing light load operation which causes oil dilution, cylinder glazing and carbon build up.                    |
| <u>Operating Cost</u>              | High operating cost due to fuel in- efficiency, high maintenance and less engine longevity.                                                             | Low operating cost due to fuel in- efficiency, reduced maintenance and engine longevity                                                            |
| <u>Flexibility</u>                 | A single speed generator set can operate over a wide range of power and replace a number of different sizes in a fixed speed generator set family.      | A single speed generator set can operate over a wide range of power and replace a number of different sizes in a fixed speed generator set family. |
| <u>Power Generation Efficiency</u> | The system utilise a less efficient synchronous alternator.                                                                                             | The system utilise an efficient permanent magnet alternator with high power density.                                                               |
| <u>Phase Balancing</u>             | Phase balancing is required (differences of less than 5% is ideally required).                                                                          | Phase balancing of the load is not required.                                                                                                       |
| <u>Mass Volume</u>                 | Rolls Royce claims that their                                                                                                                           | Rolls Royce claims that their                                                                                                                      |

|                           |                                                                                                         |                                                                                                         |
|---------------------------|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                           | variable speed generator has 34% less mass and 40% less volume than a comparable synchronous generator. | variable speed generator has 34% less mass and 40% less volume than a comparable synchronous generator. |
| <u>System Development</u> | The maintenance for and support for the sub-system to be developed locally or internationally.          | The maintenance for and support for the sub-system to be developed locally or internationally.          |

Table 1: Criteria and Considerations

## **5. Literature Review**

### **5.1 Introduction and Background**

In an organisation such as the (South African Department of Defence) a certain percentage of substantial resources are spent on sustainment and modernisation of its primary military equipment and machinery. In most cases expenditure are based on the system requirements and sustainability [9]. New equipment is typically being subjected in the highest state of material readiness and condition, fully capable of being safely and effectively used for its intended use [10].

Over the years the material readiness and condition of equipment can slowly degrade through normal wear, manufacturing default or battle damage. If these two scenarios (material readiness and condition) become excessively unacceptable, the equipment should then be repaired or restored or upgraded so that it is again available for future use and to meet the specification that it was intended for. Most points mentioned above are part of the weapon system sustainment value stream [9].

According to the DoD, the material which is available to put to its planned use is “ready material”. In other ways “material readiness” exists when material is available for use (request for use).

### **5.2 The types of maintenance strategies that are used in the military environment**

A number of different, but equally successful strategies are deployed within the Department of Defence (DoD) to achieve certain objectives [11].

**The five types of maintenance strategies (methodologies) used in the military environment:**

- Military Equipment Sustainment Strategy (Procurement Strategy)
- Continuous Process Improvement (CPI)
- Theory of Constraints (TOC)
- Depot Maintenance Core Capabilities
- Condition Based Maintenance Plus (CBM+)

A common feature regarding most of these strategies is the establishment of a weapon system maintenance capability as well as the system's efficiency to sustain a planned material readiness at the lowest possible life cycle cost. It is in most cases the optimal balancing maintenance effectiveness with the systems' cost that drives the selection of a particular maintenance strategy for military equipment.

### **5.2.1 Military Equipment Sustainment Strategy (Procurement Strategy)**

The military equipment sustainment strategy is significantly complimented by the weapon system modernisation strategy. It is complimented due to the fact that it has a high degree of variability, dependability and maintainability in weapons' technology and cost [9]. The fact of life considerations such as the average age of weapon system inventory (product system) and the keep on changing industrial base capabilities. The DoD in most scenarios does not mandate a preferred weapon system sustainment strategy but rather a strategy based on the lesson learned and those that are benchmarked resulting in an innovative maintenance and support plans that are employed to determine the optimum DoD weapons system sustainment strategy for a given Product System [11].

In combination there are a few military equipment sustainment strategies that are also used in the military environment and these are some of them [10]:

- Strategy for cost effective spares re-procurements and other material purchases in support of both maintenance and operations
- Strategy for cost effective material supply chain management
- Strategy for cost effective material transportation and distribution
- Strategy for cost effective in service engineering ( including equipment reliability monitoring and reliability improvement)

### **5.2.2 Continuous Process Improvement (CPI)**

Continuous Process Improvement is used by the DoD organisation as a means of analysing the work that is being done and the strategy that could be implemented to improve the system in executing the job in an effective and efficient manner.

CPI evolved for a DoD into a comprehensive approach from a different implementation plan that originated in the different sectors of the DoD organisations as well as the DoD's current improvement strategy which formed part of the CPI program aimed at achieving military equipment such as [9]:

#### ***Lean Manufacturing***

- Lean manufacturing focuses on the removal of waste, defined as anything not necessary to produce the required product or service [10].

#### ***Six Sigma***

- Six Sigma evolved from statistical quality control and total quality management which focuses upon satisfying customer expectations through reduction of process variation [8].

In most DoD's strategies and approaches, CPI projects on numerous occasions considers cycle times and reliability improvements as one of their goals (lowest total cost to deliver planned readiness to the war fighter). A modernised value stream approach is being utilised in order to optimise CPI benefits within the DoD's value stream enterprise [10].

### **5.2.3 Theory of Constraints (TOC)**

TOC pioneers the system improvements by concentrating on the process that slows the speed of the product through the system. In DoD's CPI program, the primary customers are war fighters and their adroitness is their primary goal. The two most important allotment for meeting the war fighters adroitness needs are cycle times and reliability at an affordable cost. Cycle time refers to the amount of time required for the DoD's to accept a current or future customer demand (normally the war fighters) and provide the requested capability (article by DoD). The objective of TOC is to align the organisation and its process and to abridge the cycle time without unsympathetically affecting the reliability and cost of the

goods and services [8]. Cycle time improvements are converged on any process to reduce the time and resources involved.

#### **5.2.4 Depot Maintenance Core Capabilities**

The generated weapon system sustainment apprehensions are acquainted to program managers and are accomplished and abide at a planned material readiness of which their objectives are at their minimum life cycle cost and work towards the improvement of the sustainment process [8]. Depot maintenance core capabilities conciliates of government-owned and government-operated core logistics. These capabilities are conserved at the DoD maintenance depots [11]. These capabilities are also fabricated to postulate a ready and controlled source of technical capability and which has resources that are responsible for an adequate and timely response to a mobilisation of the national defence contingency situation.

#### **5.2.5 Conditioned Based Maintenance Plus (CBM+)**

The CBM+ is a DoD's enterprise that delegates the services and their program managers to accompany and incorporate maintenance technologies and process to a more adequately embed for the war fighters and ultimately accommodate an improved sustainment support [4, 8, 10].

CBM+ will ameliorate the systems' supportability which will lead to a more efficient business process, and alter the maintenance environment for a distinct and devise system. Many technologies and process are incorporated in the CBM+ initiative. The extensively accustomed Condition Based Maintenance Concept (CBMC), which constitutes a need has driven modus to maintenance, conditions the base for the CBM+ [11].

### **5.3 Economic Decision Support Methods**

Product system economic analysis methods aims to identify the cheapest , feasible system or mastermind the best option in a short, medium or long-term strategies. Unfortunately there is no method which is best suited for all decision making purposes. In this paragraph we will highlight certain methods that are best suited to short, medium and long-term economic analysis.

The economic analysis decision support methods commonly used in the military environment are [4, 6]:

- Simple Payback
- Discount Payback
- Accounting Rate of Return (ARR)
- Life Cycle Costing (LCC)

The above methods form a core basis of an economic analysis and the simple payback method is the simplest while the life cycle costing is the more complex. The choice of an economic analysis method is usually influenced by [1]:

- The project cost
- The availability of information
- Time available to do analysis

In most projects especially economic analysis, the information is very limited and scarce. For this reason the simple payback method is easy to calculate for this project.

### 5.3.1 Simple Payback

Simple payback method is by far the least complicated and unsophisticated and widely used method [4]. It is generally used for evaluating the economic feasibility of utilising the product system in the military environment.

#### Approach

The simple payback is the time needed recover a capital expenditure through savings [1]. Therefore the shorter the payback period the more attraction the investment is. However, it is a very awkward method to implement. A simple payback example would look like this; we have a system savings of R10200 annually while costing R61200. This system will have a simple payback period of  $R61200/R10200$ , i.e. 6 years.

The algebraic formulation for determining the straight payback period is [1]:

$$Sp = \frac{Cip}{Ac} \quad (2.1)$$

Where  $Cip$  = Capital Investement Cost

*Ac = Annual Cost saving due to capital investment*

*Sp = Simple Payback (in years)*

When looking at different options (simple payback) the one with the shortest payback period will be the obvious choice [5].

### **Advantages**

The most important advantage of this method is its simplicity in such a point that almost anyone may calculate and give result quite easily [6]. It is a method which is highly suited for economic shorter term measures and scenarios.

### **Disadvantages**

The most serious setback for this method is it fails to consider accretion of costs, time value of money and the timing of cash flows after the payback period [1].

### **5.3.2 Discounted Payback**

This is an improved adaptation of the simple payback period. It accounts for factors such as cost accretion and the time value of money.

### **Approach**

The discounted payback method is calculated similar to the simple payback method even though it has one barring to it [7]. The barring is that all the future savings costs are intensified and discounted to their present value. In that sense, a more accurate payback period is then calculated.

The algebraic formulation for determining the payback period is [1]:

$$C_{ip} - \sum_{t=1}^Y \frac{B_t - D_t}{(1 + i)^t} = 0 \quad (2.2)$$

*Where C<sub>ip</sub> = Capital investment cost*

*Y = the number of years until the cumulative net yearly equal the initial investment*

*B<sub>t</sub> = benefits in year t*

*D<sub>t</sub> = cost in year t*

*i = discount rate (time value of money)*

It is then much easier to solve for time (t) to obtain the discounted payback period. Cost  $B_t$  and  $D_t$  should first be intensified to their future value in year t. It is abandoned if annual accretions are too small.

### **Advantages**

The critical advantage of this method is the corrected accuracy for the longer payback periods. It is thus more appropriate for longer term economic analysis. Dependability is improved because the time value of money and accretion of costs are considered. It is much simpler to interpret as well.

### **Disadvantages**

The corrected method has some impediment. It still fails to account for expenses after the payback period [1]. Therefore most systems with short payback periods are still preferred. It is also more abstruse and time consuming to use.

### **5.3.3 Accounting Rate of Return**

The accounting rate of return (ARR) gives a notion of the return that will be obtained from capital invested in a system [6].

#### **Approach**

The ARR is an awkward way of calculating the annual rate of returns which maybe predictable from an investment.

The algebraic formulation for determining the ARR is [1]:

$$ARR = \frac{ASavg}{Cip} \quad (2.3)$$

*Where ASavg = Average annual savings*

*Cip = Capital investment cost*

*ARR = Accounting rate of return*

When contemplating different options the one with the highest ARR will be the obvious choice. The higher the ARR the more agreeable the investment while for an investment to be acknowledged, it must have a minimum rate of return [7].

## **Advantages**

This method is uncomplicated and gives a quick indication of possible returns. It is also much easier to annotate.

## **Disadvantages**

The ARR method has exiguous austere drawbacks. It fails to consider the timing of cash flows, money's time value as well as cost intensifying [1].

### **5.3.4 Life Cycle Cost (LCC)**

#### **5.3.4.1 Life Cycle Cost Definition**

Life cycle cost is the total cost of ownership of machinery and equipment as well as its cost of acquisition, operating, conversation and decommissioning. (SAE 1999)

LCC are summations of all cost estimates from the acquisition phase up to the disposal phase for both machinery and equipment [3]. LCC estimates should always take cognisance the time value of money into consideration when calculating the total cost within the project life cycle. The objective of LCC analysis is to choose the most cost effective approach from a series of alternatives to achieve the long term cost of ownership [3].

LCC is the economic model over the project life span, usually the cost of operation, maintenance and disposal costs of which exceed all other first costs many times over (supporting costs are often 2-20 times greater than the initial procurement costs).

The best balance among cost elements is achieved when the total LCC is minimised. (Landers, 1996)

Factors such as cost escalations and time value of money are easily taken into account with this method [1]. LCC is the choice method when the total costs over the life of a system are to be minimised. In that instance all expenses are presented in the present value. The present values of all costs are easily calculated but it is very crucial to realise that money has a time value.

#### **5.3.4.2 Discounted Cash flows**

The time value of money may be explained by looking at a simple example. Imagine a free world without inflation. If an individual invests money in a business or otherwise it grows. For example imagine a person investing R200 and a year later, he has R220. Thus the

person's money has grown by 10%. A person only needs R200 today to cover an expense of R220 in a year's time. This is due to the fact that R200 will grow to be R220 in a year's time. The present value of a single expense in a year is calculated as follows [1, 4]:

$$Cpv = \frac{Cn}{(1+i)^n} \quad (2.4)$$

Where  $Cpv$  = present value of a cost to be expanded in year  $n$

$Cn$  = cost to be expanded in year  $n$

$i$  = discount rate

$n$  = number of years

This equation only works if we have an inflation free world, even though expenses do not stay the same throughout the life cycle of a product system. The future value of an expense may be calculated as follows [1, 6]:

$$Cfv = C(1+e)^n \quad (2.5)$$

Where  $Cfv$  = future value of a cost

$C$  = current cost of an expense

$e$  = rate of escalation

$n$  = number of years

In all the above equations costs are inflated and discounted once a year [8]. Discounted cash flows are used by all life cycle cost methods. To execute a life cycle cost analysis the following information is needed for each alternative option [1]:

- Investment or capital costs
- Operating expenses (electricity, maintenance ect)
- Replacement costs and timing
- Escalation rates (electricity, maintenance ect)
- Economic life
- Relevant taxes (depreciation resulting in tax savings)

There are three methods of applying life cycle costing that will be used in Project Malibongwe. They are:

- Net Present Value (NPV)
- Benefit Cost Ratio (BCR)
- Internal Rate of Return (IRR)

The net present value method is the most applied life cycle cost method in the defence industry.

#### 5.3.4.3 Net Present Value (NPV)

This method involves the calculating of the present value of all relevant cash flows throughout the life of Project Malibongwe [6]. The total cost of a system is found by discounting all the relevant cash flows within a certain life cycle to their present value. Any certain cash flows within a certain life cycle are taken into account. The sum of these represents the net present value (NPV) of the system [1]. The system with the highest NPV will be the most economic long term. For each option in Project Malibongwe which is to be compared the NPV is calculated as follows [1]:

$$NPV = Ci + Pe + Pm + Ot \quad (2.6)$$

*Where NPV = life cycle cost (nett present value)*

*Ci = initial capital investment*

*Pe = present value of electricity cost*

*Pm = present value of maintenance cost*

*Ot = present value of any other expenses*

All these expenses (or incomes) must be presented in the present values [1]. The alternative (option) with the lowest NPV is the correct for the organisation's interest in a long term analysis.

#### Advantages

Nett present value is relatively much easier to understand and work with. It mainly allows for the timing of cash flows, the time value of money as well as cost variations and thus much more suitable for long term analysis.

## Disadvantages

This method dependability is mostly on future trends in variations as well as discount rates. It also requires much more input data than other economic analysis methods. The individual person (user) needs to estimate all costs, timing of expenses and escalations over the entire life of the system. All this does is, it makes NPV time consuming.

### 5.3.4.4 Benefit Cost Ratio (BCR)

The benefit cost ratio is just another method to translate the discounted cash flows and to evaluate the economic feasibility of Project Malibongwe [1]. It is mostly used to evaluate if the system is economically justifiable to replace an existing one and also evaluates which alternatives are best suited for that investment [8]. The ratio is then calculated with the higher the ratio, the more viable the project will be. The benefit cost ratio is calculated as follows [1, 4, 6]:

$$BCR = \frac{SavingsPv - CostsPv}{Cp} \quad (2.7)$$

*Where SavingsPv = present value of life time savings*

*CostsPv = present value of lifetimes savings*

*Cp = initial capital investments*

In most cases if the BCR is close to the value of 1, the project will pay for itself within its lifetime. In generally, the predicted BCR should be significantly greater than 1 for a project to be viable.

## Advantages

Similar to Nett Present Value (NPV) [1]

## Disadvantages

The BCR is sensitive to the project size. As the investment increases, the BCR decreases. Thus a long term high efficiency project may have a lower BCR than a short term medium efficiency project. In that scenario, the total savings will be higher with long term project. BCR also has similar disadvantages as NPV [4].

#### **5.3.4.5 Internal Rate of Return (IRR)**

The internal rate of return (IRR) is very similar to the net present value method; however the discount rate is the unknown factor [7]. The internal rate of return is defined as the discount rate which will make the NPV of the project equal to zero [4]. Thus the IRR is a refined and well modified version of the ARR in that it uses discounted cash flows. The time value money and inflation should not be forgotten.

#### **Advantages**

The IRR is much more accurate than the ARR in calculating the rate of return for the project [4]. It calculates the rate of return which may then be compared to the return of other projects. Most organisations are familiar with this type of result. The IRR also shares similar advantages as to the NPV [1].

#### **Disadvantages**

There are cases where the IRR method gives no indication of suitable solutions [8]. Also all disadvantages of the NPV method also apply to the IRR.

### **5.4 Conclusion**

A summary of methods and their applicability as well as the maintenance strategies are summarised below. From the literature survey it is clear that many economic analysis methods exist but because of the advantages and disadvantages as well as the complexity of the problem, only one method was chosen.

It is clear that the defence industry has adapted significantly well on using the investment techniques which are simpler to understand. These economic analysis methods are categorised into short; medium and long term analysis. Although these methods are not complex but they are well suited for Project Malibongwe.

| Economic Analysis Term    |                    |                           |
|---------------------------|--------------------|---------------------------|
| Short                     | Medium             | <i>Long</i>               |
| Simple Payback            | Discounted Payback | <b>Nett Present Value</b> |
| Accounting Rate Of Return | Nett Present Value | Internal Rate of Return   |
|                           | Benefit Cost Ratio |                           |

Table 2: Economic Analysis Term

|                                      |                  | Types of Maintenance Strategies         |                                     |                                                                       |                                      |                             |
|--------------------------------------|------------------|-----------------------------------------|-------------------------------------|-----------------------------------------------------------------------|--------------------------------------|-----------------------------|
|                                      |                  | Condition Based Maintenance Plus (CBM+) | Depot Maintenance Core Capabilities | <b>Military Equipment Sustainment Strategy (Procurement Strategy)</b> | Continuous Process Improvement (CPI) | Theory of Constraints (TOC) |
| F<br>E<br>A<br>T<br>U<br>R<br>E<br>S | <b>Quantity</b>  | Medium                                  | Low                                 | <b>Large</b>                                                          | Low                                  | Low                         |
|                                      | <b>Frequency</b> | High                                    | Medium                              | <b>High</b>                                                           | Relatively high                      | Low                         |
|                                      | <b>Value</b>     | High                                    | Low                                 | <b>Industry specific</b>                                              | Low                                  | High                        |
|                                      | <b>Nature</b>    | Strategic                               | Operational                         | <b>Operational and Tactical</b>                                       | Tactical                             | Strategic                   |
|                                      | <b>Examples</b>  | Manufacturing                           | Manufacturing                       | <b>Crude oil in petroleum industry and defence industry</b>           | Lubricants, spare parts              | Machinery, computers        |

Table 3: Types of maintenance strategies [13]

The above two tables defines and summarises the strategies and the economic analysis as well as which strategy and method was chosen.

## **6. Conceptual Model Design**

### **6.1 Introduction**

The primary objective of this project is the development of a LCC model. However, since there are additional limitation to the manner in which the model will be developed such as the model should be in accordance to the user specification (SANDF). Project Malibongwe is mainly responsible for generators that can function at different capability levels such static, mobile and tactical levels. It must be noted that the conceptual model was chosen after certain benchmarking were made in response to the RFI.

There is also a different trade-off between the accuracy and the utility of a system. If incorporating a certain aspect is troublesome in the design or execution of the model, the question of whether the accuracy added by its incorporation is sufficient to warrant its inclusion must be asked. This also the case if the data pertaining to a feature is difficult to collect and quantify.

As previously mentioned, the project involves the formulation of a LCC Model for two different concepts with the system effectiveness of each concept being considered in this report.

Financial benefits are best calculated over the life of the project. This model will be used to choose the best option to be used by the SANDF.

Most defence organisations like the SANDF evaluate the feasibility of different options exclusively on their initial capital expenditure. The Armscor's main objective was to solve the problem for the lowest initial cost; however a detailed economic analysis enabled to propose a suitable and more economical solution.

The context of the model developed for Project Malibongwe for each identified concepts are presented in the figure below.

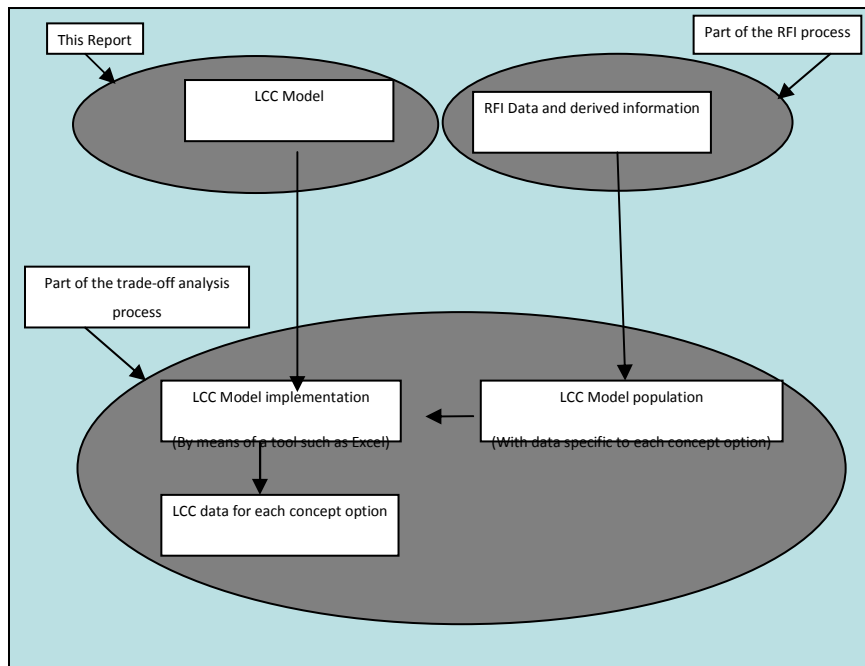


*Figure 4: Life Cycle Cost Model in Context*

**Note: RFI (Request for Information)**

## 6.2 The Cost Elements

The cost elements indicated in the figure below are addressed in the model estimation for each of the identified concepts.

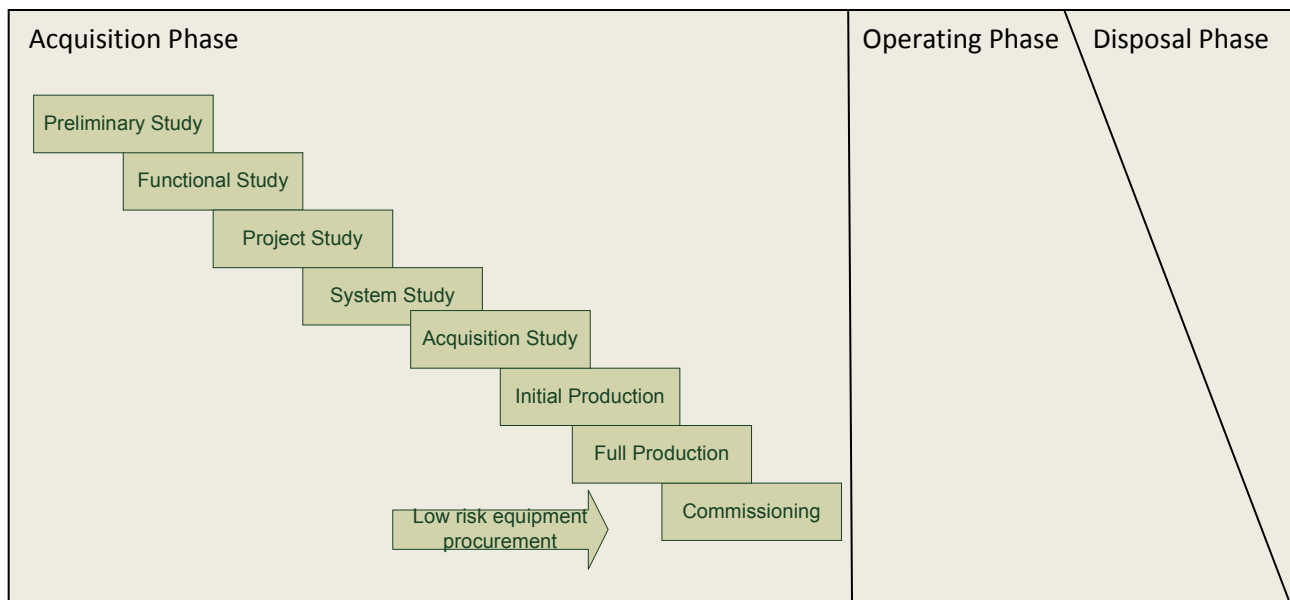


*Figure 5: Life Cycle Cost Elements*

### 1. Acquisition Phase Cost

#### I. Staff Support Services

- II. Production Cost Analysis
- III. Variable Speed Generator Unit Cost Analysis
- IV. Fixed Speed Generator Unit Cost Analysis

## **2. Operating Phase Cost**

- I. Operating Cost Breakdown
- II. Fuel Consumption
- III. Maintenance
- IV. Upgrade Cost

## **3. Disposal Phase Cost**

- I. A basic first order disposal cost element has been included in the model analysis. This has been estimated at 1% of production cost for each option concepts.

## **6.3 The Model**

The importance of the cost elements depends upon the stage of planning in which the calculation is undertaken. LCC is a decision making tool to select among alternatives projects/concepts, design or building components. Consequently, the LCC data should be presented in a way that enables such comparison. The cost breakdown structure is in this case an important aspect.

There are several cost-based LCC calculations methods available for the defence industry. They all have their different advantages and disadvantages. According to the reviewed literature, the most suitable approach the Life Cycle Cost in the defence industries are the Nett Present Value (NPV) method or, in the case of comparing alternatives schemes with different lifetimes, the Equivalent Annual Cost (EAC). The NPV method is mainly used in existing LCC tools today.

The first step of the development of a LCC Model (or indeed any mathematical formulation) is the determination of what information is to be considered during the solving of the problem. If a given function is not expected to have a significant bearing on the results from the model, it should be omitted. The user should bear in mind that different methods have been formed for different purposes. For example, in the case of a rough estimate to distinguish if the investment is profitable or not, the payback method would be suitable.

The cost elements can be divided into four main groups such as the acquisition cost, operating cost, disposal cost and other cost. All of them have to be taken into account for the LCC calculation. Therefore the Life Cycle Cost Model formula can be written as follows:

$$\text{Life Cycle Cost (LCC)} = \text{Nett Present Value (NPV)} = \text{Acquisition Cost (AC)} + \\ \text{Operating Cost (OC)} + \text{Disposal Cost (DC)} + \text{Other Cost (OC)}$$

Therefore  $LCC = NPV = AC + OC + DC + OC$  (2.8)

Where :

■ Acquisition Cost

- I. It is the cost of equipment or property after certain alterations and deductions such as depreciation of equipment and discounts but before deduction of tax.

■ Operating Cost

- I. The day to day expenses of running an organisation, business, equipment and property such as administration and electricity.

■ Disposal Cost

- I. The amount of money incurred for the action of removing or getting rid of a system that is no longer wanted. This has been estimated at 1% of production cost for each option concepts.

■ Other Cost

- I. It is those cost that do not fall into the above three categorises but which are part of the Project Malibongwe.

## **7. Conclusion**

The chosen maintenance strategy and economic model method will be consistent and it will satisfy the clients' needs (user requirement) which are the SANDF in the long term. Realising that and by using the military equipment sustainment strategy and life cycle cost method will result in a best optimal solution.

It is obvious that for short-term investment a detailed life cycle cost and military equipment sustainment strategy studies are a waste of time. Medium term investment is a suitable tool in the straight payback period.

## 8. Life Cycle Cost of System Concepts

### 8.1 Introduction

This section represents the results of a detailed LCC analysis carried out for each of the identified concepts.

The following must be noted with regard to the LCC analysis presented in this report:

- All costs are as in the September 2009 Rand values and include VAT but exclude escalation.
- The cost information was obtained from data obtained from the RFI process (and additional information requested after analysing the RFI responses) in 2010.

### 8.2 Acquisition Phase Cost

The cost analysis for the Acquisition Phase is presented in Appendices E for the fixed and variable speed concepts respectively. The cost analysis is presented as part of the LCC model analysis.

The following detailed cost analyses applicable to the Acquisition Phase are also presented in support of the LCC model analysis:

#### 8.2.1 Staff Support Services

The detailed analysis of the cost estimation for Staff Support services is presented in Appendix F. A summary of the cost estimation for the Staff Support services is presented in the table below.

| Cost Element                            | Cost (R)  |
|-----------------------------------------|-----------|
| Acquisition Study                       | 2,053,710 |
| Customisation & Industrialisation Phase | 1,872,165 |
| Commissioning Phase                     | 1,956,810 |

*Table 4: Staff Support Cost Estimation*

#### 8.2.2 Production Cost Analysis

The detailed analysis of the cost estimation for production units (excluding associated logistic support elements) is presented in appendix G. A summary of the cost estimation for the production units is presented in the table below.

| <b>Concept 1 : Fixed Speed</b> |                           | <b>Production Cost (R)</b> |
|--------------------------------|---------------------------|----------------------------|
| 1                              | Power Generation System   |                            |
| 1.1                            | Generator                 | 485,628,940                |
| 1.2                            | Power Management          | 11,250,000                 |
| 2                              | Power Reticulation System | 13,500,000                 |
| 3                              | Transport System          | 30,495,000                 |
| <b>Total</b>                   |                           | <b>540,873,940</b>         |

*Table 5: System Production Cost Estimation (Fixed Speed)*

| <b>Concept 2: Variable Speed</b> |                           | <b>Production Cost (R)</b> |
|----------------------------------|---------------------------|----------------------------|
| 1                                | Power Generation System   |                            |
| 1.1                              | Generator                 | 556,291,363                |
| 1.2                              | Power Management          | 11,250,000                 |
| 2                                | Power Reticulation System | 13,500,000                 |
| 3                                | Transport System          | 18,765,000                 |
| <b>Total</b>                     |                           | <b>599,806,363</b>         |

*Table 6: System Production Cost Estimation (Variable Speed)*

### 8.2.3 Variable Speed Generator Unit Cost Analysis

The detailed analysis of the unit production cost estimation for variable speed generators (excluding associated logistic support elements) is presented in appendix H. A summary of the estimated unit production cost for variable speed generators is presented in the table below.

| Kva | Tot Prod Unit Cost (R) | Basic Cost (R) | Militarisation Price (R) | Load Adaptation Price (R) |
|-----|------------------------|----------------|--------------------------|---------------------------|
| 7.5 | 204500                 | 65000          | 112500                   | 27000                     |
| 25  | 463000                 | 170000         | 250000                   | 43000                     |
| 80  | 730000                 | 330000         | 320000                   | 80000                     |
| 250 | 1407660                | 747143         | 541408                   | 119110                    |

*Table 7: Variable Speed Generator Unit Cost Estimation*

### 8.2.4 Fixed Speed Generator Unit Cost Analysis

The detailed analysis of the unit production cost estimation for fixed speed generators (excluding associated logistic support elements) is presented in appendix I. A summary of

the estimated unit production cost for fixed speed generators is presented in the table below.

| Kva | Tot Prod Unit Cost (R) | Basic unit cost (R) | Price (R) | Load adapt cost |  |
|-----|------------------------|---------------------|-----------|-----------------|--|
| 3.5 | 58021                  | 40014               | 18006     | N/A             |  |
| 7.5 | 73005                  | 50461               | 22544     |                 |  |
| 10  | 112912                 | 78154               | 34757     |                 |  |
| 15  | 125204                 | 86907               | 38297     |                 |  |
| 30  | 148276                 | 103798              | 44478     |                 |  |
| 60  | 189792                 | 135164              | 54628     |                 |  |
| 100 | 232084                 | 169194              | 62890     |                 |  |
| 175 | 305428                 | 233000              | 72428     |                 |  |
| 250 | 371007                 | 296806              | 74201     |                 |  |

Table 8: Fixed Speed Generator Unit Cost Estimation

### 8.3 Operating Phase Cost

The cost analysis for the Operating Phase is presented in Appendix L for the fixed and variable speed concepts respectively. The cost analysis is presented as part of the LCC analysis. The following detailed cost analyses applicable to the Operating Phase are also presented in support of the LCC analyses.

#### 8.3.1 Operating Cost Breakdown

The detailed cost analysis for the Operating Phase is presented in Appendices L for both the fixed and variable speed concepts. A summary of the operating cost breakdown is presented in the tables below.

| Concept 1 : Fixed Speed |                                  | Operating Cost [R] |                 |               |
|-------------------------|----------------------------------|--------------------|-----------------|---------------|
|                         |                                  | Cost per annum     | Operating years | Total Cost    |
| <b>1</b>                | <b>Power Generation System</b>   |                    |                 |               |
| <b>1.1</b>              | <b>Generator System</b>          | 88,459,566         | 15              | 1,326,893,492 |
| <b>1.2</b>              | <b>Power Management System</b>   | 562,500            | 15              | 8,437,500     |
| <b>2</b>                | <b>Power Reticulation System</b> | 675,000            | 15              | 10,125,000    |

|          |                         |               |                   |    |                      |
|----------|-------------------------|---------------|-------------------|----|----------------------|
| <b>3</b> | <b>Transport System</b> |               | 1,524,750         | 15 | 22,71,250            |
|          |                         | <b>Total:</b> | <b>91,221,816</b> |    | <b>1,368,327,242</b> |

*Table 9: Fixed Speed Operating Cost Estimation*

| <b>CONCEPT 2 : Variable Speed</b> |                                  | <b>Operating Cost [R]</b> |                        |                      |
|-----------------------------------|----------------------------------|---------------------------|------------------------|----------------------|
|                                   |                                  | <b>Cost per annum</b>     | <b>Operating years</b> | <b>Total Cost</b>    |
| <b>1</b>                          | <b>Power Generation System</b>   |                           |                        |                      |
| <b>1.1</b>                        | <b>Generator</b>                 | 68,091,439                | 15                     | 1,021,371,585        |
| <b>1.2</b>                        | <b>Power management</b>          | 562,500                   | 15                     | 8,437,500            |
| <b>2</b>                          | <b>Power Reticulation System</b> | 675,000                   | 15                     | 10,125,000           |
| <b>3</b>                          | <b>Transport System</b>          | 938,250                   | 15                     | 14,073,750           |
|                                   |                                  | <b>Total:</b>             |                        | <b>1,054,007,835</b> |

*Table 10: Variable Speed Operating Cost Estimation*

### 8.3.2 Fuel Consumption Cost Estimation

Fuel consumption is a major cost driver during the operating phase of both the generator concepts. The detailed cost analysis for the fuel consumption is presented in appendix J for both the fixed and variable speed concepts.

## 8.4 DISPOSAL COST

A basic first order disposal cost element has been included in the LCC analysis. This has been estimated at 1 % of production cost for each of the concepts.

## 8.5 ESTIMATED LIFE CYCLE COST

A LCC analysis on the system concepts has been carried out and the detailed are presented and set out as below.

Table 11 provides a summary of the LCC analysis carried out for each of the system concept options presented this report.

| Life-Cycle Element                                       | Life Cycle Cost In Millions [R] |                |
|----------------------------------------------------------|---------------------------------|----------------|
|                                                          | Fixed Speed                     | Variable Speed |
| <b>Level 6/5 Engineering &amp; Management</b>            | <b>7.68</b>                     | <b>7.68</b>    |
| <b>Product Customisation (industry) (incl OT&amp;E )</b> | <b>60.16</b>                    | <b>62.51</b>   |
| <b>Production</b>                                        | <b>590.80</b>                   | <b>653.28</b>  |
| <b>Total Capital Cost</b>                                | 658.64                          | 723.47         |
| <b>Operating Support (15 years)</b>                      |                                 |                |
| Power Generation M&R                                     | 1 335.33                        | 1 029.81       |
| Power Generation M&R                                     | 10.13                           | 10.13          |
| Transport M&R                                            | 22.87                           | 14.07          |
| <b>Total Operating Cost (15 years)</b>                   | 1 368.33                        | 1 054.01       |
| <b>Phase Out</b>                                         | 5.61                            | 6.20           |
| <b>Total Life Cycle Cost</b>                             | 2 032.58                        | 1 783.68       |

Table 11: LCC Analysis Results

## 9. System Concept Analysis

### 9.1 Affordability

All solutions investigated during this report, exceeded the capital funding estimation presented by the South African Department of Defence. The Fixed Speed and Variable speed options have an estimated capital cost of R658.64 Million and R723.47 Million respectively. Currently the SANDF Capital Acquisition Master Plan (SCAMP) reflects R126.87 Million for each of the project concepts.

A summary of the results of the system concept trade-off study are presented in table 12.

| CRITERIA                     | FIXED SPEED SYSTEM<br>CONCEPT    | VARIABLE SPEED SYSTEM<br>CONCEPT                              |
|------------------------------|----------------------------------|---------------------------------------------------------------|
| Capital Cost (RM)            | 658.64                           | 723.47                                                        |
| Operating Cost (15 yrs) (RM) | 1,368.33                         | 1,054.01                                                      |
| LCC(RM)                      | 2,032.58                         | 1,783.68                                                      |
| Advantages/Disadvantages     | Refer to table 1                 |                                                               |
| Risks                        | Majority commercial<br>equipment | Limited manufactures<br><br>New Technology<br><br>Maintenance |

Table 12: System Concept Trade-Off Conclusion

| CONCEPT                   | ACQUISITION<br><br>(CAPITAL)<br><br>COST [R] | YEARLY<br><br>OPERATING<br><br>COST [R] | OPERATING<br><br>COST 15<br><br>YEARS[R] | PHASE-OUT<br><br>COST<br><br>[R] | LCC<br><br>(15 YRS OPS)<br><br>[R] |
|---------------------------|----------------------------------------------|-----------------------------------------|------------------------------------------|----------------------------------|------------------------------------|
| <b>Fixed<br/>Speed</b>    | 658, 644,018                                 | 91,221,816                              | 1<br>368,327,242                         | 5,608,739                        | <b>2,032,580.00</b>                |
| <b>Variable<br/>Speed</b> | 723,469,685                                  | 70,267,189                              | 1<br>054,007,835                         | 6,198,064                        | <b>1,783,675</b>                   |
| <b>Difference</b>         | (64,825,666)                                 | 20,954,627                              | 314,319,406                              | (589,324)                        | <b>248,904,416</b>                 |

## 9.2 Economic Analysis

The economic analysis encompasses more than just the financial consideration of the project, such as the user benefits and external cost (air polluting, carbon dioxide emission and accident). The economic results of the two concept models are presented in terms of the net present value (NPV), the internal rate of return (IRR) and the benefit cost ratio (BCR). The table below shows the results of the economic analysis.

**Results of The Economic Analysis (NPV in Million R)**

| Economic Models | Fixed Speed Generator | Variable Speed Generator |
|-----------------|-----------------------|--------------------------|
| Economic NPV    | R 2,032.58 Million    | R 1.783.68 Million       |
| Economic IRR    | -93.75817926%         | -92.88717707%            |
| Economic BCR    | 0.062388688           | 0.071128229              |

**Table 13: Results of the economic analysis (NPV in Million R)**

The economic analysis shows that both concept generators are not economical beneficial. Measured as NPV, both the fixed speed and variable speed generators have the NPV way greater than the initial investment.

When looking at the IRR, it yields negative values which imply that we cannot choose any of the two option concepts because of the loss that will be incurred. For example if the SANDF invests in the Fixed Speed Generator, there will be incurring a loss of R 1,905.71 Million, as for the Variable Speed Generator there will be incurring a loss of R 1.656.81 Million (The IRR is explained in money terms instead of percentages).

The BCR yields values which are less than 1 for both option concepts for example if the SANDF invests in the Fixed Speed Generator, it will imply that for every R 1 spent, the return is 6 cents which is not be financial beneficial, as for the Variable Speed Generator for every R1 spent, the return is 7 cents which is also not financial beneficial.

Hence, the most preferable solution will depend on the available investment capital and the return on alternative investments.

## **10. Risks Associated With System Concepts**

### **10.1 Variable Speed**

The following risks have been identified:

- Limited manufactures currently exist. Only three organisations responded to the RFI of which only two offered variable speed technology (one local and one international supplier).
- The technology is currently new and it seems that the technology is mainly limited to the military environment. The scope of military application of the technology is currently also limited.
- The maintenance of variable speed technology is more complex due to the control and power electronics.

### **10.2 Fixed Speed**

The majority of fixed speed generators is commercial equipment and not militarised. No further known risks are associated with fixed speed generators due to the maturity of the technology.

### **10.3 Risk Conclusion**

The risk of the fixed speed generator is less than that of the variable speed generator due to the technology being well established and operationally applied. The risk associated with the variable speed concept is however acceptable to the MALIBONGWE project.

## **11. Conclusion**

### **11.1 Financial Consideration**

There are limitations in the funding for both concepts according to the current SANDF Capital Acquisition Master Plan (SCAMP). Further, both concepts in the defence industry have so many difficulties in attracting private risk capital due to the often large uncertainty of risk associated each concept.

Both concepts are not assessed to be realistic candidates in the short to medium term for involving private capital to take on revenue risks.

In order to improve the financial situation for both concepts Fixed Speed Generator and Variable Speed Generator, it is independently of the choice of investment option-recommended whereas in this case none of the two concepts can be chosen for investment because they are not financial feasible and optimal.

### **11.2 Economical Consideration**

Both concepts packages are considered not economically feasible as well as not financial feasible. None of the two concepts are clearly dominant although Variable Speed Generator seems to be better between the two. Both concepts provides the lowest return on investment (IRR) and it must be stated that they are not economical robust.

The economic results point in the same direction for both concepts packages and the IRRs are almost at the same level. Variable Speed Generator had a moderate better incurred loss compared to Fixed Speed Generator.

### **11.3 Local Capability**

Volt Ampere has been identified as a local company having mature variable speed technology even though the SANDF would not invest in both concepts but it is for future acquisition projects.

## **12. Recommendations**

### **12.1 System Concepts**

As no development option concept is dominant in economic terms. A trans-national agreed strategy for the development of and investigating in Project Malibongwe needs to balance:

- The economic efficiency of investments
- Funding Constraints
- The risk awareness
- The technical assistance within both concepts
- Environmental considerations

Both system concepts incorporating a variable speed generator technology and fixed speed generator technology are not recommended concepts based on the economic and affordability results of the trade-off study analysis presented in this report. These concepts have lowest IRR and BCR and they are assessed to be not economical robust options.

Combining the robustness in economic and financial terms with the financial constraints and the risk profiles, both investments concepts are not financial viable which cannot be developed over time in pace.

### **12.2 Develop/ Buy**

The recommended system concepts presented in this report should rather make use of developed military and commercial technologies that are available locally as well as internationally. It must however be noted that for both concepts, adaptations to the equipment shall be required in order to comply fully to the stated user requirements (Appendix B) and the operational theatre it is intended for. The customisation of the available logistic support system of the current products on the market shall also be required, to ensure an integrated logistic support system from a SANDF perspective. A level 5 integrated logistic systems needs to be developed, making use of the level 4 logistic products of the suppliers. This project should develop and integrate existing technologies and products.

A develop decision for the acquisition off-the-shelf system is recommended for Project MALIBONGWE. This entails proceeding directly to the compilation of an Acquisition Plan for

the recommended system concepts. The Acquisition Plan shall include the required adaptation of main equipment and the level 5 development of an integrated logistic support system.

### **12.3 Supplier/Contracting**

The recommendation for a supplier/ contractor for the provisioning of the two concepts can only be carried out by means of a formal request for provision (RFP) process to be carried out by Armscor and the subsequent supplier appointment based on their contractor adjudication process. This can only be carried out in the next phase and the supplier/ contractor recommendation shall then be provided in the Acquisition Plan.

### **12.4 System Specification**

This report presented a high-level functional design for each of the identified concepts that were used as basis for LCC estimation and concept trade-off purposes. It is recommended that a system specification be developed instead of commercial-off-the-shelf system concepts. Detailed design/ product choices shall then be carried out by industry in the next phase, based on the high-level system concept requirements presented in the system specification.

### 13. List of References

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#### *Consultations with:*

- Lucky Madonsela, Project Manager, Defence Institute
- Sabelo Ngozo, Project Manager, Defence Institute
- Tienie Nel, Technical Integrator Manager, Defence Institute

#### *Data provided by:*

- Marcelle Van Tonder, Project Manager, Defence Institute

■ Tienie Nel, Technical Integrator Manager, Defence Institute

■ Ronell Burger , Armscor Employee

## 14. Appendices

### Appendix A: Armscor list of accredited suppliers

| Supplier No. | Supplier List                         | Local | Overseas | RFI Send | RFI Return |
|--------------|---------------------------------------|-------|----------|----------|------------|
| 1.           | Umndeni Circon (PTY) LTD              | X     |          | Yes      | No         |
| 2.           | Air Systems                           | X     |          | Yes      | No         |
| 3.           | Turner Morris Electrical (PTY) LTD    | X     |          | Yes      | No         |
| 4.           | MTU South Africa (PTY) LTD            | X     |          | Yes      | No         |
| 5.           | Goscoe Engines and Forestry (PTY) LTD | X     |          | Yes      | No         |
| 6.           | Circon (PTY) LTD                      | X     |          | Yes      | No         |
| 7.           | Magnet Motors (PTY) LTD               | X     | X        | Yes      | No         |
| 8.           | Agrinet (PTY) LTD                     | X     | X        | Yes      | Yes        |
| 9.           | Stewart & Stevenson, LCC              |       | X        | Yes      | No         |
| 10.          | MTS Power Products                    |       | X        | Yes      | No         |
| 11.          | Industrial Power Systems INC          |       | X        | Yes      | No         |
| 12.          | Kohler Company                        | X     | X        | Yes      | No         |
| 13.          | Quick Cable Corporation               |       | X        | Yes      | No         |
| 14.          | Broadcrown Inc                        |       | X        | Yes      | No         |
| 15.          | Volt Ampere Electrical Engineering    | X     |          | Yes      | Yes        |
| 16.          | Diesel Electric (PTY) LTD             | X     |          | Yes      | Yes        |

Suppliers Listed = 57, Suppliers Interested = 16, Suppliers Responded = 3

## Appendix B: User Requirements

| User Requirement                                                                                                                                                                                                                                                                                                                   | Concept Deviation (Same for both concepts)                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><u>Frequencies Required.</u> The main frequencies required are 50 and 60 Hz both generated from anyone of the configurations. High frequency power tools unique to the engineers require 400Hz. It is highly recommended that the 400Hz option will be include as future demand for high frequency equipment us inevitable.</p> | <p>The user does not have a requirement for 60Hz. It is only provide a 50Hz capability. Due to technical considerations on the power reticulation side, it is recommended that 400Hz requirement be handled as a special requirement and that it not be provided by the project. The only two users are the Engineering Formation Group and SAAF. It has already been approved that SAAF will budget for and procure their own power generating equipment.</p> |
| <p><u>Voltage Required</u></p> <ul style="list-style-type: none"> <li>• 0.5 KVA to 25 KVA range will require 220-240 volts (AC) and 28 volts (DC).</li> <li>• Ranges larger than 25 KVA will require both 220-240 volts (AC) and 380-410 volts (AC) as well as 28 volts (DC).</li> </ul>                                           | <p>Not applicable</p>                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <p><u>Phases Required</u></p> <ul style="list-style-type: none"> <li>• 0.5 KVA to 25 KVA range will require</li> </ul>                                                                                                                                                                                                             | <p>It is recommended that the following provisio be made to this requirement :</p>                                                                                                                                                                                                                                                                                                                                                                             |

|                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>single phase.</p> <ul style="list-style-type: none"> <li>• Ranges larger than 25KVA will require three phases.</li> </ul> | <p>In the case were the generating capability is not sensitive to phase balancing (i.e. as is the case with variable technology), then it is recommended that a three phase capability will be required from 7.5 KVA and higher generating capacities.</p> <p>This requirement change provides much more operational flexibility, and is made possible by the recommended technology.</p> |
| <p><u>Air Dropping Capability.</u></p> <p>Rapid deployment required (including air dropping capability)</p>                  | <p>This requirement will not be achieved for the power generating units bigger than 7.5 KVA.</p> <p>It is expected that only the portable power generating units (i.e. 7.5 KVA and smaller) will have an air dropping capability. This Staff Requirement deviation is irrespective of the chosen concept.</p>                                                                             |

## **Appendix C: The companies and their options**

### **1. Agrinet**

Agrinet responded to the RFI and the responses are summarised below:

- a) A consortium consisting of the following companies was presented to provide a possible solution to the RFI. The consortium consisted of:

I. Agrinet

Agrinet has been exclusive distributor in Southern Africa for Yanmar Industrial diesel engines since 1963 and have been suppliers of Yanmar diesel products to the various divisions within the SANDF since 1986.

II. Rolls Royce

Rolls Royce is a global company providing power on land, sea and air. The company has a broad customer base, including 160 armed air forces in defence operations and commercial energy customers in nearly 120 countries. Rolls Royce provides worldwide support to over 2000 diesel generators of various sizes primarily for defence applications where reliability and capability to perform in harsh environment is important.

III. S&P Power Products

S&P Power Units (Pty) Ltd has been selling and installing alternative power sources since 2001. They are experts in both primary and rechargeable batteries, battery chargers and power suppliers, solar energy and wind turbines. S&P are suppliers to the SANDF either

directly or as sub-contractors to various companies supplying the SANDF with specialised products.

b) The Agrinet team proposes to optimise the amount of local content in support of future SANDF requirements. Initially they believe this will be structured in the following way:

c) Agrinet scope of supply:

- I. Yanmar Diesel Engine
- II. Fuel Base with relevant accessories
- III. Sound Attenuated Canopy
- IV. Assembly of the generator
- V. Through life support

d) Rolls Royce scope of supply

- i. Variable Speed Alternator
- ii. Power Conditioning System
- iii. Control Panel System
- iv. Output Panel
- v. Cooling Pack
- vi. Health and Usage Monitoring System (HUMS)

e) S&P Power Ltd scope of supply:

S&P Power will be responsible for the maintenance and repair of electrical components and equipments.

f) Solutions Offered

Agrinet has offered the following off the shelf solutions/products for:

1. Man- portable generator sets (4.2 & 6.0 Kw)
  - i. Fixed Speed
  - ii. Single Phase, 220V, 50Hz
  - iii. Delivery 8- 24 weeks depending on quantities required
2. Fixed speed generator sets (10-125 Kw)
  - I. Three phase, 400 V, 50Hz
  - II. Delivery 8-24 weeks depending on quantities required.
3. Variable speed generators
4. Power management and distribution equipment
5. Power converter



## **2. Diesel Electric Services**

Diesel Electric responded to the RFI and the response received is summarised below:

- a. Diesel Electric Services specialises in the design and manufacture of diesel generator sets, distribution boards and associated products.
- b. The RFI information received elaborates on the company profile. None of the technical information as requested in the RFI has been provided.
- c. Diesel Electric Services have included budget pricing for one of their selected ranges of small generators (up to 250 Kva), as well as budget pricing for a range of imported generating sets that they reliable access to.



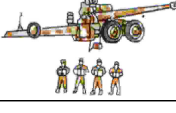
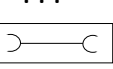
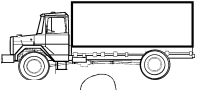
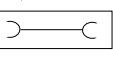
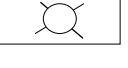
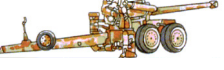
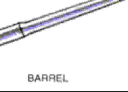
### **3. Volt Ampere Electrical and Mechanical Engineering**

Volt Ampere responded to the RFI and the response received is summarised below:

- a. Volt Ampere was founded in 1971 and it has been closely linked with the SANDF for over 30 years. They are still presently the main contractor to the South African Army for the maintenance support of power supply equipment from their workshops at the Wonderboom military base and Pretoria, with technical personnel deployed on permanent basis.
- b. Volt Ampere proposes in their response to the RFI, two technologies namely constant speed and variable speed. With regard to the variable speed option they offer the Hygen, load adaptive system which has been developed by them.
- c. Volt Ampere offers complete reticulation support.
- d. Budget prices have been provided for both fixed speed and variable speed generator sets.
- e. Volt Ampere offered various products of both fixed speed and variable speed in the ranges between 2.5 Kva and 375 Kva, supported by technical information.



## Appendix D: System Breakdown Structure

| VIRTUAL SYSTEMS | Combat and non-combat (support) capabilities | Level 8 | JOINT HIGHER ORDER MILITARY SYSTEM             | TYPICAL CAMPAIGN CAPABILITIES                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                      |                                                                                                       |
|-----------------|----------------------------------------------|---------|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
|                 |                                              | Level 7 | OPERATIONAL SYSTEM<br>(Operational Capability) | AIR FORCE<br>                                                                                                                                                                                                                                                                                                                                                                                                       | ARMY<br>                          | MARITIME<br>       |
| REAL SYSTEMS    | Matériel                                     | Level 6 | CORE SYSTEM                                    | ARTY CAPABILITY<br>                                                                                                                                                                                                                                                                                                                                                                                                 | INFANTRY CAPABILITY<br>F- ECH<br> | AIR CAPABILITY<br> |
|                 |                                              |         |                                                | A/B ECH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | FAA ECH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | F- ECH<br>                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | A/B ECH<br>LWT                                                                                                                                                                                                                                                                                                                  |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | FAA ECH<br>                                                                                                                                                                                                                                                                                                                 |                                                                                                                      |                                                                                                       |
|                 | Level 5                                      | Level 5 | PRODUCTS SYSTEM<br>(Pseudo Capability)         | GUN TRACTOR + COMMUNICATION + SUPPORT<br>GUN + AMMO + COMMUNICATION + SUPPORT<br>                                                                   |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | PRODUCT<br>                                                                                                                                                                                                                                                                                                                 |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | PRODUCT SUB-ASSEMBLY<br>GUN BARREL  RECOIL SYSTEM                                                                                                                                                                                                                                                                           |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | COMPONENT<br>BEARINGS  ROD  BREECH RING  BREECH BLOCK  BARREL  |                                                                                                                      |                                                                                                       |
|                 |                                              |         |                                                | RAW MATERIAL<br>BARREL STEEL  COTTON LINTERS                                                                                                                                                                                                                                                                                |                                                                                                                      |                                                                                                       |

## Appendix E: Fixed & Variable Speed LCC Estimation

### Fixed Speed LCC Estimation

#### Production Cost

| No. | Main Equipment Breakdown     | Rand Value | Total Unit Cost (R) | Prod Quantity | Total Prod Cost |
|-----|------------------------------|------------|---------------------|---------------|-----------------|
| 1   | 3.5 kva                      | 98635      | 98.64               | 3750          | 369900          |
| 2   | 7.5 kva                      | 124108     | 124.11              | 376           | 46665.36        |
| 3   | 10 kva                       | 191950     | 191.95              | 66            | 12668.7         |
| 4   | 15/3 kva                     | 212847     | 212.85              | 51            | 10855.35        |
| 5   | 30/3 kva                     | 252069     | 252.07              | 42            | 10586.94        |
| 6   | 60/3 kva                     | 322647     | 322.65              | 48            | 15487.2         |
| 7   | 100/3 kva                    | 394543     | 394.54              | 24            | 9468.96         |
| 8   | 175/3 kva                    | 519228     | 519.23              | 12            | 6230.76         |
| 9   | 250/3 kva                    | 630712     | 630.71              | 6             | 3784.26         |
| 10  | Power Management Subsystem   | 11250      | 11250               | 1             | 11250           |
| 11  | Power Reticulation Subsystem | 13500      | 13500               | 1             | 13500           |
| 12  | Transport Subsystem          | 30495      | 30495               | 1             | 30495           |
| 13  | Log B-type Vehicle           | 1000       | 1000                | 20            | 20000           |
|     |                              |            |                     | Total:        | 560892.53       |

### Variable Speed LCC Estimation

#### Production Cost

| No. | Main Equipment Breakdown     | Rand Value | Total Unit Cost (R) | Prod Quantity | Total Prod Cost |
|-----|------------------------------|------------|---------------------|---------------|-----------------|
| 1   | 3.5 kva                      | 98635      | 98.64               | 3750          | 369900          |
| 2   | 7.5/3 kva                    | 2045       | 204.5               | 418           | 85481           |
| 3   | 25/3 kva                     | 463        | 463                 | 69            | 31947           |
| 4   | 80/3 kva                     | 730        | 730                 | 54            | 39420           |
| 5   | 250/3 kva                    | 140766     | 1407.68             | 21            | 29561.28        |
| 6   | No Entry                     | 0          | 0                   | 0             | 0               |
| 7   | No Entry                     | 0          | 0                   | 0             | 0               |
| 8   | No Entry                     | 0          | 0                   | 0             | 0               |
| 9   | No Entry                     | 0          | 0                   | 0             | 0               |
| 10  | Power Management Subsystem   | 11250      | 11250               | 1             | 11250           |
| 11  | Power Reticulation Subsystem | 13500      | 13500               | 1             | 13500           |
| 12  | Transport Subsystem          | 18765      | 18765               | 1             | 18765           |
| 13  | Log B-type Vehicle           | 1000       | 1000                | 20            | 20000           |
|     |                              |            |                     | Total:        | 619824.28       |

## Appendix F: Staff Support Cost Estimation

|          |                                                      | <b>Staff Support Cost</b> |              |             |              |            |
|----------|------------------------------------------------------|---------------------------|--------------|-------------|--------------|------------|
|          |                                                      | <b>Cost</b>               | <b>Hours</b> | <b>Rate</b> | <b>Other</b> | <b>Vat</b> |
| <b>1</b> | <b>Functional Study</b>                              |                           |              |             |              |            |
|          | Completed                                            |                           |              |             |              |            |
| <b>2</b> | <b>Project Study/ Concept Phase @ L5 (15 Months)</b> |                           |              |             |              |            |
|          | Completed                                            |                           |              |             |              |            |
| <b>3</b> | <b>System Study (10 Months)</b>                      |                           |              |             |              |            |
|          | Not Applicable                                       |                           |              |             |              |            |
| <b>4</b> | <b>Acquisition Study</b>                             |                           |              |             |              |            |
|          | Provide evaluation support                           |                           |              | 0.45        |              |            |
|          | Provide general systems engineering support          | 246.24                    | 480          | 0.45        |              | 30.2       |
|          | Provide general logistics engineering support        | 184.68                    | 360          | 0.45        |              | 22.7       |
|          | Provide configuration data management support        | 92.34                     | 180          | 0.45        |              | 11.3       |
|          | Provide specialist technical support                 | 92.34                     | 180          | 0.45        |              | 11.3       |
|          | Maintain Specifications                              | 61.56                     | 120          | 0.45        |              | 7.56       |
|          | Compile allocated segment specs                      | 153.9                     | 300          | 0.45        |              | 18.9       |
|          | Request for proposal compilation support             | 153.9                     | 300          | 0.45        |              | 18.9       |
|          | Value system compilation support                     | 76.95                     | 150          | 0.45        |              | 9.45       |
|          | Technical evaluation of RFO's support                | 61.56                     | 120          | 0.45        |              | 7.56       |
|          | Technical evaluation technical report                | 76.95                     | 150          | 0.45        |              | 9.45       |
|          | Support to Armscor Programme Manager                 | 46.17                     | 90           | 0.45        |              | 5.67       |
|          | Compile baseline                                     | 205.2                     | 400          | 0.45        |              | 25.2       |
|          | Compile submission                                   | 92.34                     | 180          | 0.45        |              | 11.3       |
|          | Compile L5 Product Baseline Documentation            | 153.9                     | 300          | 0.45        |              | 18.9       |
|          | Internal technical integration and management        | 92.34                     | 180          | 0.45        |              | 11.3       |
|          | Contract and project management                      | 92.34                     | 180          | 0.45        |              | 11.3       |
|          | Material cost                                        | 57                        |              | 0.45        | 50           | 7          |
|          | S&T                                                  | 57                        |              | 0.45        | 50           | 7          |
|          | Unforeseen Expenses                                  | 57                        |              | 0.45        | 50           | 7          |
|          | <b>Total Acquisition Study</b>                       | <b>2053.7</b>             | <b>3670</b>  |             | <b>150</b>   | <b>252</b> |

### Staff Support Cost

|          |                                                                             | Cost   | Hours | Rate | Other | Vat    |
|----------|-----------------------------------------------------------------------------|--------|-------|------|-------|--------|
| <b>5</b> | <b>Customisation and Industrialisation Phase (15 Months)</b>                |        |       |      |       |        |
|          | Provide general systems engineering support                                 | 269.33 | 525   | 0.45 |       | 33.08  |
|          | Provide general logistics engineering support                               | 192.38 | 375   | 0.45 |       | 23.63  |
|          | Provide configuration data management support                               | 230.85 | 450   | 0.45 |       | 28.35  |
|          | Provide specialist technical support                                        | 153.9  | 300   | 0.45 |       | 18.9   |
|          | Maintain Specifications                                                     | 115.43 | 225   | 0.45 |       | 14.18  |
|          | Provide inputs to test documentation                                        | 102.6  | 200   | 0.45 |       | 12.6   |
|          | Attendance of operating test and evaluation                                 | 92.34  | 180   | 0.45 |       | 11.34  |
|          | Support with test report                                                    | 102.6  | 200   | 0.45 |       | 12.6   |
|          | Compile L5 Product Baseline Documentation                                   | 153.9  | 300   | 0.45 |       | 18.9   |
|          | Internal technical integration and management                               | 115.43 | 225   | 0.45 |       | 14.18  |
|          | Contract and project management                                             | 115.43 | 225   | 0.45 |       | 14.18  |
|          | Material cost                                                               | 57     |       | 0.45 | 50    | 7      |
|          | S&T                                                                         | 57     |       | 0.45 | 50    | 7      |
|          | Unforeseen Expenses                                                         | 114    |       | 0.45 | 100   | 14     |
|          | Total Customisation and Industrial Phase                                    | 1872.2 | 3205  |      | 200   | 229.94 |
| <b>6</b> | <b>Commissioning Phase (12 Months)</b>                                      |        |       |      |       |        |
|          | Provide general systems engineering support                                 | 246.24 | 480   | 0.45 |       | 30.24  |
|          | Provide general logistics engineering support                               | 307.8  | 600   | 0.45 |       | 37.8   |
|          | Provide configuration data management support                               | 184.68 | 360   | 0.45 |       | 22.68  |
|          | Provide specialist technical support                                        | 123.12 | 240   | 0.45 |       | 15.12  |
|          | Compile logistics documents required for operational test and qualification | 230.85 | 450   |      |       | 28.35  |
|          | Provide inputs to test documentation                                        | 102.6  | 200   | 0.45 |       | 12.6   |
|          | Attendance of operating test and qualification                              | 92.34  | 180   | 0.45 |       | 11.34  |
|          | Support with test report                                                    | 102.6  | 200   | 0.45 |       | 12.6   |
|          | Compile L5 Operating Baseline Documentation                                 | 153.9  | 300   | 0.45 |       | 18.9   |
|          | Internal technical integration and management                               | 92.34  | 180   | 0.45 |       | 11.34  |
|          | Contract and project management                                             | 92.34  | 180   | 0.45 |       | 11.34  |
|          | Material cost                                                               | 57     |       | 0.45 | 50    | 7      |
|          | S&T                                                                         | 57     |       | 0.45 | 50    | 7      |
|          | Unforeseen Expenses                                                         | 114    |       | 0.45 | 100   | 14     |
|          | Total Commission Phase                                                      | 1956   | 3370  |      | 200   | 240.3  |

## Appendix G: Power System Cost Estimation

| Concept 1: Fixed Speed Generator |                                                     | 0.2             | 0.5        |                 |          |                 |
|----------------------------------|-----------------------------------------------------|-----------------|------------|-----------------|----------|-----------------|
| Config                           | Basic Cost (prime, mover, alternator, control gear) | Power Condition | Dummy Load | Total Unit Cost | Quantity | Total Prod Cost |
| 3.5 kva                          | 58021                                               | 11604.2         | 29010.5    | 98.64           | 3750     | 369900          |
| 7.5 kva                          | 73005                                               | 14601           | 36502.5    | 124.11          | 376      | 46665.36        |
| 10 kva                           | 112912                                              | 22582.4         | 56456      | 191.95          | 66       | 12668.7         |
| 15/3 kva                         | 125204                                              | 25040.8         | 62602      | 212.85          | 51       | 10855.35        |
| 30/3 kva                         | 148276                                              | 29655.2         | 74138      | 252.07          | 42       | 10586.94        |
| 60/3 kva                         | 189792                                              | 37958.4         | 94896      | 322.65          | 48       | 15487.2         |
| 100/3 kva                        | 232084                                              | 46416.8         | 116042     | 394.54          | 24       | 9468.96         |
| 175/3 kva                        | 305428                                              | 61085.6         | 152714     | 519.23          | 12       | 6230.76         |
| 250/3 kva                        | 371007                                              | 74201.4         | 185504     | 630.71          | 6        | 3784.26         |
|                                  |                                                     |                 |            |                 | Total    | 485647.53       |

### Notes

Assume dummy load cost = generator cost (assume to use dummy load = 50% of generator capacity) (M.du Preez)  
 Budget for power electronics cost = additional 20% of generator cost apart from adaption provisioning already made (L. Punt)

| Concept 2: Variable Speed Generator |                                                     | 0.2             | 0.5        |                 |          |                 |
|-------------------------------------|-----------------------------------------------------|-----------------|------------|-----------------|----------|-----------------|
| Config                              | Basic Cost (prime, mover, alternator, control gear) | Power Condition | Dummy Load | Total Unit Cost | Quantity | Total Prod Cost |
| 3.5 kva (FS)                        |                                                     | Included        | N/A        | 98.64           | 3750     | 369900          |
| 7.5 kva/3                           | 204500                                              | Included        | N/A        | 204.5           | 418      | 85481           |
| 25 kva/3                            | 463000                                              | Included        | N/A        | 463             | 69       | 31947           |
| 80/3 kva                            | 730000                                              | Included        | N/A        | 730             | 54       | 39420           |
| 250/3 kva                           | 1407660                                             | Included        | N/A        | 1407.66         | 21       | 29560.86        |
|                                     |                                                     |                 |            |                 | Total    | 556308.86       |

| <b>2. Power Reticulation System</b>                                                  |          |          |               |                 |                 |                 |
|--------------------------------------------------------------------------------------|----------|----------|---------------|-----------------|-----------------|-----------------|
| <b>2.1 Conventional mission (provided for by equipment of peace support mission)</b> |          |          |               |                 |                 |                 |
| Item                                                                                 | Unit     | Quantity | Cost/Unit (R) | Total Unit Cost | No. of missions | Total Prod Cost |
| Cables                                                                               | m        | 2000     | 100           | 200000          |                 |                 |
| Main DB                                                                              | per unit | 2        | 60000         | 120000          |                 |                 |
| Sub DB's                                                                             | per unit | 25       | 25000         | 625000          |                 |                 |
| Single ph DB's                                                                       | per unit | 50       | 8000          | 400000          |                 |                 |
| <b>Total</b>                                                                         |          |          |               | <b>1345000</b>  | <b>0</b>        | <b>0</b>        |

| <b>2.2 Peace support mission(make provision for 3 missions)</b> |          |          |               |                 |                 |                 |
|-----------------------------------------------------------------|----------|----------|---------------|-----------------|-----------------|-----------------|
| Item                                                            | Unit     | Quantity | Cost/Unit (R) | Total Unit Cost | No. of missions | Total Prod Cost |
| Cables                                                          | m        | 6000     | 100           | 600000          |                 |                 |
| Main DB                                                         | per unit | 3        | 100000        | 300000          |                 |                 |
| Sub DB's                                                        | per unit | 60       | 25000         | 1500000         |                 |                 |
| Single ph DB's                                                  | per unit | 120      | 8000          | 960000          |                 |                 |
| <b>Total</b>                                                    |          |          |               | <b>3360000</b>  | <b>3</b>        | <b>10080000</b> |

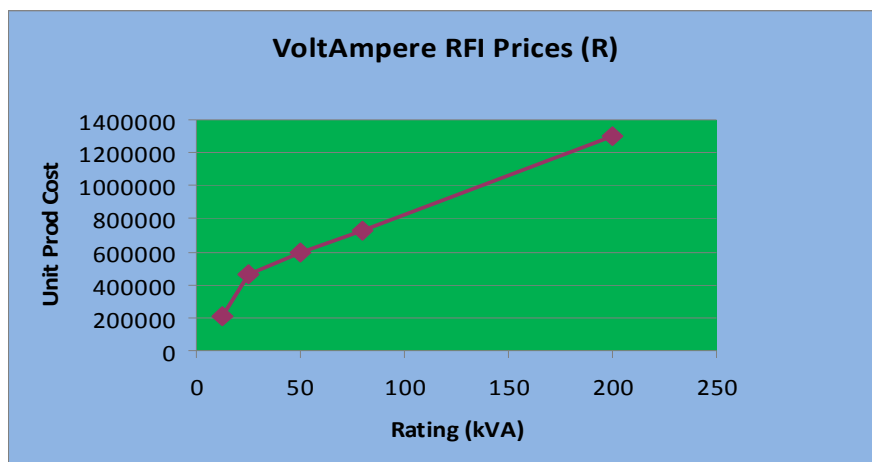
| <b>2.3 Internal Stability mission (make provision for 3 missions)</b> |          |          |               |                 |                 |                 |
|-----------------------------------------------------------------------|----------|----------|---------------|-----------------|-----------------|-----------------|
| Item                                                                  | Unit     | Quantity | Cost/Unit (R) | Total Unit Cost | No. of missions | Total Prod Cost |
| Cables                                                                | m        | 2000     | 100           | 200000          |                 |                 |
| Main DB                                                               | per unit | 2        | 60000         | 120000          |                 |                 |
| Sub DB's                                                              | per unit | 20       | 25000         | 500000          |                 |                 |
| Single ph DB's                                                        | per unit | 40       | 8000          | 320000          |                 |                 |
| <b>Total</b>                                                          |          |          |               | <b>1140000</b>  | <b>3</b>        | <b>3420000</b>  |

| 3. Transport System              |                               |                     |                          |                             |                   |                        |
|----------------------------------|-------------------------------|---------------------|--------------------------|-----------------------------|-------------------|------------------------|
| Concept 1: Fixed Speed Generator |                               |                     |                          |                             |                   |                        |
| Config                           | Estimated container unit cost | Quantity Containers | Tot Prod Cost Containers | Estimated Trailer Unit Cost | Quantity Trailers | Tot Prod Cost Trailers |
| 3.5 kva                          |                               | 0                   | 0                        |                             |                   | 0                      |
| 5 kva                            |                               | 0                   | 0                        |                             |                   | 0                      |
| 10 kva                           |                               | 0                   | 0                        | 150000                      | 104               | 15600000               |
| 15/3 kva                         | 45000                         | 51                  | 2295000                  |                             |                   |                        |
| 30/3 kva                         | 60000                         | 42                  | 2520000                  |                             |                   |                        |
| 60/3 kva                         | 90000                         | 48                  | 4320000                  |                             |                   |                        |
| 100/3 kva                        | 120000                        | 24                  | 2880000                  |                             | 0                 | 0                      |
| 175/3 kva                        | 150000                        | 12                  | 1800000                  |                             | 0                 | 0                      |
| 250/3 kva                        | 180000                        | 6                   | 1080000                  |                             | 0                 | 0                      |
| Sub total                        |                               |                     | 14895000                 | Sub total                   |                   | 15600000               |
|                                  |                               |                     |                          | Total Transport System Cost |                   |                        |
|                                  |                               |                     |                          | 30495000                    |                   |                        |

| Concept 2: Variable Speed Generator |                               |                     |                          |                             |                   |                        |
|-------------------------------------|-------------------------------|---------------------|--------------------------|-----------------------------|-------------------|------------------------|
| Config                              | Estimated container unit cost | Quantity Containers | Tot Prod Cost Containers | Estimated Trailer Unit Cost | Quantity Trailers | Tot Prod Cost Trailers |
| 3.5 kva                             |                               | 0                   | 0                        |                             | 0                 | 0                      |
| 7.5/3 kva                           |                               | 0                   | 0                        |                             | 0                 | 0                      |
| 25/3 kva                            | 55000                         | 69                  | 3795000                  | 150000                      | 35                | 5250000                |
| 80/3 kva                            | 110000                        | 54                  | 5940000                  |                             | 0                 | 0                      |
| 250/3 kva                           | 180000                        | 21                  | 3780000                  |                             | 0                 | 0                      |
| Sub total                           |                               |                     | 13515000                 | Sub total                   |                   | 5250000                |
|                                     |                               |                     |                          | Total Transport System Cost |                   |                        |
|                                     |                               |                     |                          | 18765000                    |                   |                        |

## Appendix H: Variable Speed Generator Unit Cost Analysis

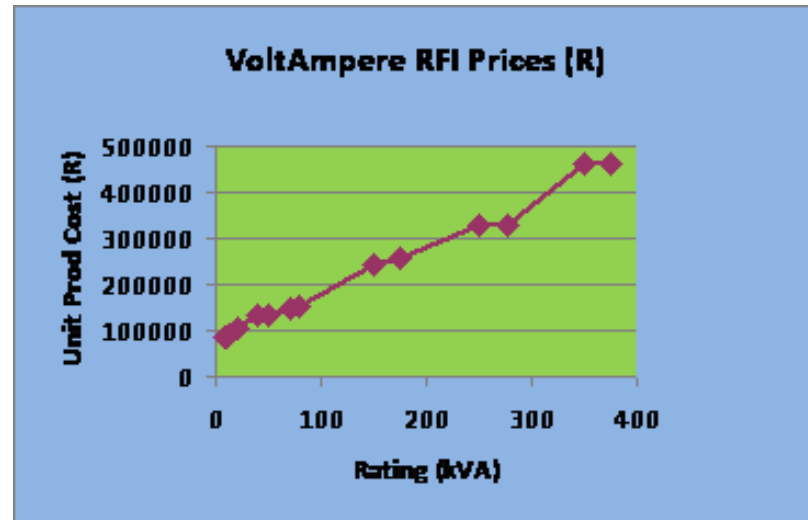
| Voltampere Request for Information (RFI) received on the 30/09/2009 |      |                |               | Militarisation Cost |                | Load Adaptation Cost |                |
|---------------------------------------------------------------------|------|----------------|---------------|---------------------|----------------|----------------------|----------------|
|                                                                     | kva  | Total Cost (R) | Prod Cost (R) | Price (R)           | % of Prod Cost | Price (R)            | % of Prod Cost |
|                                                                     | 12.5 | 204500         | 65000         | 112500              | 173.08         | 27000                | 41.54          |
|                                                                     | 25   | 463000         | 170000        | 250000              | 147.06         | 43000                | 25.29          |
|                                                                     | 50   | 595000         | 225000        | 300000              | 133.33         | 70000                | 31.11          |
|                                                                     | 80   | 730000         | 330000        | 320000              | 96.97          | 80000                | 24.24          |
|                                                                     | 200  | 1300000        | 690000        | 500000              | 72.46          | 110000               | 15.94          |



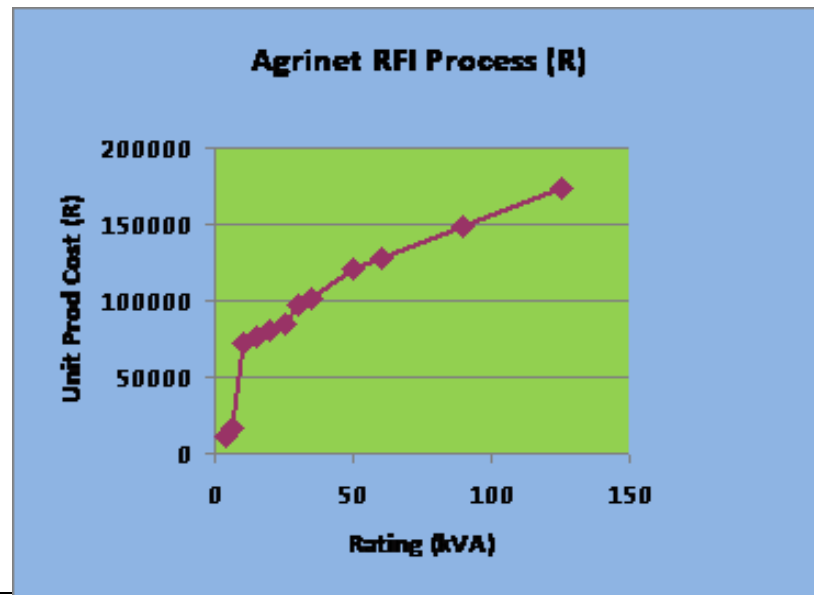
| Variable Speed Production Prices Used For Trade – Off |                        |                | Militarisation Cost |                 | Load Adaptation Cost |                 |
|-------------------------------------------------------|------------------------|----------------|---------------------|-----------------|----------------------|-----------------|
| kva                                                   | Tot Prod Unit Cost (R) | Basic Cost (R) | Price (R)           | % of basic cost | Price (R)            | % of basic cost |
| 7.5                                                   | 204500                 | 65000          | 112500              | 173.08          | 27000                | 41.54           |
| 25                                                    | 463000                 | 170000         | 250000              | 147.06          | 43000                | 25.29           |
| 80                                                    | 730000                 | 330000         | 320000              | 96.97           | 80000                | 24.24           |
| 250                                                   | 1407660                | 747143         | 541408              | 72.46           | 119110               | 15.94           |

## Appendix I: Fixed Speed Generator Unit Cost Analysis

| Volt-ampere Prices                              |     |           |
|-------------------------------------------------|-----|-----------|
| RFI original prices (entry level budget prices) |     |           |
| Description                                     | kva | Price (R) |
|                                                 | 9   | 85000     |
|                                                 | 10  | 85000     |
|                                                 | 12  | 92000     |
|                                                 | 20  | 107000    |
|                                                 | 20  | 107000    |
|                                                 | 40  | 132000    |
|                                                 | 50  | 134500    |
|                                                 | 70  | 148000    |
|                                                 | 80  | 151000    |
|                                                 | 150 | 242000    |
|                                                 | 175 | 255000    |
|                                                 | 250 | 328000    |
|                                                 | 277 | 328000    |
|                                                 | 350 | 460000    |
|                                                 | 375 | 460000    |
| Extrapolated data (low range)                   |     |           |
| 3.5 kva                                         | 3.5 | 70250     |
| 7.5 kva                                         | 7.5 | 80250     |
| 10 kva                                          | 10  | 86500     |
| Extrapolated data (top range)                   |     |           |
| 15/3 kva                                        | 15  | 97751     |
| 30/3 kva                                        | 30  | 112773    |
| 60/3 kva                                        | 60  | 142818    |
| 100/3 kva                                       | 100 | 182877    |
| 175/3 kva                                       | 175 | 257988    |
| 250/3 kva                                       | 250 | 333100    |



| Agrinet Prices                    |     |                  |
|-----------------------------------|-----|------------------|
| Description                       | kva | Quoted Price (R) |
| 1P                                | 4.2 | 11685            |
| 1P                                | 6   | 16587            |
| 3P                                | 10  | 71763            |
| 3P                                | 15  | 75810            |
| 3P                                | 20  | 80883            |
| 3P                                | 25  | 85329            |
| 3P                                | 30  | 96843            |
| 3P                                | 35  | 102030           |
| 3P                                | 50  | 120783           |
| 3P                                | 60  | 127395           |
| 3P                                | 90  | 148143           |
| 3P                                | 125 | 173223           |
| Extrapolated data (1P range)      |     |                  |
| 3.5 kva                           | 3.5 | 9779             |
| 7.5 kva                           | 7.5 | 20672            |
| Extrapolated data (3P mid range)  |     |                  |
| 10 kva                            | 10  | 69809            |
| 15/3 kva                          | 15  | 76062            |
| 30/3 kva                          | 30  | 94824            |
| Extrapolated data (3P high range) |     |                  |
| 60/3 kva                          | 60  | 127511           |
| 100/3 kva                         | 100 | 155511           |
| 175/3 kva                         | 175 | 208012           |
| 250/3 kva                         | 250 | 260512           |



| Fixed Speed Production<br>Prices Used For Trade - Off |                           |                                                          |                                       |                 |                 |     |
|-------------------------------------------------------|---------------------------|----------------------------------------------------------|---------------------------------------|-----------------|-----------------|-----|
|                                                       |                           |                                                          | Estimated provision for adapt<br>cost |                 | Load adapt cost |     |
| kva                                                   | Tot Prod Unit Cost<br>(R) | Basic unit<br>cost (R)<br>(average<br>of 2<br>suppliers) | Price (R)                             | % of basic cost | n.a             | n.a |
| 3.5                                                   | 58021                     | 40014                                                    | 18006                                 | 45              |                 |     |
| 7.5                                                   | 73005                     | 50461                                                    | 22544                                 | 44.68           |                 |     |
| 10                                                    | 112912                    | 78154                                                    | 34757                                 | 44.47           |                 |     |
| 15                                                    | 125204                    | 86907                                                    | 38297                                 | 44.07           |                 |     |
| 30                                                    | 148276                    | 103798                                                   | 44478                                 | 42.85           |                 |     |
| 60                                                    | 189792                    | 135164                                                   | 54628                                 | 40.42           |                 |     |
| 100                                                   | 232084                    | 169194                                                   | 62890                                 | 37.17           |                 |     |
| 175                                                   | 305428                    | 233000                                                   | 72428                                 | 31.09           |                 |     |
| 250                                                   | 371007                    | 296806                                                   | 74201                                 | 25              |                 |     |

## Appendix J: Consumption Cost Analysis

| Fixed Speed Fuel Consumption Calculations/Inputs |                  |                       |
|--------------------------------------------------|------------------|-----------------------|
| Agrinet                                          | Superwatt Values |                       |
| Config                                           | kva              | Fuel Consumption l/hr |
| 1P                                               | 4.2              | 1                     |
| 1P                                               | 6                | 1.38                  |
| 3P                                               | 10               | 2.59                  |
| 3P                                               | 15               | 3.49                  |
| 3P                                               | 20               | 4.69                  |
| 3P                                               | 25               | 5.56                  |
| 3P                                               | 30               | 6.9                   |
| 3P                                               | 35               | 8.33                  |
| 3P                                               | 50               | 12                    |
| 3P                                               | 60               | 15.79                 |
| 3P                                               | 108              | 23                    |
| 3P                                               | 130              | 26                    |
| 3P                                               | 160              | 30.9                  |
| 3P                                               | 200              | 38.7                  |
| 3P                                               | 250              | 54                    |

| Extrapolated data (low range) |     | Fuel Consumption l/hr |
|-------------------------------|-----|-----------------------|
| 3.5 kva                       | 3.5 | 0.56                  |
| 7.5 kva                       | 7.5 | 1.58                  |
| 10 kva                        | 10  | 2.59                  |
| 15/3 kva                      | 15  | 3.49                  |
| 30/3 kva                      | 30  | 6.9                   |
| 60/3 kva                      | 60  | 15.79                 |

| Extrapolated data (top range) |     |       |
|-------------------------------|-----|-------|
| 100/3 kva                     | 100 | 19.48 |
| 175/3 kva                     | 175 | 35.69 |
| 250/3 kva                     | 250 | 54    |

|                                                            |  |
|------------------------------------------------------------|--|
| <b>Variable Speed Fuel Consumption Calculations/Inputs</b> |  |
|------------------------------------------------------------|--|

|                                                                                  |  |  |  |     |
|----------------------------------------------------------------------------------|--|--|--|-----|
| <b>Calculation Strategy</b>                                                      |  |  |  |     |
| Use fixed speed generator values as a basis                                      |  |  |  |     |
| Allow 20% for part load advantages of variable speed                             |  |  |  | 0.2 |
| Allow 10% for higher efficiency of permanent magnet motor over synchronous motor |  |  |  | 0.1 |

| Extrapolated data | kva | Basic fuel consumption l/hr | Part load reduction | Improved Effectiveness | Estimated operation consumption l/hr |
|-------------------|-----|-----------------------------|---------------------|------------------------|--------------------------------------|
|                   | 3.5 | 0.56                        | 0.11                | 0.06                   | 0.39                                 |
|                   | 7.5 | 1.58                        | 0.32                | 0.32                   | 1.1                                  |
|                   | 25  | 5.56                        | 1.11                | 0.56                   | 3.89                                 |
|                   | 80  | 18.03                       | 3.61                | 1.8                    | 12.62                                |
|                   | 250 | 54                          | 10.8                | 5.4                    | 37.8                                 |

## Appendix L: Operating Cost Analysis

| 1. Power Generation System |           |              |                    |                     |                       |                     |                                      |                                        |                   |                      |                                        |
|----------------------------|-----------|--------------|--------------------|---------------------|-----------------------|---------------------|--------------------------------------|----------------------------------------|-------------------|----------------------|----------------------------------------|
| 1.1 Generator              |           |              |                    |                     |                       |                     |                                      |                                        |                   |                      |                                        |
| Concept 1: Fixed Speed     |           |              |                    |                     |                       |                     |                                      |                                        |                   |                      |                                        |
| Full Time Running Values   |           |              |                    |                     |                       |                     |                                      | Quantities                             |                   |                      |                                        |
|                            | Config    | Unit Cost    | M&R Unit Cost p.a. | Fuel Consump (l/hr) | Fuel Consump (l/p.a.) | Fuel Unit Cost p.a. | Major Overhaul Cost (every 8500 hrs) | Effective Major Overhaul Unit Cost p.a | Total Requirement | Effective Quantities | Effective Total Operating Cost p.a (R) |
| 4                          | 3.5 kva   | 98635        | 13406              | 0.56                | 4886.6                | 33229.1             | 34812                                | 35877                                  | 3750              | 600                  | 49507565                               |
| 8                          | 7.5 kva   | 124108       | 14000              | 1.58                | 13819                 | 93969.7             | 43803                                | 45143                                  | 376               | 60.16                | 9211238                                |
| 10                         | 10 kva    | 191950       | 14371              | 2.59                | 22655                 | 154055              | 67747                                | 69819                                  | 66                | 10.56                | 2515873                                |
| 15                         | 15/3 kva  | 212847       | 15113              | 3.49                | 30558                 | 207795              | 75122                                | 77420                                  | 51                | 8.16                 | 2450684                                |
| 30                         | 30/3 kva  | 252069       | 17340              | 6.9                 | 60414                 | 410814              | 88966                                | 91687                                  | 42                | 6.72                 | 3493331                                |
| 60                         | 60/3 kva  | 322647       | 21794              | 15.79               | 138316                | 940547              | 113875                               | 117359                                 | 48                | 7.68                 | 8292094                                |
| 100                        | 100/3 kva | 394543       | 27732              | 19.48               | 170658                | 1160473             | 139251                               | 143510                                 | 24                | 3.84                 | 5113783                                |
| 175                        | 175/3 kva | 519228       | 38866              | 35.69               | 312616                | 2125790             | 183257                               | 188863                                 | 12                | 1.92                 | 4518756                                |
| 250                        | 250/3 kva | 630712       | 50000              | 54                  | 473040                | 3216672             | 222604                               | 229413                                 | 6                 | 0.96                 | 3356242                                |
|                            |           | <b>Total</b> | <b>212622</b>      |                     |                       |                     | <b>8343345</b>                       | <b>999091</b>                          |                   |                      | <b>Total</b> <b>88459566</b>           |

**Concept 2: Variable Speed  
Generator**

| Full Time Running Values |               |           |                    |                     |                       |                     |                                      |                                        | Quantities        |                      |                                        |
|--------------------------|---------------|-----------|--------------------|---------------------|-----------------------|---------------------|--------------------------------------|----------------------------------------|-------------------|----------------------|----------------------------------------|
|                          | Configuration | Unit Cost | M&R Unit Cost p.a. | Fuel Consump (l/hr) | Fuel Consump (l/p.a.) | Fuel Unit Cost p.a. | Major Overhaul Cost (every 8500 hrs) | Effective Major Overhaul Unit Cost p.a | Total Requirement | Effective Quantities | Effective Total Operating Cost p.a (R) |
| 3.5                      | 3.5 kva (FS)  | 98635     | 9878               | 0.39                | 3420.6                | 23260.4             | 49318                                | 28802                                  | 3750              | 600                  | 37163636                               |
| 7.5                      | 7.5/3 kva     | 204500    | 10823              | 1.1                 | 9673.4                | 65778.8             | 102250                               | 59714                                  | 418               | 66.88                | 9116766                                |
| 25                       | 25/3 kva      | 463000    | 13934              | 3.89                | 34067                 | 231653              | 231500                               | 135196                                 | 69                | 11.04                | 4203843                                |
| 80                       | 80/3 kva      | 730000    | 20984              | 12.62               | 110571                | 751880              | 365000                               | 213160                                 | 54                | 8.64                 | 8519249                                |
| 250                      | 250/3 kva     | 1407660   | 42038              | 37.8                | 331128                | 2251670             | 703830                               | 411037                                 | 21                | 3.36                 | 9087945                                |
|                          |               |           |                    |                     |                       |                     |                                      |                                        |                   | <b>Total</b>         | <b>68091439</b>                        |

**Notes**

Assume Major overhaul cost = 50% of unit production cost excluding dummy load cost

Effective quantity = total requirement \* 40% fleet utilisation \* 40% duty cycle = 16% **0.16**

Fuel consumption values are typical values obtained from glossys

Assume a fuel cost of R 6.80/liter **6.8**

|                                    |                                                      |          |
|------------------------------------|------------------------------------------------------|----------|
| <b>1.2 Power management</b>        |                                                      |          |
|                                    | Assume yearly operating cost = 5% of production cost |          |
|                                    | Total Production Cost ®                              | 11250000 |
|                                    | Total Operating Cost p.a. ®                          | 562500   |
|                                    |                                                      |          |
| <b>2 Power Reticulation System</b> |                                                      |          |
|                                    | Assume yearly operating cost = 5% of production cost |          |
|                                    | <b>Total Production Cost ®</b>                       | 13500000 |
|                                    | <b>Total Operating Cost p.a. ®</b>                   | 675000   |
|                                    |                                                      |          |
| <b>3 Transport System</b>          |                                                      |          |
|                                    | Assume yearly operating cost = 5% of production cost |          |
|                                    | <b>Concept 1: Fixed Speed Generator</b>              |          |
|                                    | <b>Total Production Cost ®</b>                       | 30495000 |
|                                    | <b>Total Operating Cost p.a. ®</b>                   | 1524750  |
|                                    |                                                      |          |
|                                    | Concept 2: Variable Speed Generator                  |          |
|                                    | <b>Total Production Cost ®</b>                       | 18765000 |
|                                    | <b>Total Operating Cost p.a. ®</b>                   | 938250   |

| <b>Fixed Speed Configurations</b>      | <b>250 kva</b> | <b>7.5 kva</b> |
|----------------------------------------|----------------|----------------|
| Maintenance cost p.a.                  | 39000          | 11000          |
| Preventative maintenance cost p.a.     | 10000          | 2500           |
| Repair (incl in warranty)              | 0              | 0              |
| Total p.a.                             | 49000          | 13500          |
| Rounding off cost p.a.                 | 50000          | 14000          |
| Above assumes 167 hr service intervals |                |                |