

A TRADE-OFF STUDY ON OUTSOURCE OR IN-HOUSE PAINTING PROCESS

by

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Executive Summary

MKDesigns is a Mechanical Engineering and Project Management firm. Initially three skid-mounted pump assemblies are being built for a copper mine, Konnoco Zambia Limited. Thirty nine skid-mounted pump assemblies are anticipated to be built in the future. The sandblasting and spray painting of parts and final assemblies are costly and time consuming. The quality thereof is also highly specified.

A trade-off study was conducted to make the best decision regarding the make-or-buy (In-house or Outsourcing) of the sandblasting and spray painting of the parts, because of the potential to significantly reduce design risk, engineering changes, cycle time and specifically production-, transportation- and mark-up costs.

The trade-off study was performed using the Analytic Hierarchy Process (AHP), a cost analysis and risk analysis. A consistency study was performed to ensure that the data used, analyzed and given in results are a trustworthy source for making decisions.

Quality cannot be compromised for any amount of cost savings or schedule adjustments. To ensure a quality product is supplied, whether outsourcing or in-house painting process is followed, a painting Quality Control Plan (QCP) was developed.

Although the data and methods used in this study may recommend a specific solution or conclusion, the student is in no way responsible for any losses or damages to anyone or their companies or any goods or materials affected by this study.

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List of Acronyms

AHP	Analytic Hierarchy Process
BM	Basic Measure
CDR	Critical Design Review
CMMI	Capability Maturity Model Integrated
COTS	Commercial Off The Shelf
DAR	Decision Analysis and Resolution
DFT	Dry Film Thickness
DM	Decision Maker
DoF	Degree of Fulfillment
EV	Expected Value
HSE	Health, Safety and Environment
ISO 9001	International Standard for Quality Management
IPT	Integrated Product Development Team
KPI	Key Performance Indicator
MAUT	Multi-Attribute Utility Technique
PAL	Process Asset Library
PC	Personal Computer
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
PQP	Project Quality Plan
ProACT	Problem, Objectives, Alternatives, Consequences and Tradeoffs
QA	Quality Assurance
QCP	Quality Control Plan
QFD	Quality Function Deployment
QMS	Quality Management System
RA	Risk Assessment
SMART	Specific, Measurable, Actionable, Realistic, Time bound
SRR	System Requirements Review

Chapter 1

Background

MKDesigns is a Mechanical Engineering and Project Management firm situated in Pretoria West. The engineers appointed by the firm are registered with the Engineering Council of South Africa. No Industrial Engineers are appointed by the firm, although major projects with large project teams are constantly being taken on.

A new project has been undertaken to initially build three skid-mounted pump assemblies for Konnoco Zambia Limited, a copper mine located in Chillilabombwe in the Northern Copperbelt Province of Zambia. Ultimately, thirty nine skid-mounted pump assemblies may be built in future. The success of the project for building the first three are thus of vital importance.

The mine, partially owned by South Africa's - African Rainbow Minerals (ARM) and Brazilian mining specialist - Vale, is currently being developed. The skids consist of a steel frame on which a pump, a motor, a steel sump, pipes and accessories are mounted. MKDesigns are to manufacture the complete assembly. Safe manufacture, assembly and transportation of the final products is the top priority of the project.



Figure 1: A skid built by MKDesigns for the Konnoco Zambia Limited.

On the mine when holes are drilled for blasting, water is required to keep the drill cool. This water then needs to be extracted. This pump unit can remove the water and can also be moved around as the mine develops. The water, after being pumped into the sump, can also be transferred to other required surfaces.

Chapter 2

Introduction

Several mechanical and electrical engineers are part of this project, as well as welders, assemblers and general workshop workers. MKDesigns has been operating in such a way that the engineer working on the project was responsible for both the project management and quality assurance tasks.

The sandblasting and spray painting of the parts and final assembly according to the standard specification for corrosion protection of structural steelwork, platework and mechanical equipment makes up a very large part of the budget and is a critical decision making issue. This blasting and painting process should be analyzed by using applicable Project Management and Industrial Engineering tools.

Project Aim

The aim of the project is to use standard Industrial Engineering methods, tools and techniques for MKDesigns and to use them where applicable to this specific project. These methods should enable MKDesigns to perform objective decision making, trade-off studies and project management. The methods should however make room for some subjective insight.

The methods should be applied as part of the project's life cycle, so that problems and difficult decisions can be made without jeopardizing the success of the project.. Applicable Project Management and Industrial Engineering tools should form part of their business strategy and project plans. To manage the quality assurance will prove to be a major part of the project, because of the many standards to be met in each project.

The sandblasting and spray painting of the parts and final assembly takes up a large part of the project budget and schedule. The quality thereof is also highly specified.

The Industrial Engineering methods, tools and techniques will be applied to execute a trade off study to make the best decision regarding the make-or-buy of the sandblasting and spray painting of the parts. The aim of the project is to recommend a solution out of the identified alternatives and supply the involved costs and risks.

Project Scope

The sandblasting and spray painting of the parts and final assembly is a costly part of the manufacturing process. It makes up a very large part of the project budget. The options to perform the process in-house or outsource is a critical decision making issue and will be analyzed by considering costs, risks, quality, labour and the schedule.

A thorough trade-off study will be completed to recommend either the outsourcing or to build a paint shop which meets all the standards and perform the paint jobs in-house. A cost and risk analysis will be performed to ensure the lowest cost, so as to stay within the budget, but also to remain on schedule and minimize the risk of non-compliance to the set standards.

- a) The cost analysis includes a break-even graph which shows after what amount of skids the in-house production's initial investments will break even.
- b) The risk analysis identifies the possible risks, consequences and measures to be taken to prevent or at least minimize the probability of occurrence.
- c) Some of the quality assurance standards regarding the Corrosion Protection, which includes the sand blasting and spray painting of all material, are to ensure the correct:
 - ✓ Material traceability
 - ✓ Ambient conditions
 - ✓ Surface preparation
 - ✓ Application of primer coat within 'window' time period
 - ✓ Mixing
 - ✓ Over-coating times
 - ✓ Film thickness
 - ✓ Witness and secure points

The Quality Assurance Standards are discussed as the second part of this project and the results will be presented in a user friendly manner.

ARM has strict minimum requirements in the form of Quality Assurance Procedures to which all suppliers and Project Management Organisations (PMO's) must comply. The following is the main quality assurance procedures to be executed and requirements to be adhered to by MKDesigns:

- ✓ Quality Management System
- ✓ Project Quality Plan (PQP)
- ✓ Quality Control Plans (QCPs)
- ✓ Document Requirements
- ✓ Resource Management
- ✓ Measurement
- ✓ Analysis
- ✓ Improvement and Risk Analysis.

The QCP applicable to this project is the Painting QCP and is discussed in Chapter 5.

Chapter 3

Literature Study

Decision Making

It is necessary for humans in their daily lives to make decisions. Management need to make decisions which will greatly affect the success of projects. To perform these decisions while staying objective, instead of making subjective decisions which may not include the demands of all stakeholders, is difficult.

The importance of performing and documenting decision making and trade-off studies correctly cannot be over-emphasized. In the Mid-Atlantic Regional Conference held by International Council on Systems Engineering (INCOSE) on November 2-4 of 2004, the topic of "*Standard Approach to Trade Studies: A Process Improvement Model that Enables Systems Engineers to Provide Information to the Project Manager by Going Beyond the Summary Matrix*" was discussed. During the discussion of the standard approach to trade-off studies, the following detailed aspects were included:

- ✓ "The steps for performing and documenting a trade study (trade-off study),
- ✓ developing products for the Decision-Making Authority (DMA),
- ✓ guidelines in tailoring the study to meet the needs of the program." (Felix 2004)

Trade-off studies are widely used to make decisions, but a systematic approach should be taken to ensure the objectiveness of the study as far as possible.

Decisions are typically categorized into:

- ✓ Mutually exclusive decisions like the allocation of resources to competing projects,
- ✓ The generation of schedules and plans,
- ✓ Negotiating with other parties to reach an agreement or finally
- ✓ The choosing amongst alternatives.

When choosing among some alternatives, the analysis can be performed in a sequential or simultaneous matter. This simultaneous view of the alternatives and criteria supports the decision making model called the trade-off study.

A simple decision making tool can be used to keep an organized and objective trade-off study on track. The ProACT model is an example of such a basic decision making model available.

PrOACT

A basic decision making model called **PrOACT** is also an acronym of the five core elements of the decision model: **P**roblem, **O**bjectives, **A**lternatives, **C**onsequences and **T**radeoffs. (Hammond, Keeney and Raiffa 2002) The model also considers three more elements: Uncertainty, Risk Tolerance and Linked Decisions. These eight elements are used in a systematic approach to help make better decisions and will be considered and incorporated in the trade-off study.

Capability Maturity Model® Integration (CMMI®) and Decision Analysis and Resolution (DAR)

Trade-off studies is a technique which is categorized in the Decision Analysis and Resolution (DAR) process area. This process area is described in CMMI® (Capability Maturity Model® Integration) models, which is a compilation of the best practices from diverse engineering companies. DAR is one of the twenty two process areas described by the CMMI® Model Foundation. (Carnegie Mellon University 2011)

The purpose of Decision Analysis and Resolution (DAR) is to analyze decisions using a formal structured evaluation process which evaluates the identified alternatives against the established criteria. The DAR process consists of the following basic steps:

- a) Establishing the criteria for evaluating alternatives
- b) Identifying alternative solutions
- c) Selecting methods for evaluating alternatives
- d) Evaluating alternative solutions using established criteria and methods
- e) Selecting recommended solutions from alternatives based on evaluation criteria

This structure provides for objective rather than subjective decision making and ensures all stakeholders are being considered. The DAR process is usually for technical issues, but can also be applied in non-technical issues. Usually the technical issues involve trade-off studies for equipment and software. The development of potential service capabilities is also compared using the DAR process area.

Trade-off Study

DAR is a common process which a user can access, tailor to his needs and apply during the project life cycle to any critical decision making problem. If the decision has been made that formal evaluation is needed, a trade-off study can be performed.

A trade-off study is helpful because according to Professor Terry Bahill in his Systems Engineering Process course, from the University of Arizona, "*emotions, cognitive illusions, biases, fallacies, fear of regret and use of heuristics make humans far from ideal decision makers.*" Performing tradeoff studies will aid decision makers to make rational decisions. He also describes six methods of performing trade-off studies and the rules to which they should be applied in his "Mathematical Summary of Multi-criterion Decision-Making Methods" (Szidarovszky and Bahill 1999)

The trade-off study method described by DAR requires evaluation criteria to be established, alternative solutions to be identified, evaluation methods to be selected and the alternatives evaluated. The preferred solution can then be selected. The complete trade-off process is shown in Figure 2 and further discussed in detail. Feedback loops are not shown on the diagram, but is

however part of the process. The process is recursive and is usually not completed after one cycle only.

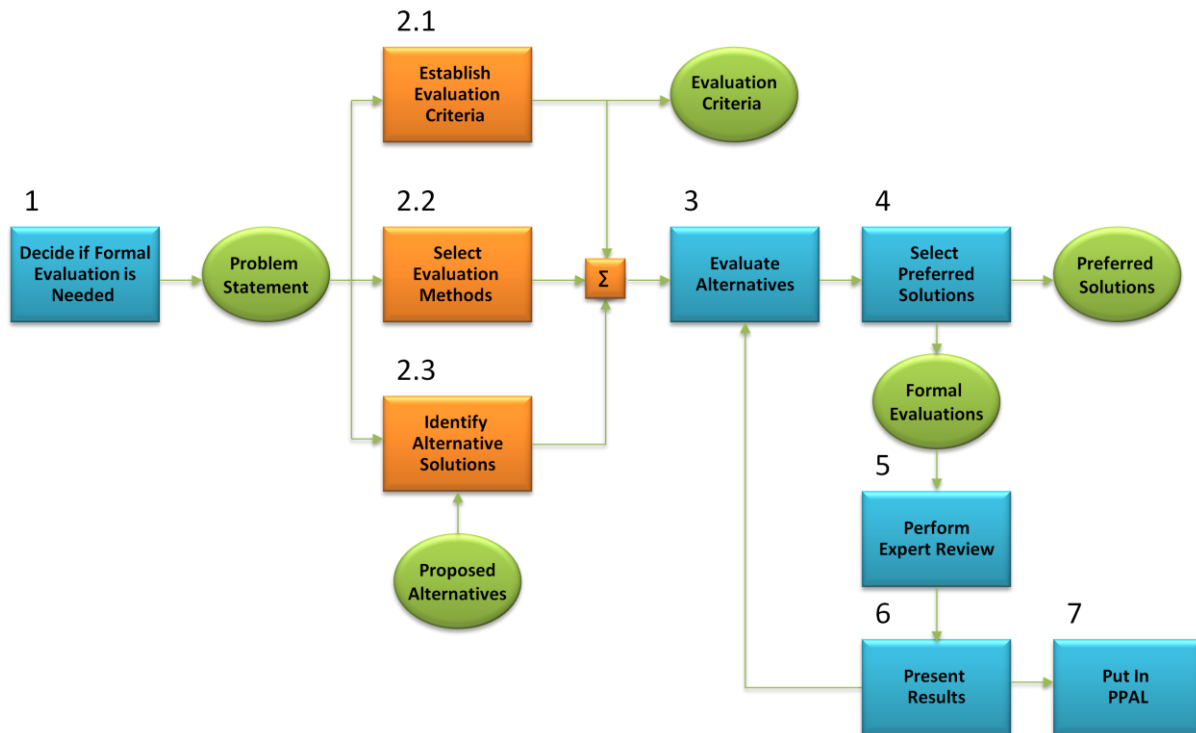


Figure 2: The Trade-Off Study Process according to the CMMI's DAR process (Bahill 2011)

In Figure 2:

- ✓ the Blue blocks represent a process, and is described in the numbered seven steps below.
- ✓ the Orange blocks are sub-processes which will be used together to perform a process and
- ✓ the Green circles represent data in the form of lists or documents

The seven steps of the Trade-off study process shown in Figure 2 is discussed below.

Step 1: Decide if Formal Evaluation is Needed



The decision of the necessity of formal evaluation depends on the decisions impact on risks, costs, schedules and the ability to achieve project objectives. The potential to significantly reduce design risk, engineering changes, cycle time and especially production costs will support the need for the study. If the resources to perform the study is acquired, the trade-off study can begin.



The problem statement is important to ensure an aim and scope for the problem is identified. The context in which the problem is found is also an important aspect to consider.

Step 2 of the trade-off study process is not done sequentially, but is rather performed in parallel and considered simultaneously. The sub-process first described is the establishment of evaluation criteria. The second discussed sub-process is the evaluation method selection and finally the third is the feasible alternative solutions.

Step 2.1: Establish Evaluation Criteria

2.1. Establish Evaluation Criteria

The generic evaluation criteria of the company, if available, should contain the following:

- ✓ Criteria name
- ✓ Description
- ✓ Weight of importance (priority)
- ✓ Basic measure
- ✓ Units
- ✓ Measurement method
- ✓ Input (with expected values or the domain)
- ✓ Output
- ✓ Scoring function (type and parameters)

These generic criteria of the company should be well documented and accessible to be used in studies. The generic evaluation criteria is displayed in figure 2 as the green circle:



The criteria applicable to the trade-off should be selected and modified to be used in the evaluation of alternatives. Evaluating alternatives is very expensive, thus if alternatives can be eliminated early in the trade-off process, it should be done. Selecting important criteria, often referred to as Key Performance Parameters, should eliminate some alternatives.

Step 2.2: Select Evaluation Methods

2.2. Select Evaluation Methods

A few available evaluation methods for alternatives, according to Bahill, include:

"Multi-Attribute Utility Technique (MAUT), Ideal Point, Search Beam, Fuzzy Databases, Decision Trees, Expected Utility, Pair-wise Comparisons, Analytic Hierarchy Process (AHP), Financial Analysis, Simulation, Monte Carlo, Linear Programming, Design of Experiments, Group Techniques, Quality Function Deployment (QFD), radar charts, forming a consensus and Tradeoff Studies." (Bahill 2011) It is necessary to ensure the correct evaluation method is followed. A too complex method may be too costly and difficult to apply to the problem. A simpler method, completed in a more thorough manner may provide a better analysis.

The following three methods cover all the important aspects required to make the best decision. These methods are applied during the blasting and painting trade-off study.

Analytic Hierarchy Process (AHP)

The AHP process is well-known and a simple yet comprehensive way to analyze evaluation criteria and alternatives. The AHP is taught as a decision making tool in engineering courses in top universities, not only in South Africa, but also in America like University of Arizona.

For this multiple criterion decision making problem the Analytic Hierarchy Process (AHP) method will be used. Both Prof. P.S. Kruger (University of Pretoria) and Prof. A.T. Bahill (University of Arizona) have referenced Thomas L. Saaty in his book *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*.

The usual decision situations to which the AHP may be applied may include planning, allocating resources, setting priorities, and choices among alternatives. Pair-wise Comparisons will also be used for evaluating the alternatives. According to Prof P.S. Kruger: "Pair-wise comparison generally refers to any process of comparing entities in pairs to judge which of each pair is preferred, or has a greater amount of some quantitative property." This is applicable to the current trade-off study. Expert Choice and ERGO computer software is widely used practical applications of AHP decision making computer software.

The consistency study, as performed by Wayne L Winston in his book: *Operations Research: Vol 2 - Introduction to Probability Models* (Winston 2004) will be performed to ensure the data used, analyzed and given in results are a trustworthy source for basing decisions on.

Cost Analysis


A break-even cost analysis shows how fast the initial investment of equipment, in the in-house painting alternative, will break even with the cost of outsourcing per unit pump assembly. This method provides a visual conclusion and is key in the decision making process.

The cost analysis includes calculation of the various available blasting equipment for the in-house painting process, and will be compared to the outsourcing of the painting process separately.

Risk Analysis

Although the cheaper alternative may look promising, all the involved risks in each alternative should be thoroughly researched and documented. The risk analysis may prove to be useful in removing a selected alternative, due to the involved risk's high probability or high level of consequences for the project's success.

Step 2.3: Identify Alternative Solutions



2.3. Identify Alternative Solutions

To Identify alternative solutions, a creative brainstorming session can be held. Excellent tools for brainstorming is described by Ritter and Brassard (1998) in their book *The Creativity Tools Memory Jogger*. Brainstorming is one of 14 tools described in this practical guide to innovative thinking. Restating the problem, generating new ideas, transferring knowledge from other areas, and

identifying all possible solutions to the problem is also described. This book explains how to establish a creative environment, and how to integrate the tools in your organizational improvement activities. (Ritter and Brassard 1998)

Less common ideas should also be considered to test the evaluation criteria. All the alternatives should abide by the mandatory requirements and Key Performance Parameters. The source of the evaluation data and the method for evaluating the data should be selected.

In this trade-off study a few alternatives are researched and considered as a possible solution. The proposed alternatives are represented by the following green circle in figure 2:



A discussion of the proposed alternatives follow.

Outsourcing the Painting Process

A good alternative solution to consider for the problem is outsourcing. Outsourcing is the transmission of the execution of a specific function in the company, which is being performed in-house, to another company. The output of that function is then reintegrated into the process. (Jacobs, Chase and Aluilano 2009) The third-party organisation will handle and manage reverse flows when personnel, infrastructure, experience and capital is insufficient to implement the activity. (Langley, et al. 2008) To decide whether or not to outsource an activity, several factors need to be considered, such as the core skills of employees, project length, specialization, costs and employee flexibility. (Recca 2008) The reasons for outsourcing may be organisational, improvement-, financially-, revenue-, cost- or employee-driven. To name a few reasons or benefits in outsourcing, the following applies:

- ✓ Enhanced effectiveness and flexibility, because the company is more focussed on their best practices
- ✓ Improve control and risk management
- ✓ Acquire creative innovative ideas
- ✓ Reduce investments in assets and apply resources elsewhere
- ✓ Commercially exploit existing skills and resources
- ✓ Transform fixed costs into variable costs (Greaver 1999)

Core competencies of the company should be kept in-house under management supervision whereas all other activities can potentially be outsourced. To evaluate an activity to determine whether it should be outsourced, it is best to consider required coordination, strategic control and intellectual property. Required coordination is the level of involvement or integration of the activity with the overall process. Uncertainty in the activity with recursive information exchanges should not be outsourced, although standardized activities can easily be outsourced to specialists.

The strategic control is basically the loss incurred if the partnership should be ruined. The loss of intellectual property should also be considered because the amount of losses to intellectual property if the partnership fails could have a major effect on the company. (Hayes, et al. 2005) It is better to keep control of the activities providing a competitive advantage and outsourcing the rest.

A lot of research indicates that the modern trend is to outsource, but in each activity the application of this trend needs thorough analysis. Performing activities through in-house manufacturing, means eliminating transportation and mark-up costs to outsourcing companies and gives more control over schedules and quality of the activity. The risk of performing activities in-house is however only the company's and is not shared with outsourced companies.

In terms of cost, the Transport -, Mark-up -, and Insurance costs are expected to be higher for this alternative. There is also a risk of loss of intellectual property present due to the designs being handled by external parties. The schedule may need to allow for transportation times (to and from the outsourcing company), buffer times (in case of the outsourcing company running late with the order) and time for the extra paperwork to be completed and approved. The outsourcing company will need to provide quality documents and compliance to quality requirements will need to be guaranteed. More about this in later chapters. Quotes have been requested from the following companies: Bambanani and Uniquote. Both provides a feasible solution in case the outsourcing option is decided on.

In-House Painting Process

A lot of research with regard to building an on-site sandblasting and spray paint shop to perform painting jobs in-house have been conducted. The required space for the activity needs to be located in an easily accessible part of the property. As space is very limited on the property, with more than six large projects in process, this requires very careful consideration. It would be pointless for this study to recommend In-House Sandblasting and Spray Painting if it is not a feasible solution to implement.

Facilities Planning for MKDesigns should thus be considered when making recommendations for implementation.

Process flow of storing materials before sandblasting and spray painting, area for performing sandblasting and spray painting, and temporary storage of materials while drying is of great practical importance. Finished parts ready for final assembly should be easily accessible.

The basic needed components is a clean painting room (like a container), ventilation system (like a water filtered system) to ensure compliance to the Occupational Health and Safety Act (OHSA), the correct Personal Protective Equipment (PPE) for multiple and single use, a sufficiently strong compressor (for both the sandblasting and spray painting), sand and paint barrels (for spraying and storage), spray nozzles and many more equipment.

The life time, risks, health impacts and costs of these equipment is being gathered to ensure this alternative is considered considering all its impacts.

The Health and Safety of building such a facility to accommodate the activity needs to be carefully considered.

Training of the employees who will execute the activity needs to be done before any in-house manufacturing is commenced. The regular updates of these skills should be monitored and planned.

After all these considerations have been made, a quote from the company Storm Machinery was requested.

The close monitoring of conformance to the strict quality control requirements will be under direct supervision of the project managers if the activities are performed in-house. However the risk will be carried by MKDesigns only in this case. When outsourcing, the risk is carried by the outsourcing company.

In-House Offsite Painting Process

Mostly the same considerations are made as for In-House, except more risks are involved. The extra risks are due to management not being able to do quality check as often as for In-house painting. Theft of material and equipment is also a big problem, especially in the area where the company is situated. Transport of material to and from the original warehouse adds another head ache to management due to higher risk of damage when materials are handled more.

Off shoring Painting Process

The off shoring alternative will require MKDesigns to relocate their sandblasting and spray painting activity to another location, where the costs will be lower. More risks are involved as management will not be able to check quality at any point in time. If they are in the country in which off shoring is taking place, a costly transportation of material is also added. As there are limited resources of labour, and MKDesigns is a small local company with offices in South Africa only, this alternative is not worth the cost or effort of considering to implement.

Step 3 of the trade-off process includes all the evaluation and comparison of the alternatives, using the evaluation methods chosen by referring to the set evaluation criteria.

Step 3: Evaluate Solutions



3. Evaluate Alternatives


The evaluation of solutions comprise the third step in the trade-off process. The three sub-processes of step two is used in performing the evaluation. The selected evaluation criteria is used to evaluate the alternative solutions by applying the suitable evaluation methods.

a)The Analytic Hierarchy Process (AHP) is the first evaluation method used. This method compares the criteria and alternatives to establish which is a more preferred solution.

b) The Cost Analysis identifies as far possible all the incurred costs of each alternative, and how it may benefit the company in future.

c)The Risk Analysis describes the possible risks, their chances of occurring, implications in case of occurrence and effects on the project.

Step 4: Select Preferred Solutions



4. Select Preferred Solutions

Selecting the alternatives are sometimes an iterative process of selecting alternatives, formally evaluating them, getting an expert review and presenting the results. Experimenting, simulating and

prototyping sometimes form part of the conclusions of selections. Selecting alternatives requires the combining of results from the evaluation process by the many combining tools available. To validate the results a consistency analysis may support the recommendations.

The selected alternative and the supporting documents for the decision is represented by the Selected Alternative green circle in Figure 2 as follows:



Consulting previous studies and the proper documentation of the current study takes place during the Formal Evaluation. The subject is further discussed in Step 7. The formal evaluations of the solution is represented by the green circle in figure 2:

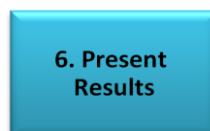


Step 5: Perform Expert Review



Following the formal evaluation, the expert review will take place. The review covers all aspects of the study and may be performed by different specialists. The technical review of a product reviews the product of an Integrated Product Team (IPT) and is performed by specialists in the field.

Step 6: Present the Results



The presentation of the results includes the preferred solution or may recommend a broader investigation, re-evaluation of the problem or negotiations with the stakeholders. The validation in the form of the sensitivity analysis should form part of this presentation.

Results should be presented in a thorough but simple format, as not all stakeholders possess the technical understanding and insight of the project. A visual and descriptive final presentation is supplied.

Step 7: Update PPAL**7. Put In
PPAL**

The formal evaluations should be included in the Process Asset Library (PAL) or the Project Process Asset Library (PPAL) of the organization. Bahill says "*Evaluation data for tradeoff studies come from approximations, analysis, models, simulations, experiments and prototypes. Each time better data is obtained the PAL should be updated.*" The next trade-off study may benefit greatly from the previous trade-off studies conducted. To have the previous studies in the PAL will increase efficiency of future studies.

Conclusion

The trade-off study is an applicable process which provides structure to the decision making process. A proper trade-off study is more than effective enough to provide the required solution.

A very famous trade-off study is the San Diego County Regional Airport Tradeoff Study that cost \$17 million. In Chapter 4 the trade-off study is applied on the painting process.

Chapter 4

Trade-Off Study

The Trade-off study process is applied to the painting problem according to Figure 2. The process is followed to select the preferred solution and detailed descriptions of each step is provided.

The first step of the trade-off study process is to identify the need for formal evaluation.

1. Need for Formal Evaluation

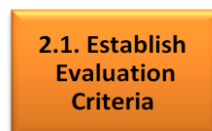


The need for formal evaluation depended of the impact on risks, costs, schedules and the ability to achieve project objectives. The decision of outsourcing or in-house painting process is suitable for a trade-off study, because of the potential to significantly reduce design risk, engineering changes, cycle time and especially production, transportation and markup costs. The complexity and trade-offs that need to be made needs proper investigation and a formal evaluation. The cost of the thorough study is worth knowing the preferred solution to the problem. The problem description and documentation on the context of the problem is kept together in the Problem Statement folder.



The second step involves the evaluation criteria to be established, evaluation methods to be selected and alternative solutions to be identified. These three parts of step 2 will be done in parallel.

2.1 Evaluation Criteria



The main basic evaluation criteria for the alternatives are cost, risk, schedule and quality. Many more criteria exist such as feasibility in term of practicality, time to implement, time and effort to train employees, further investigations etc. The criteria chosen for the problem of the painting process is defined according to the trade-off study process requirements described previously.

All of the criteria are chosen to be **SMART**.

Specific

A specific description of the criteria is necessary to have a consistent study of all the alternatives. If the criteria is adapted for each alternative, the study will not give consistent results.

Measurable

The criteria should each be measurable in a certain quantifiable manner. The comparison of alternatives is easier and more consistent this way.

Actionable

To choose criteria which are merely a subjective opinion will complicate the study while making it less trustworthy. If the criteria can be tested, repeated, tried-out or simulated, the comparison of alternatives is more consistent.

Realistic

A realistic criteria, which is applicable to the painting problem, is required. A complicated or too analytic criteria will move away from reality and more towards a complex comparison of alternatives.

Time bound

The criteria is measured at a certain time in specific conditions. The alternatives will be compared at a certain time with reference to the criteria and the applicable influences at that time will be considered. An all-time solution will not be possible as technology and standards develop quickly.

The criteria is chosen to suit the most important strategic focus points of the company. A graph shows the relative importance of these focus points and a discussion of each of the seven criteria follows.

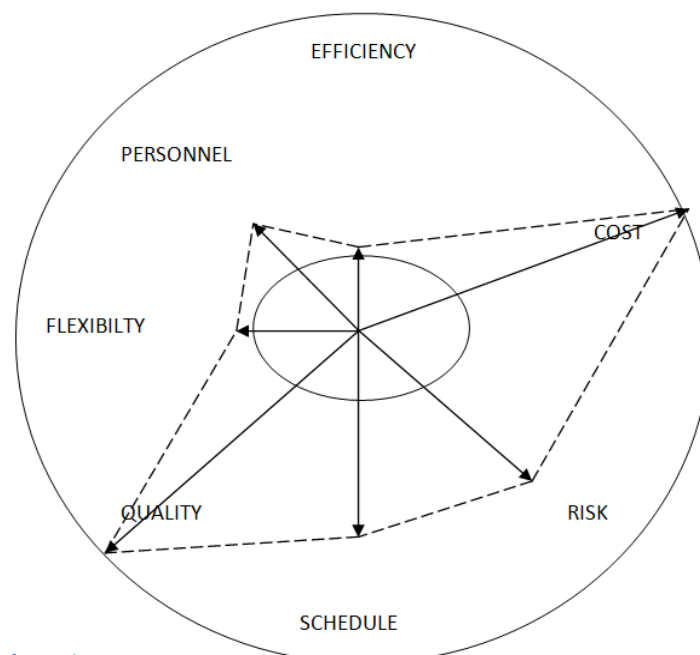



Figure 3: Criteria Relative Importance

A green oval icon with a white border and a slight shadow, containing the text "Evaluation Criteria" in black.

The set of evaluation criteria specified for the painting process is discussed below.

Criteria 1: Cost

The company's focus is to make profit. Cutting unnecessary costs are very important to the owner of the company. It is crucial to select cost as a criteria for the painting problem. A separate cost analysis is done, additionally to making cost a criteria for the AHP, due to the importance of the cost criteria.

The cost of acquiring assets are considered in the painting problem. A higher initial cost will be present when buying equipment for the In-House painting process, but a transport vehicle in the case of Outsourcing is also expensive. To outsource the transport to the outsourcing painter will also cost extra. The labour costs are also considered. When Outsourcing any process, a certain part of the total cost will be for the mark-up. Insurance costs are included.

Research into the specific requirements for the alternatives and its costs were extensively done. Certain predictions and expert opinions supplied enough information to consider and compare the alternatives. Through different quotations and visits to outsourcing companies a good cost comparison was possible.

Criteria 2: Risk

The possibility of project failure grabs any employee's attention. There are great amounts of money, not to mention a company's reputation, at stake. The involved risks range from great to insignificant but all risks should be identified and considered. Risk management is easier in certain alternatives. The criteria of risks are thus justified.

A short additional risk assessment is also completed. The probability and possible consequence of the risk is discussed.

A few smaller risks in the various alternatives are:

- ✓ Loss of Intellectual Property - due to outsourcing companies handling sensitive information and designs.
- ✓ Damage to material - through handling, storage, transport
- ✓ non-compliance to quality standards
- ✓ Exceeding the budget
- ✓ Maintaining and Adjusting the Schedule
- ✓ Risk Probability measured in fractions), Consequence of risk occurring.

Guarantees can supply some form of protection against serious consequences.

Criteria 3: Schedule

The schedule should be adjustable and flexible. The various alternatives each support a different level of flexibility and the schedule is thus a worthy criteria to measure alternatives against.

On-time delivery, time lost due to transportation or transfer and other delays are considered in the schedule criteria.

The schedule is measured in duration of time, usually weeks but sometimes days, depending on the total project length.

Forecasting and expert opinion are used to gather information for each alternative.

Criteria 4: Quality

To ensure all parts and the final assembly conforms to the strict quality control requirements, a Quality Control Plan (QCP) for each aspect of the project is set up and approved. The measurement method is described and should be correctly followed and documented. The proof of measurements is an important backup in case anything does go wrong later. The quality management is easier to apply for some alternatives. In certain alternatives the control of quality is mostly out of the hands of the company. Quality is a justified criteria to compare alternatives with.

Quality conformance during Simulation, Prototype and Testing provides good information to forecast outcomes in terms of quality.

ARM provides quality requirements and standards to which all painting processes should comply. Whichever alternative is ultimately chosen, the quality requirements must still be met.

Criteria 5: Flexibility

The mine is still in its development stage. This leaves most facts subject to change. The painting process may change completely. Different standards and requirements are most definitely possible in the near future. The alternative chosen should be flexible and adaptable to accommodate the changes. A worthy and important criteria to measure alternatives by.

Criteria 6: Personnel


The required resources like labour will be affected by the instalment of an in-house process. The personnel will require training and will have to perform new tasks. Most workers resist change at first. The approach taken to implement an alternative, may it be in-house, in-house off site or another, needs to be considerate of personnel needs.

The higher work load and added health and safety risks need to be discussed and agreed upon.

Criteria 7: Efficiency

The painting process needs to be efficient and without regular interruptions. When a part is to be painted and finished, the effectiveness of the system is very important. Good maintenance and a systematic approach will create an efficient painting process. Waste should be kept to a minimum to limit the environmental impact.

2.2 Evaluation Methods



2.2. Select Evaluation Methods

The many evaluation methods needed to be traded off themselves to decide which is more appropriate. Referring to

Analytic Hierarchy Process AHP

The AHP uses any amount of evaluation criteria, from two and upwards, to evaluate any amount of more than two alternatives. The evaluation criteria is firstly compared to each other to determine each pair's importance relative to the other. A pair-wise comparison matrix is drawn up from this step. Seven criteria will therefore use a 7x7 matrix. Each column's values are added together.

An Intermediate Matrix is then calculated by dividing each value in the pair-wise comparison matrix by the sum of that value's column. The average of each row in the Intermediate Matrix is then calculated.

The averages of the rows in the Intermediate Matrix gives the weight of each of the evaluation criteria. The sum of these weights must be one.

The alternative solutions are then compared with relation to each of the seven criteria. Thus, four alternatives will have a 4x4 matrix for each of the seven criteria. The pair-wise comparison matrix, intermediate matrix and average of the Intermediate Matrix's rows are calculated as for the criteria.

The average of the alternative from the Intermediate Matrix for a specific criteria is then multiplied by the weight of the criteria, calculated previously.

The final answer for each alternative is the sum of these multiplications.

Consistency Indexes are then calculated to ensure a consistent decision maker. This validates the AHP process and final answers. The specifics about the calculations of the Consistency Indexes are explained later in chapter 4.

Cost Analysis

Due to the high importance of cost in the decision making process, a separate cost analysis is performed. Gathering the actual costs of implementing an in-house painting process proved to be the largest part of the cost analysis.

Identifying the correct equipment for the painting process required some expert advice. Several quotes were requested for various equipment. Due to the sensitivity of the information, the original


quotes are not included in this document. A summary of the costs used in the calculations are however attached.

All costs are truthful at the time of going to printers. Costs are subject to change without prior notice.

Risk Analysis

Identifying the risks involved before an alternative is finally chosen is important. Risk is also an important criteria in the decision making process. The risk is defined, its probability of occurring is discussed together with its possible consequences and a remedy is mentioned. The formal evaluation and expert review provide more opportunities to identify probably risks for the project.

2.3 Alternative Solutions



2.3. Identify Alternative Solutions

Not only should plenty solutions to the problem be considered, but the feasibility of alternatives is of great importance. The practical implementation of the alternative is part of this criteria. Four options that are available in this study are:

Outsourcing the activity to another company

Performing the activity in-house

Performing the activity in-house off-site

Off shoring the activity to another location.



Proposed Alternatives

Careful consideration is given to each alternative and each is further described in the literature study in chapter 3 in terms of definition, advantages, feasibility and ability to implement. This information regarding the alternatives considered and those now considered are documented and represented by the Proposed Alternatives green circle in Figure 2.

Feasibility Analysis

An alternative can only be considered if it poses a feasible solution to the problem. The alternative is required to fit in with the company's strategies. The possibly implication to the company's other projects are also considered.

3. Evaluate Alternatives

3. Evaluate Alternatives

The evaluation of the identified feasible alternatives using the evaluation criteria and methods is performed in this section. The three methods namely AHP, cost- and risk analysis are each applied to the painting problem and the results are presented.

Analytic Hierarchy Process AHP

In using the AHP process, the criteria is awarded a numerical value when compared pair-wise. The following scale was used:

	Numerical Value*
Equally Important	1
Moderately more Important	3
Strongly more Important	5
Very Strongly more Important	7
Strongly more Important	9
<i>Intermediate values</i>	<i>2, 4, 6, 8</i>

Figure 4: Numerical Scale

* if negative value, replace "more" with "less"

The Pair-wise comparisons of the evaluation criteria yield the following results:

Table 1: Pair-wise Comparisons of Criteria

	Cost	Risk	Schedule	Quality	Flexibility	Personnel	Efficiency
Cost	1	3	1/3	1	7	5	7
Risk	1/3	1	1	1/2	5	3	5
Schedule	3	1	1	1/3	3	3	3
Quality	1	2	3	1	8	6	7
Flexibility	1/7	1/5	1/3	1/8	1	1/4	1
Personnel	1/5	1/3	1/3	1/6	4	1	5
Efficiency	1/7	1/5	1/3	1/7	1	1/5	1
Total	5 5/6	7 3/4	6 1/3	3 1/4	29	18 4/9	29

The Intermediate matrix in Table 2, wherein the results of the division of the cell by the sum at the end of that cell's column in Table 1, is shown on the next page.

Table 2: Intermediate Matrix

	Cost	Risk	Schedule	Quality	Flexibility	Personnel	Efficiency	Average
Cost	0.17	0.39	0.05	0.31	0.24	0.27	0.24	0.24
Risk	0.06	0.13	0.16	0.15	0.17	0.16	0.17	0.14
Schedule	0.52	0.13	0.16	0.10	0.10	0.16	0.10	0.18
Quality	0.17	0.26	0.47	0.31	0.28	0.33	0.24	0.29
Flexibility	0.02	0.03	0.05	0.04	0.03	0.01	0.03	0.03
Personnel	0.03	0.04	0.05	0.05	0.14	0.05	0.17	0.08
Efficiency	0.02	0.03	0.05	0.04	0.03	0.01	0.03	0.03

The average of each row in Table 2 represents the weight per criteria, also referred to as the Importance of the criteria. This is tabulated in Table 3 and ranked according to importance.

Table 3: Weight per Criteria

Quality	0.29
Cost	0.24
Schedule	0.18
Risk	0.14
Personnel	0.08
Efficiency	0.03
Flexibility	0.03

The selected alternatives need to be compared to each other while considering only one criteria at a time. The four alternatives compared to **each** of the seven criterion yield the following results:

Table 4: Alternatives compared in terms of Quality

Quality Management	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/3	1/3	2
In-house	3	1	5	7
In-house off-site	3	1/5	1	4
Off shoring	1/2	1/7	1/4	1
Total	7.50	1.68	6.58	14.00

In terms of Quality, it seems as if In-house production will have the easiest and best Quality management.

Table 5: Alternatives compared in terms of Cost

Cost Management	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/4	1/3	3
In-house	4	1	5	7
In-house off-site	3	1/5	1	3
Off shoring	1/3	1/7	1/3	1
Total	8.33	1.59	6.67	14.00

When considering the cost of the alternatives, the in-house production will have the best and most controllable cost management.

Table 6: Alternatives compared in terms of Schedule

Schedule Management	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/4	1/3	1/2
In-house	4	1	4	6
In-house off-site	3	1/4	1	3
Off shoring	2	1/6	1/3	1
Total	10.00	1.67	5.67	10.50

The schedule is most adaptive and manageable in the in-house alternative, due to the possibility of moving certain materials forward in the queue if it is needed sooner. This may be costly or impossible with outsourcing companies.

Table 7: Alternatives compared in terms of Risk

Risk Management	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/7	1/5	1/3
In-house	7	1	3	5
In-house off-site	5	1/3	1	2
Off shoring	3	1/5	1/2	1
Total	16.00	1.68	4.70	8.33

The risk management proves to be easier to manage in the In-house alternative.

Table 8: Alternatives compared in terms of Personnel

Personnel/Labour	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	5	7	9
In-house	1/5	1	3	7
In-house off-site	1/7	1/3	1	3
Off shoring	1/9	1/7	1/3	1
Total	1.45	6.48	11.33	20.00

Due to no costs and zero responsibility towards the managing of personnel in the outsourcing alternative, the best score is achieved by the outsourcing of the painting process.

Table 9: Alternatives compared in terms of Efficiency

Efficiency	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/3	3	5
In-house	3	1	5	7
In-house off-site	1/3	1/5	1	3
Off shoring	1/5	1/7	1/3	1
Total	4.53	1.68	9.33	16.00

Efficiency is more manageable in In-house painting. A proper flow of materials into and out of the painting process will make the overall process of production much more efficient. No transportation of materials also gives MKDesigns 2 extra days per painting batch, which they wouldn't have had available in any of the other alternatives.

Table 10: Alternatives compared in terms of Flexibility

Flexibility	Outsourcing	In-house	In-house off-site	Off shoring
Outsourcing	1	1/7	1/5	1/3
In-house	7	1	3	5
In-house off-site	5	1/3	1	3
Off shoring	3	1/5	1/3	1
Total	16.00	1.68	4.53	9.33

The flexibility of applying design changes, colour changes, moving materials up and down the painting queue, adjusting painting schedules, qualities and quantities is better in the in-house production alternative.

The final score of each alternative is calculated. The highest score is the best alternative, according to the AHP. The calculation of the AHP results in Table 11 is explained in a diagram, Figure 5, on the next page.

Table 11: AHP final results

Outsourcing	0.155
In-house	0.545
In-house off-site	0.217
Off shoring	0.083

The highest score is achieved by the In-House alternative, with a great amount of 54.5%, followed by the In-House Off-site alternative with 21.7%. Close behind is the Outsourcing alternative, 15.5%, and far behind is the Off shoring alternative with a mere 8.3%.

Objective Hierarchy for Alternatives and Final Weights

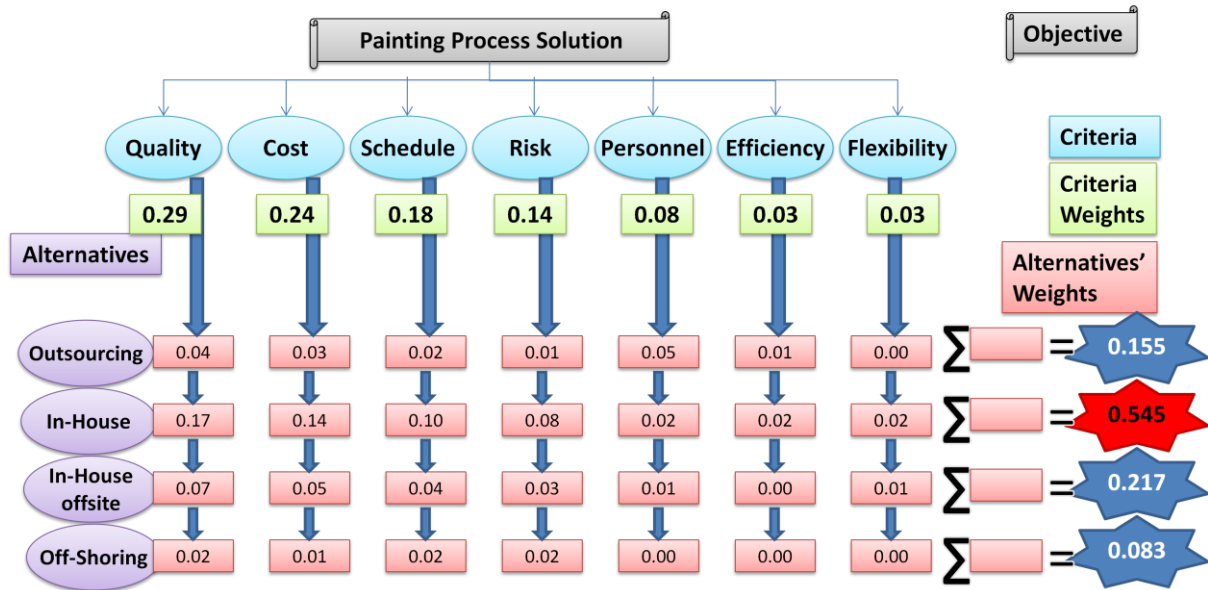


Figure 5: AHP results describing criteria and alternatives

The weight of each criteria, green blocks, are multiplied by the score awarded of each alternative when considering that criteria only, shown in the red blocks. These multiplications are summed for each alternative and the final results of the alternatives are shown in the stars. The red star indicates that In-House is the best alternative due to the fact that it scored the highest in the AHP.

To ensure that these AHP calculations and results are valid answers, a consistency index calculation is completed on each of the matrices used. (Winston 2004)

Consistency Index

The calculation of the Consistency Index (CI) is done as follows:

Step 1: Calculate Matrix AW

Pairwise Comparison Matrix **A** (Table 1) x Weight Matrix **W** (Table 3) = Matrix **AW**

Equation 1: Calculating Matrix AW to be used in CI Equation 2.

Step 2: Calculate CI

$$CI = \frac{\frac{1}{n} \sum_{i=1}^{i=n} \frac{(AW)_i}{W_i - n}}{n-1} \quad n = \text{Number of Criteria}$$

Equation 2: Consistency index = CI

n=7 where the seven criteria are compared in a matrix (Table 1)

n=4 where the four alternatives are compared in matrices (Tables 4-10)

Step 3: Calculate CI/RI

$$\frac{CI}{RI} < 0.1$$

Equation 3: Results for Consistency Index test

RI is a set value for each amount n. The values of Random Index (RI) give the average values of CI, if the entries in A are randomly chosen. The constraint is however that all diagonal values equal one, and for all other values: $a_{ij} = 1/a_{ji}$.

Table 12: Values of the Random Index (RI) (Winston 2004)

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Thus, from Table 12: n = 7 has RI = 1.32 and n = 4 has RI = 0.9

CI / RI should be less than 0.1 for the AHP to provide useful estimates of the weights. This is true in the case of the painting process AHP analysis.

For a perfectly consistent decision maker (CI = 0) :

$$(AW)_i \approx n \times W_i$$

Equation 4: Consistency of the Decision maker.

Equation 3 is satisfied in the painting process AHP analysis and proves the decision maker to be consistent in her analysis.

All Consistency Index Calculations are shown in Appendix D. All the matrices went through all three steps and their CI / RI values are less than 0.1. The AHP results and calculations are thus valid.

Cost Analysis

The data to be used in the cost analysis was gathered by requesting quotes from outsourcing companies and suppliers of the equipment which will be required in the case of in-house painting.

Quotes were obtained from the following companies:

- ✓ Two outsourcing companies, namely *Bambanani* and *Uniquote*, and
- ✓ Three in-house equipment supplier companies, namely *Storm Machinery*, *Speccoats* and *Ultimate Spray & Blast Equipment*.

A summary of the quotes and calculation can be viewed in Appendix C.

Table 13 shows the results from the calculated areas to be painted. The calculations are based on the design drawings. The design drawing are regularly updated as necessary. The areas are used to calculate the amount of paint to buy for each part of the assembly and also how much abrasive grit is required.

Table 13: The areas in m² to be painted calculated from the design drawings.

Areas for painting purposes	
m ²	
Structure	122.762
Piping external	4.5
Piping internal	4.5
TOTAL	131.762

The abrasive material selected for sand blasting the pump assemblies are grit abrasive. The grit is suitable for the type of material of which the pump assemblies are made of. The abrasives cost a fixed amount. The fixed amount depends on the type of abrasive bought. The fact that less than a ton will be bought also influences the cost per ton.

Additional to the fixed amount, a variable cost ,which changes each month, is added. Another separate variable cost is also added. A delivery cost to the Pretoria area is also added. All these costs excluded VAT which means adding 14% VAT is also required. The final cost per ton of abrasive grit is R11 443.32. Bags of 25kg suit the needs of this project and will cost R286.08.

Table 14: Cost of Abrasives for use in the Sand Blasting Process.

Blasting Abrasives		
	< 1 ton /ton	> 1 ton /ton
Fixed Cost	R 6 545.00	R 5 583.00
Variable Cost	R 2 862.00	R 5 168.00
	R 441.00	
Delivery to PTA	R 190.00	
excl VAT	R 10 038.00	
incl VAT	R 11 443.32	per 1000kg
	R 286.08	per 25kg

The type of paint for the first four pump assemblies is as listed in Table 15. The type of paint used for the pump assemblies built in future may change, due to the mine being in development and constantly changing their standards. The spreadsheet is simple enough to be updated with different types of paint if necessary.

Table 15: Costs of Paint used in the Painting Process.

	Amount (ℓ) per can	Cost per Can	m ²	Amount of Cans Required	Total Cost
Carbothane 134	5	R 863.00	12.0	11	R 9 493.00
Carboguard 890 ZA	10	R 1 320.00	6.0	1	R 1 320.00
Carboguard 187 ZA Primer	5	R 523.00	5.4	0	R 0.00
Carboguard 187 ZA Finish	5	R 590.00	5.4	0	R 0.00
Carboguard 893 ZA	10	R 958.00	10.3	13	R 12 454.00
Carbomastic 200 ZA Black	5	R 490.00	3.9	0	R 0.00
Carbomastic 200 ZA Red	5	R 523.00	3.9	0	R 0.00
Carbomastic 200 ZA Black	20	R 1 867.00	3.9	0	R 0.00
Carbomastic 200 ZA Red	20	R 1 997.00	3.9	0	R 0.00
Fenoline 300	5	R 622.00	3.9	2	R 1 244.00
Fenoline 302	5	R 704.00	7.8	1	R 704.00
					R 25 215.00

per pump assembly

The paint currently being used is mostly sold in 5ℓ or 10ℓ cans. They cover different areas (m²) which is also listed in Table 15. The total amount of cans required are calculated by ensuring the area of the pump assembly to be painted with that type of paint, can be properly covered by the paint. The total cost of the paint for each pump assembly is R25 215.

The cost analysis is shown in Table 16. The In-House painting will require an initial investment. Equipment for both blasting and painting need to be bought. Different equipment is available to achieve the same results and quality. Some equipment to however affect the quality. The equipment included in the cost analysis are most applicable to the specific pump assembly project requirements. Obviously, it will be a great advantage if the equipment bought is adaptable to be used in other projects as well.

Plan A was developed to include the sand blasting equipment most commonly used. The equipment includes:

- ✓ a 200 ℓ sandblast pot complete with all hoses and nozzles required.
- ✓ a internal pipe blast attachment for the blasting of the specific pipe internal diameters.
- ✓ the steel grit abrasive as calculated in Table 14.
- ✓ surface profile gauge to check the correct surface finish is acquired in all areas.
- ✓ salt test kit.

Plan B contains different sandblasting equipment. A Power Gun is selected and replaces both the 200 ℓ sandblast pot and internal pipe blast attachment. This is a huge cost saving. The salt test kit is also unnecessary in this case.

The spray painting costs for Plans A and B are identical.

The total initial costs of Plan A is **R 118 478.08** and for Plan B is **R 69 701.48**. Plan B is clearly much cheaper and supplies the same capabilities as Plan A.

Running costs for Plan A and B includes:

- ✓ Paint, as calculated in Table 15
- ✓ Labour
- ✓ Electricity

Each unit of pump assembly built incur these running costs, a total of **R 26 565**.

Table 16: Cost of In-House blasting and painting process.

IN-HOUSE PAINTING		
Initial Costs		
Sand Blasting		
<u>Equipment</u>	PLAN A	PLAN B
Power Gun		R 10 670.40
200L Sandblast pot	R 31 179.00	
Internal pipe blast attachment: Pipe size 80-305mm	R 26 700.00	
Steel Grit Abrasive 25kg	R 286.08	R 286.08
Digital surface profile guage 0-800µm	R 6 380.00	R 6 380.00
Salt test kit	R 1 568.00	
Spray Painting		
<u>Equipment</u>		
Internal pipe coater	R 11 900.00	R 11 900.00
56 : 1 Airless Spray Pump	R 23 500.00	R 23 500.00
DFT guage basic model, ferrous, 1-1500µm	R 8 700.00	R 8 700.00
Dew,Temp and RH meter	R 8 265.00	R 8 265.00
TOTAL INITIAL COSTS	R 118 478.08	R 69 701.48
Running Costs		
Paint per unit	R 25 215.00	
Labor	R 1 000.00	
Electricity	R 350.00	
TOTAL RUNNING COSTS per unit	R 26 565.00	R 26 565.00

The outsourcing cost is gathered from an outsourcing company currently painting pump assemblies. They charge the company a total of **R 33 500** per unit pump assembly blasted and painted.

Table 17: Cost of Outsourcing blasting and painting process.

OUTSOURCING	
Price per unit	R 33 000.00
Transport per unit	R 500.00
TOTAL OUTSOURCING COSTS per unit	R 33 500.00

The costs for in-house and outsourcing painting process is compared in the following two graphs. Figure 6 compares Plan A of the In-House painting process to the Outsourcing painting process. At 18 pump assemblies, the costs will break even.

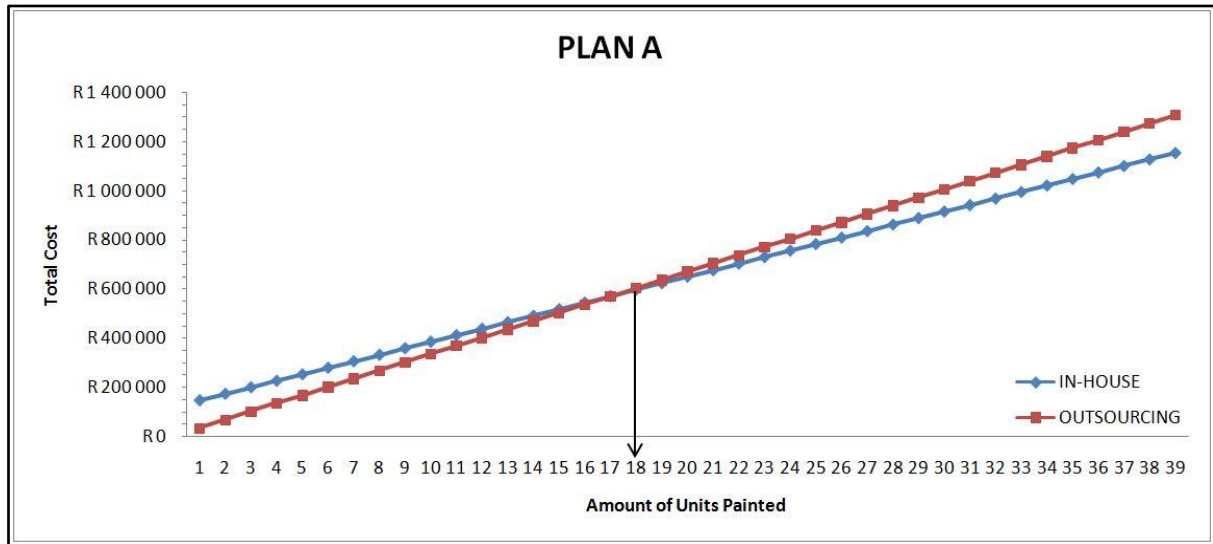


Figure 6: Plan A In-House painting and Outsourcing the painting process Break-Even graph.

Figure 7 compares Plan B of the In-House painting process to the Outsourcing painting process. At blasting and painting 11 pump assemblies, the costs will break even.

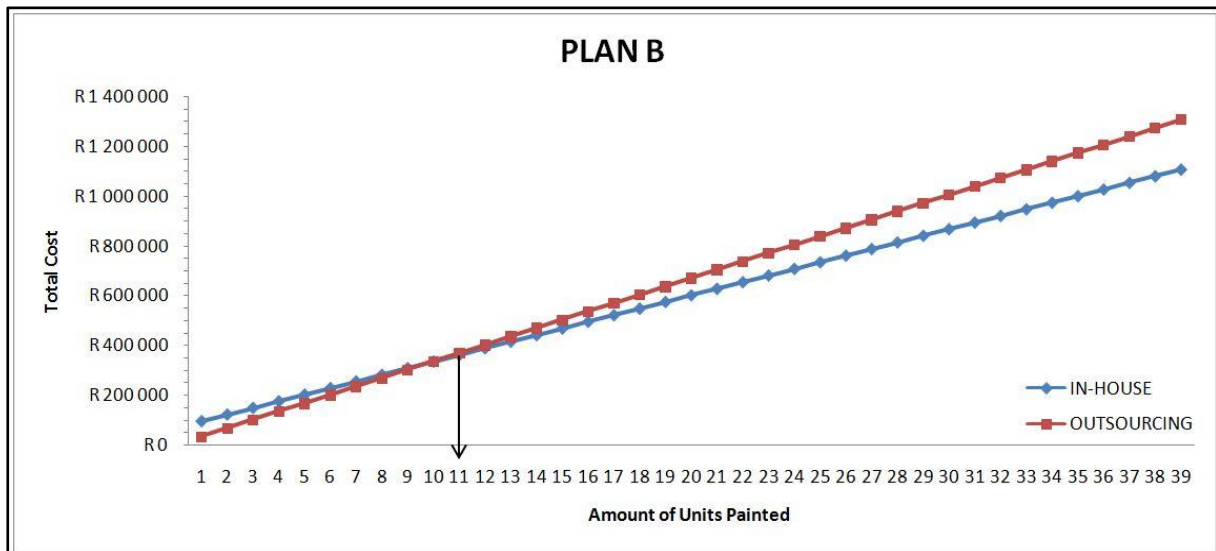


Figure 7: Plan B In-House painting process and Outsourcing the painting process Break-Even graph

Risk Analysis

1. Non-compliance to Quality Standards.

There is always a possibility that some external factor will impact the quality of a product. The uncertainty of the external environment pose many threats to quality.

The weather affects the painting process. That is why the temperature and humidity is tested and recorded. If the painted parts are set out to dry uncovered, rain will certainly deem the painting process useless. A blasted part will rust, and will have to be re-blasted. With sufficient planning and resources, the weather will not disturb the painting process.

Due to certain paints being supplied in components, mixing should also be done properly to ensure a even distribution of paint. Following the mixing directions of the paint, a smooth consistency will be achieved and will comply to standards.

Following the handling, transportation and storage instructions of the paint and painted parts, the quality will not be affected by these actions.

2. Employee resists Training

Although sand blasting and spray painting of parts are fairly simple and easy to learn, training is necessary to make absolutely sure the correct process is followed. The training should not only cover the mixing, storage, painting and safe handling of the paints and painted parts, but also the cleaning and maintenance of equipment to ensure long equipment life and quality operations.

3. Resources shortage - labour

The labour to perform these actions should be available and willing to stay on schedule with the painting process. A shortage of labour or low efficiency will cause low quality paint jobs.

4. Health & Safety Risk

A suitable area should be available where the blasting and painting process can safely be completed. All the required safety equipment, including a ventilation system and Personal Protective Equipment (PPE), should be supplied in sufficient quantities. The maintenance of the equipment and regular cleaning is key.

The sand blasting operation is noisy and dusty and the personnel need to be protected in the correct ways. The paint fumes are dangerous to the health of the operator and the environment. Equipment should be functioning properly and clean. All regulations and safety precautions are supplied by the paint suppliers and should be read and followed.

5. Law

The rights of workers and neighbors need to be considered. The Constitution of South Africa: Bill of rights specifies some fundamental rights regarding labour relations.

6. Environmental Impact

The sand from the sand blasting process should be contained. The sand can be re-used which will save money and limit the environmental impact. The safe disposal of excess paints and sand should be done according to supplier recommendations.

4. Select Preferred Solution

4. Select Preferred Solutions

The AHP and Cost Analysis both suggested that performing the painting process In-House would be the better alternative. The AHP awarded the In-House alternative the winning percentage of 54% over the other three alternatives. This is a strong victory for an alternative to achieve. The Cost Analysis showed that after blasting and painting 11 pump assemblies (using Plan B) the costs would break even and it will be cheaper to perform the painting process in-house.

Preferred Solutions

The preferred solution is thus the In-House painting process. The supporting documents for this solution will be kept in the Project PAL.

Formal Evaluation

Formal Evaluations

The formal evaluation may be completed by more than one person in management. A formal evaluation team may also be created. The study is checked for major and minor errors and it is ensured that the data used is still valid. To conform to quality requirements is highlighted.

The Quality Assurance Procedures are extremely important in this project. Not only for the great contact and partnership which can potentially bring in more contract work, but also to keep the company's good name in term of complying to quality standards. The quality requirements have been extensively defined in the Scope of Work for the project called the Project Quality Plan (PQP). This contains, among others, the content and schedule of quality audits.

The Quality Control Plan (QCP) for the sandblasting and spray painting procedure was developed from these requirements. The contractors' QCP's was also used and the quality control officer from Konnoco approved the document on his MKDesigns quality audit in August. See Appendix A for the attached document.

5. Expert Review

5. Perform Expert Review

The trade-off study and all the AHP steps will be reviewed by an expert in the field of decision making to ensure correct results.

The Mechanical Engineers of MKDesigns namely Mr. M. Kruger, A. Labotski and M.Adam is further responsible for the expert review and final decisions regarding the trade-off of outsourcing or in-house production. They may also request further investigation on different equipment and paint.

6. Present the Results

A blue rectangular button with a slight gradient and a drop shadow, containing the text "6. Present Results" in white, bold font.

The process of analysis, containing all documentation, will be explained during a visual presentation to MKDesigns. The findings and recommendations of the study will also be presented and discussed.

This study will also be presented at the University of Pretoria to Mr. M Nienaber and Prof. K Adendorff in a formal project meeting on 25/10/2011.

The focus of the presentation will be to sell the idea of performing processes in-house, but keeping in mind the costs and risks involved. An engineering approach will be taken, but not too much technical information will be discussed. The final presentation is of great importance. Although all the studies and results may show a solution, if the solution is not sold to the stakeholders as being a possible saving, the whole project would be insignificant.

7. Project Process Asset Library (PPAL)

A blue rectangular button with a slight gradient and a drop shadow, containing the text "7. Put In PPAL" in white, bold font.

The documentation process for all data gathered and analyzed is one of the most important parts of the trade-off study process. The company should have a Process Asset Library (PAL) to support their current decisions and to aid them in performing future studies. This project will form part of MKDesigns' PAL for future reference.

Conclusion

The trade-off study structures the decision making process. The process is successfully completed and the desired aim is reached. The preferred solution is the In-House painting process.

In Chapter 5, the quality assurance of the painting process is discussed.

Chapter 5

Quality Assurance

The quality of the final sandblasted and painted units cannot be compromised for any amount of cost savings or schedule adjustments. To ensure a quality product is supplied, whether outsourcing or in-house painting process is followed, a painting Quality Control Plan (QCP) was developed.

The requirements from the paint specification "Specification Number 44" and the related standards, as listed in Appendix A, was used to write this painting QCP. The QCP document was signed off by the quality inspector from VALE/ARM. The final painting QCP document, which forms part of the databook of the project, can be viewed in Appendix B.

All equipment required to test and satisfy the quality requirements are described in Appendix E.

1. Approve QCP - DRG

The QCP is designed using the requirements in the Painting Specification. The quality inspector from VALE/ARM needs to sign off the document to ensure that they agree on the process used in the painting process.

2. Verify Paint Specification (Color & Total EFT) - SPEC JV2009 - SPEC 44

To ensure the correct color and effective film thickness (EFT) is achieved, the original paint specification or concessions need to be utilized.

3. Receive material - DRG - BATCH CERTS

The transportation and receiving of material to be painted is a prescribed process. All documentation is to be completed. The Batch Certificates of the supplied material needs to be placed in the databook. Copies of these certificates are kept with the material. At any time, the quality inspector from VALE/ARM can ask which materials are in a certain process. This can be proved by showing the Batch Certificates of the material.

4. Remove oil / grease / contaminants - SPEC - SABS 767

Before the blast, the visible contaminants need to be removed using standard procedures specified by SABS 767.

5. Abrasive blast clean (As per Specification) - SPEC JV2009 - SPEC 44/ SABS 772

Abrasive Blast SA 2.5, min 50micron max 100micron

The sand blasting is completed to specification using the correct and safe methods. The surface finish is measured using a digital surface profile gauge 0-800µm to ensure compliance to standards and requirements are met (SPEC 44/SABS 772). The Degrees of Cleanliness of Blast Cleaned Surfaces is explained in Appendix E on page 63. The "Near White" Blast Cleaning is the quality requirement for the pump assemblies.

6. Dust and debris - SPEC - SABS 1217 / SABS767

To ensure the paint applications adhere as required and can have a surface finish free from impurities and glossy as required. Additional comments on this subject in Appendix E on page 61.

7. Salt contamination test - SPEC - ISO 8502 / (BRESLE TEST)

The salt test ensures that the steel is clean and no previous corrosion is still evident on the steel. This test is however more for refurbishment paint processes and will not be employed on future jobs. Additional information on this subject in Appendix E on page 61.

8. Record Humidity and Temp prior to Painting - SPEC JV2009 - SPEC 44

RH <85% / 5°C < temp < 50°C

The painting process is executed in specific environment concerning temperature and humidity. The conditions need to be recorded throughout the process and will be checked by the quality inspector from VALE/ARM. Equipment required for this step is listed in Appendix E.

9. Apply Primer to spec. (coating times, visual deviations and runs) SPEC JV2009 SPEC 44

STRUCTURE - Carboguard 893, DFT (75µm)

PIPING EXTERNAL - Carboguard 893, DFT (75µm)

PIPING INTERNAL - Fenoline 300 - DFT (300µm) Modified Phenolic primer updated supplier

The Primer is the first coat painted. The different parts have different primers, according to the specific final coat which will be applied later.

10. Inspect prime coat after curing (DFT, EID etc) - SPEC JV2009 - SPEC 44

The inspection of the prime coat includes dry film thickness DFT measured using a DFT gauge basic model, ferrous, 1-1500µm. The thickness should be controlled to be thicker than the minimum requirement, however making the paint too thick can cause cracking as well as waste of paint and money.

11. Apply Intermediate Coat (coating times , visual deviations and runs) - SPEC JV2009 - SPEC 44

STRUCTURE - NONE

PIPING EXTERNAL - NONE

PIPING INTERNAL - Fenoline 302 - DFT (100µm) Modified Phenolic updated supplier

The Intermediate Coat is painted secondly. The different parts have different intermediate coatings, according to the specific final coat which will be applied later. Certain parts do not have any intermediate coatings.

12. Inspect Intermediate coat after curing (DFT, EID etc) - SPEC JV2009 - SPEC 44

The inspection of the intermediate coat includes dry film thickness DFT measured using a DFT gauge basic model, ferrous, 1-1500µm. This DFT inspection is similar to all DFT inspections.

13. Apply Final Coat - SPEC JV2009 - SPEC 44

STRUCTURE - Carbothane 134, DFT (125µm) BLUE

PIPING EXTERNAL - Carboguard 890 DFT (125µm) GREEN

PIPING INTERNAL - Fenoline 302 - DFT (100µm) Modified Phenolic - BLACK updated supplier

The final coat is painted lastly. The different parts have different final coatings. All parts need to have a final coating. The final coating is colored as specified.

14. Inspect Final coat after curing (DFT, EID etc) - SPEC JV2009 - SPEC 44

The inspection of the final coat includes dry film thickness DFT measured using a DFT gauge basic model, ferrous, 1-1500µm. The color is also checked. An even painted part containing no faults moves on to the final inspection. This DFT inspection is similar to all DFT inspections.

15. Final Inspection

During the final inspection, an overall quality inspection process is followed to ensure no runs or other external damage could have occurred during handling and the painting process.

16. Final Release

Before the materials can be moved, transported, assembled or handled in any way, the painting job needs to be signed off by the quality inspector from VALE/ARM. The process followed and the documentation is checked. A final "all clear - proceed" is given when the materials are released. Materials not conforming to the specifications may be sent back for touching up or repainting. In the case of a colour mistake, the paint is removed and repainted correctly or a concession with the quality inspector from VALE/ARM and the project manager needs to be arranged.

17. Databook

Once the QCP is signed off as being sufficient by the quality inspector from VALE/ARM, the signed copy is placed in the databook. All other QCP's completed by painters etc. is also placed in the databook.

Whoever executes the painting process, whether it is an outsourced company or the in-house painting team, this QCP needs to be followed and documented in detail. Any deviation from the QCP will place the executing company subject to fines.

Some of the quality assurance standards regarding the Corrosion Protection, which includes the sand blasting and spray painting of all material, are explained below. The importance thereof is also included.

Material traceability

The original Batch Certificates of the supplied material needs to be placed in the databook. Copies of these certificates are kept with the material. At any time, the quality inspector from VALE/ARM can ask which materials are in a certain process. This can be proved by showing the Batch Certificates of the material. The material is thus traceable due to the fact that the company is aware where in the process their materials are, and can prove it.

Ambient conditions

The conditions in which the materials are stored, transported, blasted, painted and assembled are important for the final inspection. Any conditions which may have an effect on the quality of the material needs to be documented. The ambient conditions are especially important during the painting process. The specific temperature and humidity testing and documentation during the painting process are the main focus of this quality assurance standard.

Surface Preparation

The sandblasting is performed using the correct equipment, methods and safety measures. The required result of the surface preparation is specified in the QCP. The required equipment is a digital surface profile gauge 0-800µm.

Application of primer coat within 'window' time period

The time between the surface preparation and the application of the primer coat is specified. The times should be documented. If the primer is not painted in the window time period, the blasting needs to be performed again.

Mixing

The paints are mixed and prepared according to the paints' specifications. All mixing needs to be performed in the correct conditions and using the correct equipment. Mixing times are also specified.

Over-coating times

To ensure proper adhesion and surface cleanliness the coating times will ensure that the surface preparation is still within specification and the paint properties during the intervals are still appropriate to have second and third applications. This ensures a homogenous application with the additional coats adhering to each other properly.

Film thickness

The Dry Film Thickness is measured using a DFT gauge basic model, ferrous, 1-1500µm. This ensure a thick enough coat is applied in various places on the unit. The DFT is measured by the painter, but is also checked by the quality inspector from VALE/ARM before signing off the materials.

Witness and secure points

The different action points ensure that the proper authority has inspected to the required level of inspection. Each inspection will be a hold point for the contractor to ensure no further actions are taken without the approval of the inspectors. Each step has a defined inspection type: I.E. visual, certificate etc.

Conclusion

It remains a difficult task to initially establish applicable quality standards for a mine in its development phase. This is a difficult situation, but by collaborating with experts in the quality field, a good quality standards document will be created. The quality of the paint is an important part of the final delivered product.

In Chapter 6, the final recommendation and conclusion is discussed.

Chapter 6

Recommendation

With a convincing 54.5%, the AHP suggested the In-House painting process. The validation of the AHP gives the decision makers the assurance of a trustworthy result. It is recommended that the In-House painting process is implemented.

The Cost Analysis supports the recommendation of the AHP by proving the In-House painting process to be cheaper on the long run. When 11 pump assemblies are painted, the initial investment of In-House painting process breaks even with the Outsourcing alternative. From the 12th to the 39th or more pump assemblies, it is cheaper to perform the painting process In-House.

It is recommended that when additional investigations are performed in future partnerships and contracts, this study is used as a reference. The study is documented in the company PAL.

Some quality faults in the material becomes more visible once the material is painted. This causes great problems when the quality inspector from VALE/ARM inspect the material at the outsourcing company. The inspector needs to release the material so as to allow the final assembly. However, when welding or other faults are noticed at an outsourcing painting company, the problems can't be easily fixed.

If the painting process is performed In-House, management can inspect the material before the quality inspector from VALE/ARM is notified to inspect the painted material. Faults noted can be fixed before the quality inspector from VALE/ARM does his inspection. Time, money and the good professional relationship is saved and protected.

Conclusion

Thirty nine skid-mounted pump assemblies to be built. The painting process is costly and time consuming. The quality thereof is also highly specified.

A trade off study is performed to make the best decision regarding make-or-buy. The recommended solution is supported by a valid AHP and involved costs and risks.

Considering the results of the trade-off study using the AHP process and cost analysis, the In-House painting process is the recommended option.

Bibliography

- Bahill, T, "Slides for Bahill's Lectures." *Bahill's Systems Engineering Site*, 9 6 2011, accessed 9 5 2011 <<http://www.sie.arizona.edu/sysengr/slides/>>
- Carnegie Mellon University, *CMMI Process Areas*. 2011, accessed 9 5, 2011 <<http://www.sei.cmu.edu/cmmi/solutions/pas.cfm>>
- Chapman, WL, Bahill, AT & Wymore, AW, 1992, *Engineering Modeling and Design*, CRC Press, Boca Raton.
- Felix, A, *Standard Approach to Trade Studies*, Technical Paper presentation at INCOSE 2004 - 14th Annual International Symposium Proceedings, 20-24 June 2004
- Greaver, MF, 1999, *Strategic Outsourcing*, Amacon, New York.
- Hammond, J S, Keeney, RL & Raiffa H, 2002, *Smart Choices: A Practical Guide to Making Better Decisions*, Crown Business, New York.
- Hayes, R, Pisano, G, Upton, D & Wheelwright, S, 2005, *Operations Strategy and Technology: Persuing the competitive Edge*, John Wiley& Sons, New York.
- Jacobs, FR, Chase, RB & Aluilano, NJ, 2009, *Operations and Supply Management*, McGraw-Hill/Irwin, New York.
- Langley, CJ, Coyle, JJ, Gibson, GJ, Novac, RJ & Bardi, EJ, 2008, *Managing Supply Chains: A Logistics Approach*, Cengage Learning, ISE.
- Peters, MR , 2009, *Standard Specification For Corrosion Protection Of Structural Steelwork, Platework & Mechanical Equipment*, ARM/Joint Venture, Zambia.
- Recca, P, *Outsourcing vs. In-House - A Guideline to Help You Decide*, 5 11 2008, accessed 9 6 2011 <<http://www.submityourarticle.com/articles/Phyllis-Recca-3294/outsouce-44720.php>>
- Ritter, D, & Brassard, M, 1998, *The Creativity Tools Memory Jogger: A Pocket Guide for Creative Thinking*, GOAL/QPC,.
- Saaty, TL, 1980, *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, McGraw-Hill, New York.
- Speccoats Paint (Pty)Ltd, *Speccoats Paint South Africa*, 2011, accessed 9 20 2011 <<http://http://www.speccoats.co.za>>
- Szidarovszky, F & Bahill T, 1999, *Mathematical Summary of Multicriterion*, University of Arizona, Tucson.
- Winston, WL, 2004, *Operations Research: Vol 2 - Introduction to Probability Models*, Brooks/Cole - Thomson Learning, California.

Appendix A

Painting Specifications for Skid-Mounted Pump Assembly

The VALE / ARM Joint Venture document "Specification Number 44: Standard Specification For Corrosion Protection Of Structural Steelwork, Platework & Mechanical Equipment" defines all processes and quality standards used in the painting process.

It is a requirement (Peters 2009) that all painting should comply to the following standards:

- ✓ SANS ISO 1461 - Hot-Dip Zinc Coatings (galvanised).
- ✓ SANS 801 - Epoxy Tar Paints.
- ✓ SANS 926 - Two Pack Zinc Rich Epoxy Primer.
- ✓ SANS 1158 - Two Pack Epoxy Resin Based Primers.
- ✓ SANS 1091 - National Colour Standards.
- ✓ ISO 8501-1 - Surface Preparation.
- ✓ SANS 901 - Paint & Varnish Brushes.
- ✓ SANS 552 - Paint Rollers.
- ✓ SANS 064 - Preparation of Steel Surfaces for Coating.
- ✓ SABS Method 772 - Profile of Blast Cleaned Steel Surfaces.
- ✓ SABS Method 141 - Dry Film Thickness of Paints.
- ✓ SIS 055900 - Pictorial Surface Preparation Standards.
- ✓ SANS 1198 - Production & Quality of Rubber Linings on Steel Pipes, Pipe Fittings and Vessels.

The following Coating systems are specified for the Skid-Mounted Pump Parts and Assembly:

Coating System No. 2* – Epoxy Tar - Tank Linings and Pipes Interior for Slurry- 65m²

* *Rubber lining when specified by Project Engineer shall be in accordance with SANS 1198.*

General

This specification details the coating of structural steelwork and platework situated in wet conditions for all pH ranges, specifically:

Underground applications.

Brown's/Pachuca tanks - inside top 2 000 mm only.

Coating

Surface Preparation: All surfaces are to be abrasive blasted to Swedish Standard SIS055900, Sa2½ with a minimum blast profile of 50 micrometers, measured in accordance with SABS Method 772.

First Coat: Brown epoxy tar, with a minimum dry film thickness of 90 micrometers.

Second Coat: Black epoxy tar, with a minimum dry film thickness of 90 micrometers.

Remarks

Only available in black and brown colours.

Contractors to comply with minimum and maximum curing time between coats to supplier's recommendations.

Coating System No. 3 - Polyurethane - Tank and Pipes Exteriors - 65m²

General

This specification details the coating of structural steelwork, platework, piping and mechanical equipment used in mild mining environments and mildly acidic environments.

Coating

Surface Preparation: All surfaces are to be abrasive blasted to Swedish Standard SIS055900, Sa2½ with a minimum blast profile of 50 micrometers, measured in accordance with SABS Method 772.

Primer Coat: One coat of epoxy polyamide, with a minimum dry film thickness of 75 micrometers.

Final Coat: One coat of aliphatic acrylic polyurethane, with a minimum dry film thickness of 40 micrometers.

Remarks

Specified colour of final coat for Tank and Pipes Exteriors.

Two final coats may be required if application is by brush or roller.

Appendix B

Quality Control Plan for Sandblasting and Spray painting.

Project: SKID MOUNTED PUMP SETS		Date: 26-Aug-11		REV: 0.2			
Client: KONOCO / DRA / KONIOLA		Job #: 11016		Page: 1			
Project Code: 11016		Document #: 11016-00-10009					
Fabricator: MKDesigns		Inspection Authorities		Classification			
Painter: Uniquate Paints Panel		1 MKD	1 Critical	Client Order #: KN-E-11-0113			
Equipment: Skid Mounted Pump Sets		2 DRA	2 Major	Quantity Req: 1			
Drawing #: 11016-01-00000		3 ARM	3 Minor	Contract #:			
		4					
Classification: H = Hold		Control Activities		Inspection Results (sign)			
R = Review		1	2	3	4		
W = Witness		Doc Ref	Despatch	Code	Description of Operation		
S = Surveillance							
V = Verify							
C = Certify							
Item #	Description of Operation	Code	Doc Ref	Despatch	Control Activities	Inspection Required	Inspection Results (sign)
1	Approve OCP	DRG			1	Doc	MKD DRA ARM
2	Verify Paint Specification (Colour & Total EFT)	SPEC	JV2009 SPEC 44		H	Doc	
3	Receive material	DRG	BATCH CERTS		H	Doc	
4	Remove oil / grease / contaminants	SPEC	SABS 767		H	Doc	
5	Abrasive blast clean (As per Specification)	SPEC	JV2009 SPEC 44 / SABS 772		H	Doc	
6	Abrasive Blast SA 2.5, min 50micron max 100micron	SPEC	SABS 1217 / SABS 767		H	Doc	
7	Dust and debris	SPEC	ISO 8502 / (BRESLE TEST)		H	Doc	
8	Record Humidity and Temp prior to Painting	SPEC	JV2009 SPEC 44		H	Doc	
9	Apply Primer to spec. (coating times, visual deviations and runs)	SPEC	JV2009 SPEC 44	X	H	Doc	
10	Inspect prime coat after curing (DFT, EID etc)	SPEC	JV2009 SPEC 44	X	H	Doc	
11	Apply Intermediate Coat (coating times, visual deviations and runs)	SPEC	JV2009 SPEC 44	X	H	Doc	
12	Inspect intermediate coat after curing (DFT, EID etc)	SPEC	JV2009 SPEC 44	X	H	Doc	
13	Apply Final Coat	SPEC	JV2009 SPEC 44	X	H	Doc	
14	Inspect Final coat after curing (DFT, EID etc)	SPEC	JV2009 SPEC 44	X	H	Doc	
15	Final Inspection	DRG	REL REPORT		H	Doc	
16	Final Release	DRG	REL REPORT		H	Doc	
17	Databook	DRG	REL REPORT		H	Doc	
Compiled by: M Adam		Approved by:		Date:		Date:	
MKDesigns		DRA		DRA		Konoco / ARM	

Appendix C

Data for Cost Analysis - Quotations

SANDBLAST EQUIPMENT

Abrasive Blast SA 2.5, min 50micron max 100micron

200L Sandblast pot with:

- 12m Sandblast hose + Hose coupler
- 08mm Nozzle + Holder
- Remote valve
- Deadmans Handle
- Sandblast Hood
- Air hose for Sandblast hood
- CPF 80 Filter
- Apron + gloves

R 31 179.00

200L Remote Blast Pot Package:

- Includes 200lt Remote Plumbed Blast Pot,
- c/w Safety Exhaust Silencer
- 10meter Blast Hose,
- c/w Nozzle Holder,
- Hose Coupler,
- 6mm Venturi Blast Nozzle,
- Deadman's Handle
- c/w 11meters Twinline Signal Hose,
- 1 x Vinyl Helmet,
- c/w 12 meters Helmet Hose,
- Leather Gloves,
- Tarpaulin Apron

R 22 500.00

Internal pipe blast attachment:

Pipe size 80-305mm

R 26 700.00

SPRAY EQUIPMENT

Primer

STRUCTURE - Carboguard 893, DFT (75µm)

PIPING EXTERNAL - Carboguard 893, DFT (75µm)

PIPING INTERNAL - Fenoline 300 - DFT (300µm) Modified Phenolic primer

Intermediate Coat

STRUCTURE - NONE

PIPING EXTERNAL - NONE

PIPING INTERNAL - Fenoline 302 - DFT (100µm) Modified Phenolic

Final Coat

STRUCTURE - Carbothane 134, DFT (125µm) BLUE

PIPING EXTERNAL - Carboguard 890 DFT (125µm) GREEN

PIPING INTERNAL - Fenoline 302 - DFT (100µm) Modified Phenolic - BLACK

(Most Pipes Internal D150mm, 1x Pipe Internal D80mm (100mm long) & 2x Pipe Internal D100mm)

Internal pipe coater with:

- 20L Air agitated spray pot
- 15m Fluid and air hose
- Rotor coater attachment

R 11 900.00

30:1 Airless spray machine with:

- 15m Airless hose
- Spray Gun
- Spray Tip

R 20 500.00

56 : 1 Airless Spray Pump with:

- Gun
- 3/8 Airless Hose ,
- Tip,
- Tip Guard

R 23 500.00

68:1 Airless spray machine with:

- 15m Airless hose
- Spray Gun
- Spray Tip

R 32 800.00

INSPECTION EQUIPMENT

RH <85% / 5°C< temp< 50°C

- | | |
|---|----------------------|
| 1. DFT guage basic model, ferrous, 1-1500µm | R 8 700-00/ea |
| 2. Dew, Temperature and RH meter | R 8 265-00/ea |
| 3. Dust tape test kit | R 1 595-00/ea |
| 4. Digital surface profile guage 0-800µm | R 6 380-00/ea |
| 5. Salt test kit | R 1 568-00/ea |

Data for Cost Analysis - Calculations

IN-HOUSE PAINTING		
Initial Costs		
Sand Blasting		
Equipment	PLAN A	PLAN B
Power Gun		R 10 670.40
200L Sandblast pot	R 31 179.00	
Internal pipe blast attachment: Pipe size 80-305mm	R 26 700.00	
Steel Grit Abrasive 25kg	R 286.08	R 286.08
Digital surface profile guage 0-800µm	R 6 380.00	R 6 380.00
Salt test kit	R 1 568.00	
Spray Painting		
Equipment		
Internal pipe coater	R 11 900.00	R 11 900.00
56 : 1 Airless Spray Pump	R 23 500.00	R 23 500.00
DFT guage basic model, ferrous, 1-1500µm	R 8 700.00	R 8 700.00
Dew,Temp and RH meter	R 8 265.00	R 8 265.00
TOTAL INITIAL COSTS	R 118 478.08	R 69 701.48
Running Costs		
Paint per unit	R 25 215.00	
Labor	R 1 000.00	
Electricity	R 350.00	
TOTAL RUNNING COSTS per unit	R 26 565.00	R 26 565.00

OUTSOURCING	
Price per unit	R 33 000.00
Transport per unit	R 500.00
TOTAL OUTSOURCING COSTS per unit	R 33 500.00

Areas for painting purposes

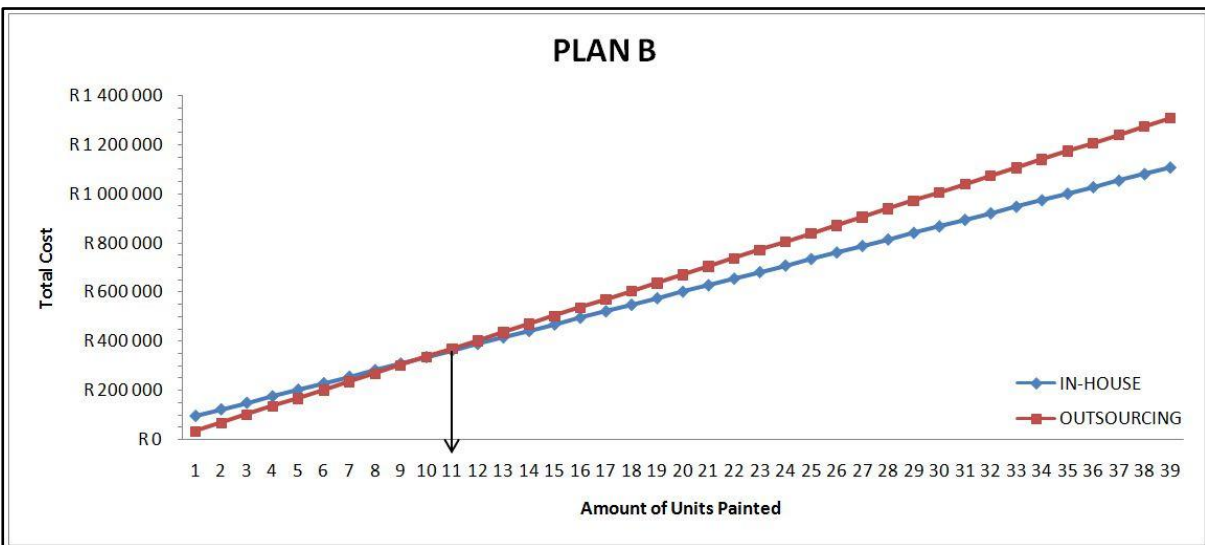
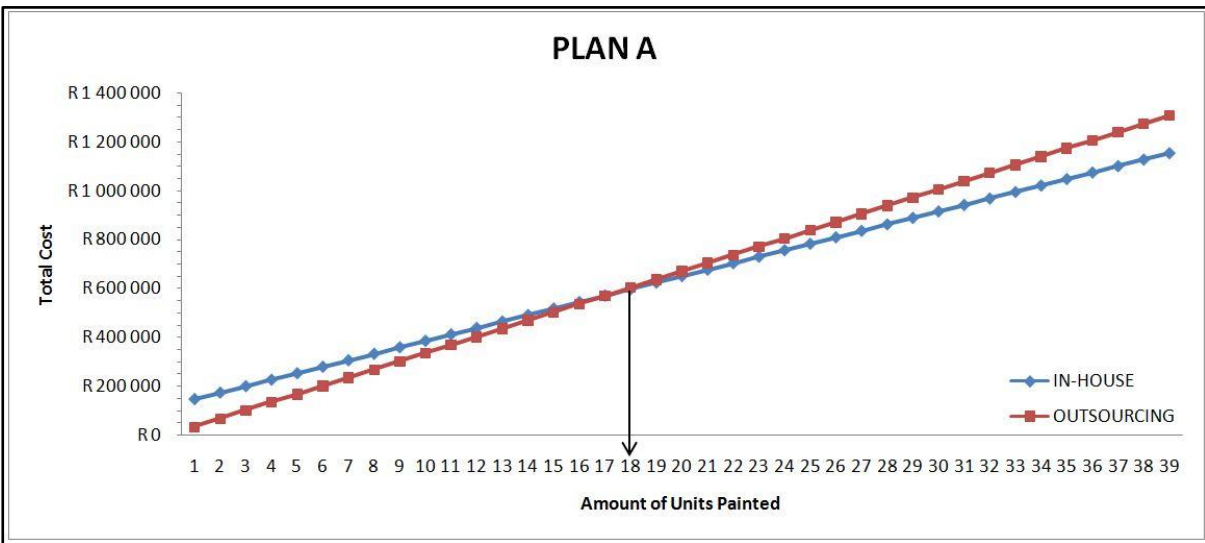
	m ²
Structure	122.762
Piping external	4.5
Piping internal	4.5
TOTAL	131.762

	Amount (ℓ) per can	Cost per Can	m ²	Amount of Cans Required	Total Cost
Carbothane 134	5	R 863.00	12.0	11	R 9 493.00
Carboguard 890 ZA	10	R 1 320.00	6.0	1	R 1 320.00
Carboguard 187 ZA Primer	5	R 523.00	5.4	0	R 0.00
Carboguard 187 ZA Finish	5	R 590.00	5.4	0	R 0.00
Carboguard 893 ZA	10	R 958.00	10.3	13	R 12 454.00
Carbomastic 200 ZA Black	5	R 490.00	3.9	0	R 0.00
Carbomastic 200 ZA Red	5	R 523.00	3.9	0	R 0.00
Carbomastic 200 ZA Black	20	R 1 867.00	3.9	0	R 0.00
Carbomastic 200 ZA Red	20	R 1 997.00	3.9	0	R 0.00
Fenoline 300	5	R 622.00	3.9	2	R 1 244.00
Fenoline 302	5	R 704.00	7.8	1	R 704.00

R 25 215.00

per pump assembly

Blasting Abrasives		< 1 ton /ton	> 1 ton /ton	
Fixed Cost		R 6 545.00	R 5 583.00	grit type abrasive
Variable Cost		R 2 862.00	R 5 168.00	shot type abrasive
		R 441.00		
Delivery to PTA excl VAT		R 190.00		
		R 10 038.00		
incl VAT		R 11 443.32		per 1000kg
		R 286.08		per 25kg



Appendix D

Data and Calculations for AHP

Criteria Pairwise Comparison

	1	2	3	4	5	6	7
	Cost	Risk	Schedule	Quality	Flexibility	Personnel	Efficiency
1 Cost	1	3	1/3	1	7	5	7
2 Risk	1/3	1	1	1/2	5	3	5
3 Schedule	3	1	1	1/3	3	3	3
4 Quality	1	2	3	1	8	6	7
5 Flexibility	1/7	1/5	1/3	1/8	1	1/4	1
6 Personnel	1/5	1/3	1/3	1/6	4	1	5
7 Efficiency	1/7	1/5	1/3	1/7	1	1/5	1
Total	5 5/6	7 3/4	6 1/3	3 1/4	29	18 4/9	29

Intermediate Matrix

	Cost	Risk	Schedule	Quality	Flexibility	Personnel	Efficiency	Average
Cost	0.17	0.39	0.05	0.31	0.24	0.27	0.24	0.24
Risk	0.06	0.13	0.16	0.15	0.17	0.16	0.17	0.14
Schedule	0.52	0.13	0.16	0.10	0.10	0.16	0.10	0.18
Quality	0.17	0.26	0.47	0.31	0.28	0.33	0.24	0.29
Flexibility	0.02	0.03	0.05	0.04	0.03	0.01	0.03	0.03
Personnel	0.03	0.04	0.05	0.05	0.14	0.05	0.17	0.08
Efficiency	0.02	0.03	0.05	0.04	0.03	0.01	0.03	0.03

Weight Per Criteria

Cost	0.24
Risk	0.14
Schedule	0.18
Quality	0.29
Flexibility	0.03
Personnel	0.08
Efficiency	0.03

1.00

Consistency Indexes

AW $\frac{AW}{W}$

1.86	7.80		
1.11	7.71		
1.57	8.61		
2.32	7.90		
0.24	7.63		
0.57	7.35		
0.25	7.58		
	7.80	0.13	0.10
			Acceptable

Quality Management	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/3	1/3	2
In-house	3	1	5	7
Off shoring	1/2	1/7	1/4	1
Total	7.50	1.68	6.58	14.00

Cost Management	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/4	1/3	3
In-house	4	1	5	7
In-house off-site	3	1/5	1	3
Off shoring	1/3	1/7	1/3	1
Total	8.33	1.53	6.67	14.00

Schedule Management	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/4	1/3	1/2
In-house	4	1	4	6
In-house off-site	3	1/4	1	3
Off shoring	2	1/6	1/3	1
Total	10.00	1.67	5.67	10.50

Risk Management	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/7	1/5	1/3
In-house	7	1	3	5
In-house off-site	5	1/3	1	2
Off shoring	3	1/5	1/2	1
Total	16.00	1.68	4.70	8.33

Personnel / Labor	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	5	7	3
In-house	1/5	1	3	7
In-house off-site	1/7	1/3	1	3
Off shoring	1/9	1/7	1/3	1
Total	1.45	6.48	11.33	20.00

Efficiency	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/3	3	5
In-house	3	1	5	7
In-house off-site	1/3	1/5	1	3
Off shoring	1/5	1/7	1/3	1
Total	4.53	1.68	9.33	16.00

Flexibility	Outsourced	In-house	In-house off-site	Off shoring
Outsourcing	1	1/7	1/5	1/3
In-house	7	1	3	5
In-house off-site	5	1/3	1	3
Off shoring	3	1/5	1/3	1
Total	16.00	1.68	4.53	9.33

Intermediate Matrix					Average	CI
0.13	0.20	0.05	0.14	0.13	0.23	0.04
0.40	0.60	0.76	0.50	0.56	0.17	0.07
0.40	0.12	0.15	0.23	0.24	0.07	0.07
0.07	0.09	0.04	0.07	0.07	0.02	0.02

Intermediate Matrix					Average	CI
0.12	0.16	0.05	0.21	0.14	0.24	0.03
0.48	0.63	0.75	0.50	0.59	0.14	0.03
0.36	0.13	0.15	0.21	0.21	0.05	0.05
0.04	0.09	0.05	0.07	0.06	0.01	0.01

Intermediate Matrix					Average	CI
0.10	0.15	0.06	0.05	0.09	0.18	0.02
0.40	0.60	0.71	0.57	0.57	0.10	0.10
0.30	0.15	0.16	0.23	0.23	0.04	0.04
0.20	0.10	0.06	0.10	0.11	0.02	0.02

Intermediate Matrix					Average	CI
0.06	0.09	0.04	0.04	0.06	0.14	0.01
0.44	0.60	0.64	0.60	0.57	0.08	0.08
0.31	0.20	0.21	0.24	0.24	0.03	0.03
0.19	0.12	0.11	0.12	0.13	0.02	0.02

Intermediate Matrix					Average	CI
0.69	0.77	0.62	0.45	0.63	0.08	0.05
0.14	0.15	0.26	0.35	0.23	0.02	0.02
0.10	0.05	0.09	0.15	0.10	0.01	0.01
0.08	0.02	0.03	0.05	0.04	0.00	0.00

Intermediate Matrix					Average	CI
0.22	0.20	0.32	0.31	0.26	0.03	0.01
0.66	0.60	0.54	0.44	0.56	0.02	0.02
0.07	0.12	0.11	0.19	0.12	0.00	0.00
0.04	0.09	0.04	0.06	0.06	0.00	0.00

Intermediate Matrix					Average	CI
0.06	0.09	0.04	0.04	0.06	0.03	0.00
0.44	0.60	0.66	0.54	0.56	0.02	0.02
0.31	0.20	0.22	0.32	0.26	0.01	0.01
0.19	0.12	0.07	0.11	0.12	0.00	0.00

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
0.5257	0.523821668		4.031460882		
2.2561	2.611720505		4.630536512		
0.9563	1.007593432		4.211734913		
0.2613	0.271417826		4.154323051		
			4.26	0.09	0.095

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
0.5412	0.541828288		4.00437444		
2.3578	2.632445548		4.465330179		
0.8498	0.32461439		4.351916539		
0.2511	0.26290946		4.187878342		
			4.25	0.08	0.094

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
0.3564	0.364215686		4.087223862		
2.2773	2.519047619		4.424600246		
0.9122	0.978256303		4.289728236		
0.4541	0.462640056		4.075570635		
			4.22	0.07	0.081

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
0.2303	0.231366768		4.01886923		
2.2724	2.360686854		4.155427404		
0.9641	0.984843291		4.08536229		
0.5332	0.540146277		4.052101282		
			4.08	0.03	0.029

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
2.5275	2.844330573		4.501546068		
0.9067	0.95531852		4.21461466		
0.388	0.396230261		4.085278082		
0.1779	0.179331276		4.033761889		
			4.21	0.07	0.077

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
1.0534	1.099376114		4.174653294		
2.2316	2.355519481		4.222174676		
0.4875	0.491902215		4.036193804		
0.2276	0.229881953		4.040828887		
			4.12	0.04	0.044

Consistency Indexes				CI	CI / RI
n x W	AW	AW/W			
0.2276	0.229881953		4.040828887		
2.2316	2.355519481		4.222174676		
1.0534	1.099376114		4.174653294		
0.4875	0.491902215		4.036193804		
			4.12	0.04	0.044

TEST: 0.11
NOT

checked		
Outsourcing	0.15494	0.15
In-house	0.54496	0.54
In-house off-site	0.21694	0.22
Off shoring	0.08316	0.08

Test Sum = 1 1.00 1.00

Appendix E

Equipment Descriptions

The importance of using the correct equipment cannot be over-emphasized in reaching the quality standards and requirements. For this reason, the specific equipment required for the blasting and painting process is identified and the product descriptions (Speccoats Paint 2011) are attached.

▶ Power Gun

The Clemco Power Gun is a suction blast tool designed for dry abrasive blasting where the air supply is limited or the job is small.

The tool is lightweight and compact and ideal where setting up a conventional pressure blast machine would be awkward or inconvenient. The Power Gun can be used with all common media to clean or etch metal, clean masonry, etch glass, and other durable surfaces.

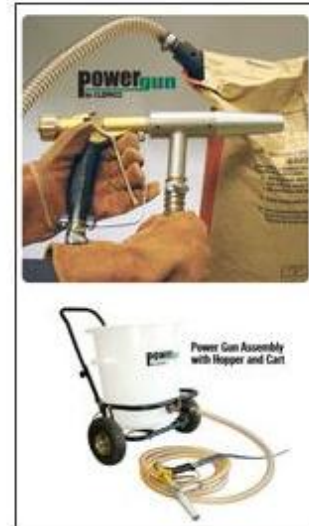
The optional heavy-duty plastic hopper holds an ample supply of media. The amount of media loaded will be dictated by the application and the location of the blast job.

Advantages:

- Lightweight, portable, easily transportable tool.
- Can be used with any media container or right out of the bag.
- Simple setup—partially submerge suction lance into bag of abrasive.
- Easy to use and maintain

Popular applications:

- Touch-up work or re-blasting areas that may have failed inspection.
- Onboard ship.
- On a scaffold or other elevated or difficult to reach location.
- Small jobs.



▶ Blast Machine 200 Litre

High-performance, versatile blast cleaning systems, removes contamination, corrosion, mill scale, and coatings from most surfaces. Produces a uniform surface texture, and creates a surface profile to increase bonding for coatings.

- 200 Litre Capacity
- Remote Controls RMS 2000
- Water Separator
- 1-1/4" Piping



▶ Hollo-Blast

The Clemco Hollo-Blast cleans the full 360 degree inside diameter of pipe to white metal finish. It operates without need of rotating the pipe or the tool. deposits such as rust, carbon millscale, coke and paint are easily removed.

The Hollo-Blast will accommodate pipes from 2 inch to 12 inch I.D. and lengths up to 40 feet. Any abrasive (except aluminum oxide or silicon carbide) 20 mesh or finer may be used.



Available Models	Literature Downloads
Hollo-Blast	» Download Technical Datasheet - PDF

▶ Internal Pipe Coating Equipment

Speccoats offer internal pipe coating solutions for pipes ranging in diameters & lengths.

- Internal airless spray painting with hollow cone spray nozzle.
- Internal centrifugal type impeller type spray painting equipment.
- Internal airless rotating nozzle type spray painting equipment.
- Customized internal coating systems to suit various requirements, whether it be hot application, single component application, two component application, we are able to assist.



Elcometer 319 Dewpoint Meter with Bluetooth

This rugged gauge is designed to measure and record all relevant climatic parameters required to determine whether the conditions are suitable for painting. The Elcometer 319 can be used as a hand-held gauge or a stand alone data logger - ideal for monitoring climatic conditions over a period of time.

- Integrated magnets allow remote data monitoring on steel substrates.
- Store 25,000 records in up to 999 batches.
- USB and Bluetooth data output to a PC or PDA.
- Dustproof and waterproof gauge with fully sealed sensors (equivalent to IP66).
- Visual and audible indication of user defined limits against any or all parameters.
- Easy to use, intuitive multi-lingual menu structure.
- A hand-held Dewpoint meter with manual and interval data logging in one gauge.
- Large, customer definable illuminated display operates over the full temperature range.
- Measure and record climatic parameters:
 - Relative humidity.
 - Air temperature.
 - Surface temperature.
 - Dewpoint temperature.



- $T\Delta$ (the difference between surface temperature and dewpoint).
- Dry Bulb temperature.
- Wet Bulb temperature

Accurate

- Meets ISO 8502-4.
- Rapid response time.
- Each instrument is supplied with a Calibration Certificate.
- Readings are switchable between Celsius and Fahrenheit.
- Time and date stamp is recorded for each set of readings.

Simple

- Easy menu-driven interface in multiple languages.
- Clear, illuminated display showing up to five parameters from:
 - RH: % Relative Humidity
 - T_s : Surface Temperature
 - T_a : Ambient Air Temperature
 - T_d : Dewpoint Temperature
 - $T\Delta$: the difference between the T_d and T_s
 - T_{db} : Dry Bulb Temperature.
 - T_{wb} : Wet Bulb Temperature.
 - Arrow indicators show temperature trends.

Flexible

- The gauge can be used as either a hand-held Dewpoint meter or as a remote data logging monitor*
- Integrated K-Type connector allows measurement of surface temperature during remote logging.

- Integrated K-Type connector allows measurement of surface temperature during remote logging.
- Selecting the "Te" mode transforms the gauge into a simple thermometer - ideal for measuring a coating's temperature prior to application or other external temperatures (Te).
- Hold/freeze function allows manual readings to be taken and reviewed before being logged into memory.

Durable

- Manufactured from temperature resistant materials ensuring safe use in climates ranging between -20°C (-4°F) and +80°C (+176°F) • Waterproof and dust proof rating equivalent to IP66.
- The rugged and ergonomic design extends to include durable industrial sensors ideal for harsh environments.
- The instrument's clear illuminated display operates over its full temperature range.

Versatile

- Data can be downloaded to a PC via USB or Bluetooth and evaluated using ElcoMaster 2.0 Software
- ElcoMaster Software supplied with unique "Watchguard" functionality allowing the user to remotely monitor up to 42 gauges on one screen*.
- Each gauge can be powered by either 2 AA batteries (for up to 400 hours use) or directly via the USB cable.
- Adjustable limits can be set for each measurement parameter which triggers visual and audible alarms whenever a limit is exceeded - even if it is not displayed on the screen.

*Top Model only



Elcometer 213 Digital Thermometer

The Elcometer 213 Digital Thermometer allows quick and easy measurement for a wide range of applications using the K-type thermocouple and gives readings in °C.

Features:

- Measures temperature in the range of -50°C to 850°C, (the maximum temperature is dependent on probe type), with high accuracy and resolution.
- Quick temperature response.



*Probes are available to purchase separately.

Elcometer 456 Integral Coating Thickness Gauge

The new Elcometer 456 Coating Thickness Gauge sets new standards making measuring dry film thickness faster, reliable and accurate; helping you to become more efficient.

The Elcometer 456 is available in four different models: E, B, S and T. Each gauge provides the user with increasing functionality - from the entry level Elcometer 456 E, to the top of the range Elcometer 456 T, with memory, alpha-numeric batching and Bluetooth® communication.

Integral coating thickness gauges are ideal for single handed operation as the wide footprint of the Bigfoot™ internal probe provides greater stability during measurement - allowing for consistent, repeatable and accurate results.



» [View Separate Gauge](#)

Key Features of the Elcometer 456 Coating Thickness Gauge include:

Easy

- Large buttons ideal for gloved hands.
- Easy to use menus in multiple languages.
- High contrast colour LCD with auto rotate.
- High and low reading limit indicators.
- Factory calibrated for immediate use.



Accurate

- Measurement Capability to $\pm 1\%$.
- Conforms to national & international standards.
- Temperature stable measurements.
- Increased reading resolution for thin coatings.
- Measures accurately on smooth, rough, thin and curved surfaces.

Reliable

- Repeatable and reproducible.
- 2 year gauge warranty.
- Supplied with fully traceable test certificates.
- Batch date and time stamp facility.

Rugged

- Sealed, heavy duty and impact resistant.
- Dust and waterproof equivalent to IP64.
- Scratch and solvent resistant display.
- Durable gauge and probe construction.
- Suitable for use in harsh environments.

Efficient

- Fast reading rate of 70+ per minute.
- Multiple calibration memories.
- Alpha numeric batch identification.
- User selectable calibration methods.
- Compatible with all Elcometer software including ElcoMaster 2.0

Powerful

- Wide range of interchangeable probes.
- USB and Bluetooth™ data output.
- Stores up to 75,000 readings in 999 batches.
- Measures up to 30mm (1200mils) of coating on metal substrates.

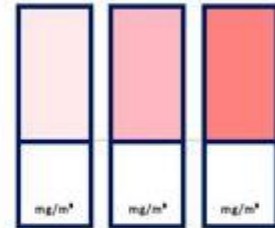
The new ElcoMaster 2.0 is a fast, easy to use software solution for all your reporting requirements.

► Dust & Debris Removal

It often occurs that a surface is dusty, greasy, dirty or generally contaminated. Speccoats supply a range of Brooms, Brushes, Cleaning Rags, Tack Rags, Mops, Scotchbrite Sponges, Vacuum Systems & Air Guns.

Weber Rielly Soluble Salts Test Kit

- Soluble Iron Salts – Ferrous Chloride and Ferrous Sulphate are found in the bottom of corrosion pits of badly corroded steel.
- These salts are soluble in water & can cause osmotic blistering of coatings applied to steel.
- Soluble salts must therefore be removed prior to coating a surface.
- This test kit identifies the presence of soluble salts on abrasive blast cleaned steel.



Elcometer 142 ISO 8502-3 Dust Tape Test Kit

- The Elcometer 142 Dust Tape Test kit allows assessment of the quantity and size of dust particles on surfaces prepared for painting.
- Dust on blast cleaned surfaces can reduce coating adhesion, leading to premature coating failure and sub-standard coating finish.
- The kit can be used in accordance with the recommendations of BS EN ISO 8502-3 either as a pass/fail test or as a permanent record of the presence of dust.
- Supplied in a carry case for use in the field to assess surface cleanliness.



Elcometer 224 Digital Surface Profile Gauge

The Elcometer 224 provides the very latest in surface profile measuring technology. Accurate, fast and very user friendly, this gauge is available with or without memory. The Elcometer 224 Top model is available with wireless technology and can store up to 50,000 readings in 999 batches.

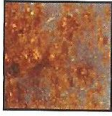


- Fast reading rate at 40+ readings per minute.
- Accurate, immediate and repeatable results.
- Intuitive menus in multiple languages enables use straight from the box.
- Large backlit screen makes viewing readings easy.
- Digital display prevents reading interpretation errors.
- Measure profiles up to 500µm (20 mils) in a single gauge.
- Tough tungsten carbide user replaceable tip, can be used for up to 20,000 readings.
- Counted average mode stores the average value of a pre-set number of readings.
- Statistics are calculated and displayed in real time.
- Readings can be downloaded to a PC and reports created in seconds.
- Store up to 50,000 readings in 999 batches.
- Bluetooth® wireless technology & RS232 data output for cable free data transfer.
- Cost per test is significantly lower than other test methods.

Degrees of Cleanliness of Blast Cleaned Surfaces

Condition of Steel

Grade A



Steel where mill scale has started to flake and light rusting occurs

Grade B



Steel where all mill scale has flaked off and complete rusting has taken place

Grade C



Steel where pitting and complete rusting has occurred

"Near White" Blast Cleaning

Specs: Sa 2 1/2, NACE-2 and SSPC-SP-10

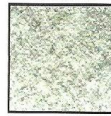
Grade A



Grade B



Grade C

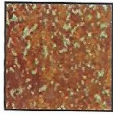


Cleaning to this standard requires that mill scale, rust and foreign particles are removed to such a degree that the only traces remaining are slight stains in the form of spots or strips

Light Blast Cleaning

Specs: Sa 1, NACE-4 and SSPC-SP-7

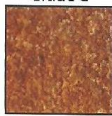
Grade A



Grade B



Grade C



This is often referred to as whip blasting. Cleaning to this standard requires that loose mill scale, loose rust and foreign matter are removed.

"White Metal" Blast Cleaning

Specs: Sa 3, NACE-1 and SSPC-SP-5

Grade A



Grade B



Grade C



Cleaning to this standard requires the entire removal of all mill scale, all rust and all foreign particles. The cleaned surface shall have a uniform metallic colour.

Medium Blast Cleaning

Specs: Sa 2, NACE-3 and SSPC-SP-6

Grade A



Grade B



Grade C



Cleaning to this standard requires that mill scale, rust and foreign particles are substantially removed and that grey metal is visible.

