

LOGISTICAL SUPPORT: AN EVALUATIONAL STUDY
AT ALUSAF HILLSIDE

by


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ABSTRACT

Tydens die ontwerp en beplanning van 'n sisteem kan dit gebeur dat die elemente wat direk te doen het met die bereiking van die sisteemmissie die meeste aandag geniet. Die lewensiklus ondersteuning van die sisteem word afgeskeep wat tot onnodige finansiële uitgawes lei, omdat:

1. Koste van die sisteem ondersteuning meestal 'n groot deel van die projek se algehele lewensiklus koste uitmaak.
2. Koste van die sisteemondersteuning hoofsaaklik bepaal word deur keuses wat gedurende die vroeë fases van die lewensiklus gemaak word.

Om gevolglik die projek se totale lewensiklus-koste te minimiseer, moet die sisteemondersteuning so vroeg moontlik in die projek se lewensiklus geoptimiseer word.

Die oorkoepelende doel is om te ontwerp vir ondersteuning. Elke subsisteem se moontlike probleemareas moet geïdentifiseer word en 'n optimale ondersteuningsplan moet daarvoor bepaal word.

Alusaf bestaan uit die Hillside-smelter en die Bayside-smelter. Bayside produseer 174 000 ton aluminium per jaar en Hillside 466 000 ton. Hillside is die nuwe smelter en sal einde 1996 in volle produksie wees. Hillside is geheel en al uit eksterne bronne aangekoop. Die ontwerp van Hillside se logistieke ondersteuningstelsel was in groot mate nie Hillside se verantwoordelikheid nie. Die ondersteuningstelsel is deur die verskaffers bepaal. Die doel van hierdie verslag is om te bepaal of die Elektrode-aanleg in die Koolstof-aanleg te Alusaf Hillside ontwerp is vir ondersteuning.

Die Elektrode-aanleg is deel van die Koolstof-aanleg wat op sy beurt weer deel is van Hillside as geheel. Namate die lewensiklus vorder sal definitiewe probleemareas geïdentifiseer word in terme van die verskaffers se siening van logistieke ondersteuning en Hillside se behoefte aan logistieke ondersteuning.

Om hierdie verskille te identifiseer, evalueer hierdie studie die volgende vier areas van logistieke ondersteuning in die Koolstof-aanleg:

- Betroubaarheid
- Instandhouding
- Verskafferondersteuning
- Data

Waar probleemareas geïdentifiseer word, gaan voorstelle gemaak word wat spesifiek gerig is op die optimisering van Hillside se logistieke ondersteuningstelsel.



CHAPTER 1

INTRODUCTION

1.1 TITLE

An evaluation of the planned logistical support system in the rodding shop at Alusaf-Hillside smelter.

The rodding shop is a subfunction of the carbon department. The carbon department is one of the functional departments of Alusaf Hillside. This study will evaluate the logistical support of the rodding shop in terms of its optimality, and make recommendations accordingly.

1.2 INTRODUCTION



1.2.1 Background

During the design and development of a system, it can easily happen that the elements directly associated with the prime mission statement receive the most attention. The life-cycle support of the system is neglected, which leads to unnecessary financial burdens because:

1. the cost of the system life-cycle support contributes to a large proportion of the overall system life-cycle cost.
2. the cost of the system life-cycle is largely dependent on choices made during the earlier design stages of the system life-cycle (Blanchard & Fabrycky 1981: 448).

In order to minimize the system life-cycle support cost, it is important to optimize the system life-cycle support cost as soon as possible in the project life-cycle. According

to Ronald (1992:Xiii), the logistical support of a system can contribute to as much as 30 percent of the product cost. The level of logistical support has to be compared to the logistical support cost. Logistical support analysis (LSA) is used to optimize the logistical support plan.

The overall goal is to design for supportability. Each subsystem and possible problem area has to be identified, and an optimal support plan has to be developed.

According to a study conducted by Anderson Consulting and the Chair of Logistics at the University of Pretoria, businesses across South Africa are turning to logistics to answer the problems they face in respect of rising costs, greater competition, changing customer needs and the application of technology (*Productivity SA* 1995:21). This illustrates the importance of optimizing the logistical support system. It also indicates the ability of an optimal support plan to reduce overall operating costs.

1.2.2 Aim of report



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The aim of this report is to evaluate the logistical support system of the rodding shop at Alusaf Hillside.

The report will indicate the following:

1. a formulation of the problem statement.
2. an overview of the aluminium business, with specific reference to the problem statement.
3. a literature study to determine the critical areas that need to be evaluated.
4. a comparison of the logistical support system of the rodding shop with the theory.

5. identification of problem areas and proposed improvements to be researched in depth in subsequent studies.

1.2.3 Scope and limitations

The study will be confined to the rodding shop of the carbon department at Alusaf Hillside. The interface of the rodding shop with the rest of the plant and with external suppliers and contractors will constitute the boundaries of the study.

The study is limited in that the results are obtained in the rodding shop and cannot be regarded as representative of the whole plant. Hence the study cannot be generalized throughout Alusaf Hillside.

1.3 PROBLEM STATEMENT

A system without an optimal logistical support plan will incur unnecessary financial cost and is therefore a nonoptimal system.

Large systems require an effective logistical support system throughout the system lifecycle. It is of vital importance to design logistical support optimally for the primary mission equipment (ie elements without which the system cannot complete its mission). The elements of logistical support must be designed in such a way that they can be integrated into the primary mission equipment. Because the different elements of logistical support interact with each other, they must be able to integrate. System support in some companies is so advanced nowadays, that suppliers of the equipment maintain the systems on site. They even do improvements/modifications to the system on site. A US company, McDonnell Douglas, provides a wide range of logistical support to the USA Navy. It performs extensive modifications to the equipment on site. Any

modification kits needed, are sent to the navy for use on site. (*Aviation Week and Space Technology* 1993: 42-43).

The end goal is to develop a system with a balance between the primary mission equipment and the logistical support (Blanchard & Fabrycky 1981:451). This goal can be achieved by means of a concept known as integrated logistical support (ILS). This system ensures that the prime mission equipment can be economically and reliably supported throughout the system lifecycle.

According to *Productivity SA* (1995: 21), most industries have similar problems, for example:

- A picking slip is issued for a product not in the warehouse.
- The wrong merchandise arrives.
- The right merchandise arrives late or in a damaged state.
- Just-in-Time (JIT) suppliers let their customers down.
- Shipments go astray.

To eliminate these problems, it is necessary to implement an effective logistical support plan that will optimize the organization and ensure that all spare/repair parts and other consumables are at the right place at the right time in the right condition.

The rodding shop is part of the carbon department which is a function of Alusaf Hillside. The whole plant, and therefore all its systems were purchased from external vendors. Up to now the development of logistical support, was not part of the Alusaf operational team's responsibility. As the lifecycle matures, many problems will be encountered and corrected.

A study is being carried out to evaluate the logistical support of the rodding shop. The whole rodding shop will be evaluated and critical areas identified. The rodding shop will be evaluated against each of these criteria.

1.4 OBJECTIVES

The success of the study will depend on the successful realisation of the following objectives:

1. Literature study.
2. On completion of the literature study, characteristics that need to be evaluated in order to evaluate the logistical support plan will be identified. Typical characteristics will be as follows:
 - reliability.
 - maintainability.
 - supportability.
 - supplier supportability.
 - test and support equipment.
 - transport and handling.
 - personnel and training.
 - facility.
 - data.
 - software.
3. An accurate evaluation of the rodding shop in terms of the characteristics identified



4. suggestions for improvement

1.5 RESEARCH METHODOLOGY

After analysing the study objectives, it is clear that this will be a descriptive study. Emory & Cooper (1991:141) define a descriptive study as follows: “If the research is concerned with finding out who, what, where, when or how much, the study is descriptive”.

With reference to objective 2, an investigative study must be carried out to determine the characteristics that need to be measured in order to evaluate the systems logistical support. Emory & Cooper (1991:144) define a research study as one that enables the researcher to get a better idea of a concept, determine priorities and therefore improve the final design of the research. Secondary data will be the main source of information for this study.

1.5.1 Primary data capturing

Primary data originate from original sources. These are data that are specifically accumulated for a specific research study (Emory & Cooper 1991:286).

The accumulation of these data will take place when the actual logistical support of the rodding shop has been analyzed. Primary data will also be obtained from the vendors of the different systems during the commissioning phase.

1.5.2 Secondary data

Emory & Cooper (1991: 287) define secondary data as “... a vast inventory of information stored in books, pamphlets, periodicals, microfilm, computer files and other media”.

These data will be used mainly to determine the characteristics of a system that has to be evaluated and what the dimensions of these characteristics must be to classify the system as optimal.

1.6 DEFINITION OF TERM

1. **Logistical support (system support)** "... is viewed as the composite of all considerations necessary to assure the effective and economic support of a system throughout its programmed life cycle. It is an integral part of all aspects of the system planning, design and development, test and evaluation, production and/or construction, consumer use and system requirements" (Blanchard & Fabrycky 1981: 449).
2. **Logistical support analysis (LSA)**. This is the integration of different analytical techniques to ensure that the logistical support system is optimal. The results of the LSA are the identification and documentation of the required logistical support system throughout the system life cycle. According to Blanchard (1976: 458) a typical LSA evaluation will entail the following:
 - a) support analysis
 - b) life-cycle cost analysis
 - c) logistical modulation
3. A **System** is a collection of elements grouped together to ensure that a certain need is stimulated. The elements of a system comprise the primary mission elements and their associated support functions (Blanchard 1974: 2).
4. **Levels of maintenance**: The different levels of support can be defined as follows:

Organizational maintenance is performed at the organizational location by organizational personnel . It is mainly simple, low level maintenance such as visual inspections, small services and other minor activities.

Intermediate maintenance is mostly done by specialized organizations using mobile or semimobile maintenance workstations. Maintenance at this level will typically include actions such as main inspections, main services and other more comprehensive activities.

Depot maintenance is the highest level of maintenance. This type of maintenance will take place at the supplier depots and will include items such as difficult repairs or modifications, specialized setting changes and other more difficult maintenance procedures (Blanchard & Fabrycke 1981: 244-246).

1.7 PROBLEMS ENCOUNTERED IN THE STUDY

Not all the systems in the rodding shop have been fully commissioned. The logistical support for the systems that have not yet been fully commissioned will have to be estimated. The estimate will be made on the basis of the logistical support planned for that system and the logistical support available for systems that have been fully commissioned in the rodding shop.



1.8. LAYOUT OF THE STUDY

CHAP 2:	An introduction to the aluminium production process. This chapter will provide a brief description of the aluminium business. The problem statement will be formulated in relation to the environment in which it operates.
CHAP 3:	Critical areas of evaluation. A literature study will be conducted to determine which areas/aspects should be evaluated to determine the logistical support of the rodding shop.
CHAP 4:	Alusaf Hillside smelter: logistical support evaluation. The actual logistical support of the rodding shop will be evaluated against the criteria determined in chapter 3.

CHAP 5:	Summary. This chapter will provide a brief but comprehensive summary of the whole study.
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CHAPTER 2

AN INTRODUCTION TO THE ALUMINIUM PRODUCTION PROCESS

2.1 INTRODUCTION

2.1.1 Background to Alusaf

Alusaf is the sole producer of primary aluminium in South Africa. It is one of the 10 largest aluminium producers in the world. Primary aluminium refers to the produced aluminium cast in ingots (blocks of aluminium, ready to be sent to clients). Products made out of aluminium are the business of companies that purchase primary aluminium and transform it into usable product such as softdrink cans, car bodies and inside of electrical cables. Alusaf is situated in Richardsbay which makes it extremely cost effective in that the harbour is close. Alusaf imports its raw material, and since the new smelter has begun operating, will be able to export a very large portion of its annual production.

Alusaf consists of Alusaf Bayside Smelter and Alusaf Hillside Smelter. Both operate independently and are managed by Alusaf Corporate.

Alusaf Bayside Smelter is the older company. Some of its technology is outdated, but a big effort is being made to upgrade it. Although the technology is relatively old, the company is still extremely efficient and showed an excellent profit in the previous financial year. Bayside produces roughly 174 000 tons of aluminium per annum.

Alusaf Hillside Smelter is the new smelter. It is the biggest investment by a private company in the history of South Africa. The estimated cost of the construction of Hillside was R7,2 billion. On 30 August 1995, construction was six months ahead of schedule and

R1,2 billion under budget (Alusaf Employee Report 1994-1995). This smelter produced its first ingot of primary aluminium in July 1995. The technology for this smelter which is the newest and most modern technology in the world was purchased from a French company. The technology has never been used on this scale anywhere in the world. Hillside will produce 466 000 tons of aluminium per annum and will be in full production at the end of 1996. Hillside is a very valuable earner of foreign capital because it imports raw material and exports a product. Hillside will export all its production and has already sold nearly 90 percent of its production for the next four years (Alusaf Employee Report 1994-1995). Hillside also negotiated a deal with Escom in which the price of electricity is linked to the price of aluminium. Electricity constitutes a huge portion of an aluminium producer's inset cost. This means that when the aluminium price is low, Hillside pays less for electricity, putting less strain on the company. However when the aluminium price is high, Hillside pays more for electricity. Hillside will be able to absorb this because the price is high and it receives good money for its products.

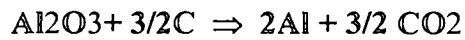
Hillside has an extremely flat management structure. The different departmental managers report to the operational manager who reports to the managing director of Alusaf as a whole. This study is conducted specifically inside one of the departments, the carbon department.

Hillside also benefits Bayside because the Escom deal covers Bayside as well. Hillside benefits from Bayside in that the latter has good experience and can therefore assist Hillside (*Hillside News*, 1995).

2.1.2 Backround to the production of aluminium

The production of aluminium occurs on the basis of electrolysis. The simplest form of this reaction can be described as follows: alumina reacts with carbon to produce

aluminium (Al) and carbon dioxide (CO₂) or carbon monoxide (CO). The reaction can be illustrated as follows:



The reaction takes place in large pots, which are basically constructed and consist of the following elements (figure 1):

- a steel casing.
- refractories for electrical insulation.
- a fixed cathode.
- a removable anode.

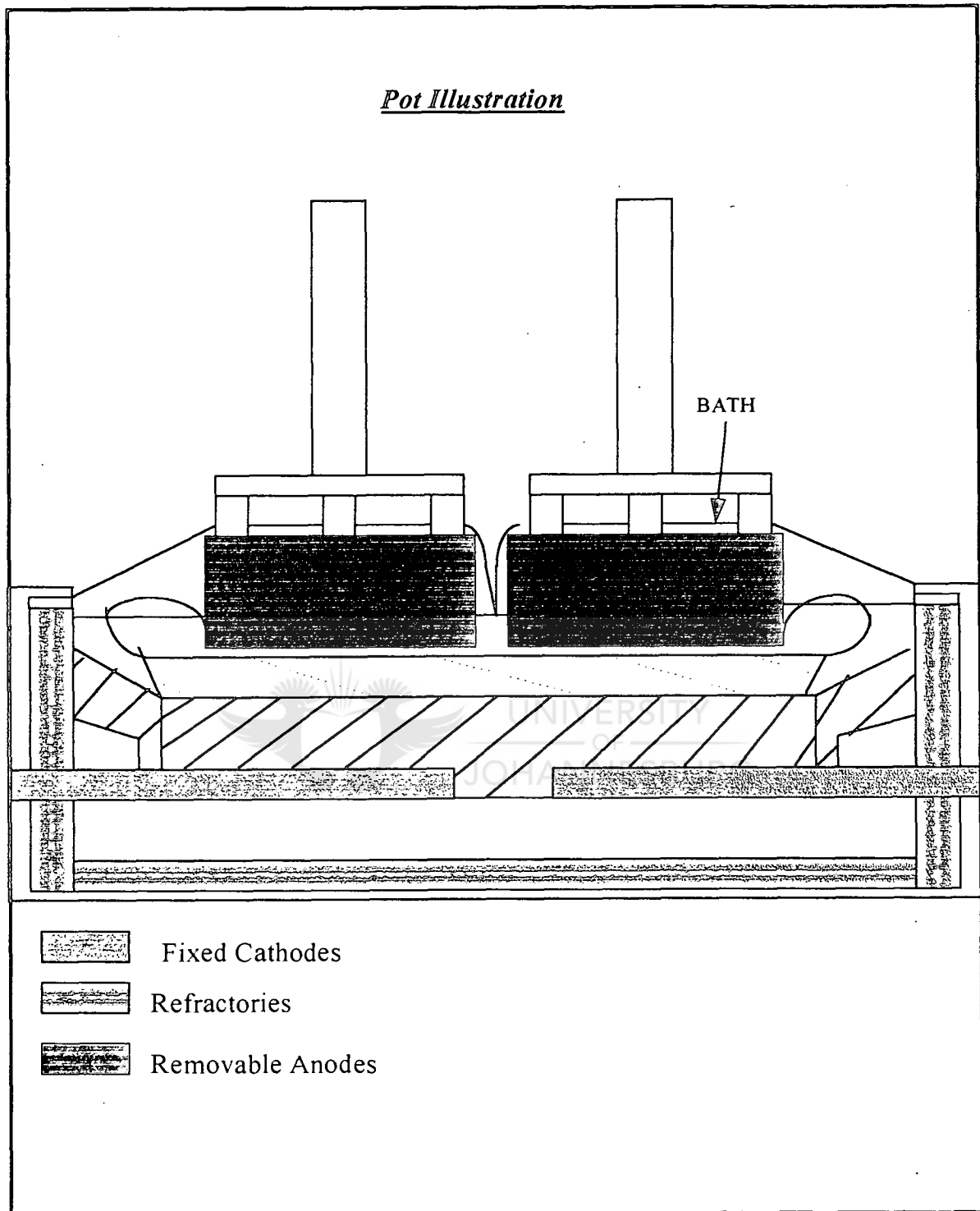
The reaction illustrates that the two primary ingredients required for the reaction are:

- alumina (AL₂O₃)
- carbon (C)

Alumina and carbon are imported from overseas vendors. Carbon is introduced into the reaction by means of a removable anode. Figure 2.2 illustrates the anode assembly. This anode is very rich in carbon.

Alusaf makes the removable anodes in-house. The anodes are produced by the carbon department. As explained earlier, the carbon department is one of the functions of Hillside.

FIGURE 2.1: Pot illustration



Source: Adapted from Alusaf Training Module 1994. Reduction: The Process

2.2 THE CARBON DEPARTMENT

The carbon department consists of three main subfunctions each with a definite purpose.

The three departments are as follows:

- the paste plant.
- the baking furnace.
- the rodding shop.

In order to understand the exact approach to the problem statement, the basic functions of each department will now be discussed.

2.3 THE PASTE PLANT

The paste plant is responsible for formation of anodes. An anode is a block (very rich in carbon) comprising the following dimensions (figure 2):

length = 1450 mm

height = 600 mm

width = 650 mm

The raw material going into the anodes are **coke** and **pitch**. Coke is a by-product of petroleum, whereas pitch is a by-product of coal.

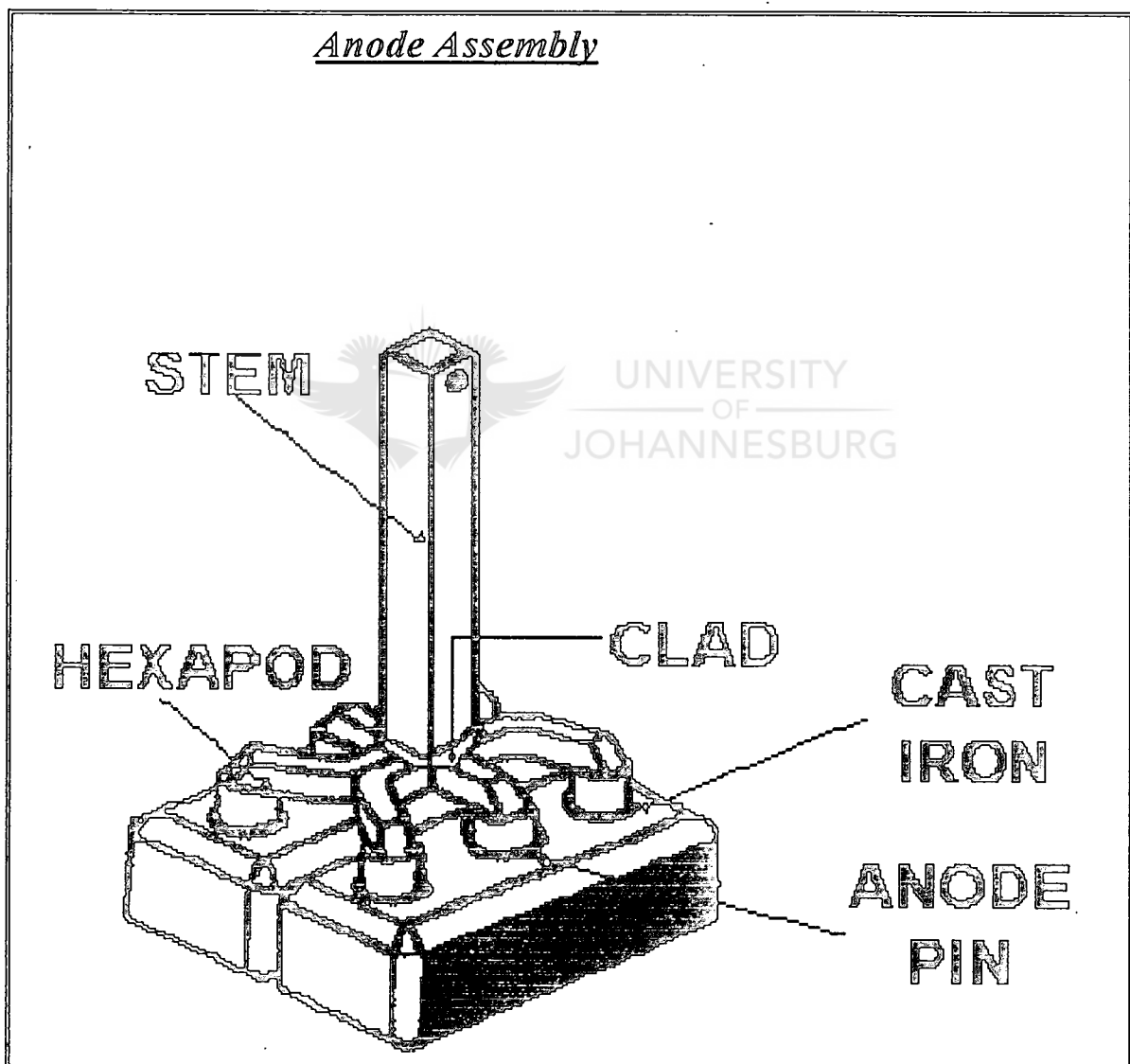
2.3.1 Coke

Coke is a by-product of a crude petroleum oil refinery. It has the texture of small stones, and is black in color. It is product mainly in Europe (0,9 million tons per year) and in the

2.3.2 Pitch

During the production of coal, tar is produced as a by-product, which is then further refined to produce pitch. This pitch is a black, highly viscous liquid product. The paste plant correctly mixes these two products, and then moulds the mixture into a block consisting of the above dimensions. The formation is done by a vibrocompacting machine, which firmly compacts the coke and pitch together resulting in a product known as a **green anode**.

FIGURE 2.2: Anode assembly



Source: Adapted from Alusaf Training Module 1994. Rodding shop

Pitch acts as the binding product in the process. It can be described as a glue used to hold together all the grains of carbon. As will be seen in the next section (baking furnace), the pitch transforms from pitch to coal at a certain temperature to produce the solid carbon block.

2.4 THE BAKING FURNACE

The green anodes are taken to the baking furnace where they are baked at a temperature of about 1200°C. The reason for the baking is manifold, and can be described as follows (Alusaf Training Module 1994. Baking furnace: The process):

1. *Converting pitch to coke.* Pitch is the binding element in the green anode. During the baking process, the pitch is converted to coke, resulting in a homogeneous **baked anode** very rich in carbon.
2. *Improving the mechanical property of the anode.* The anodes have to withstand very high temperatures in the pots. If the mechanical property is not of an acceptable level, the anodes will break up in the pots. This could lead to the production of substandard aluminium, which is rejected, resulting in Alusaf losing money.
3. *Ensuring electrical conductivity in the anode.* The reaction is based on electrolysis - hence these anodes need to be electrically conductive, and this is what baking ensures. As the pitch is transformed to coke, the anode as a whole becomes more electrically conductive.
4. *Obtaining the lowest possible differential chemical reactivity.* This ensures that all the anodes react in the same way in the pots. During mixing in the paste plant, a certain portion of the anode may have more pitch than another part. During baking, the pitch is transformed into coke, ensuring that the whole anode block has the same properties. Controlling the process over a long period of time, also ensures that all the anodes react in the same way in the pots over that period.

On completion of this process, a baked anode emerges. This is then physically ready for aluminium production. The problem is that the anode cannot be thrown into the pot. It has to be attached to an aluminium stem in order to insert, take out and control the anode assembly in the pot.

For this operation, the anodes are taken to the rodding shop where they are married to a stem to produce anode assemblies (figure 2).

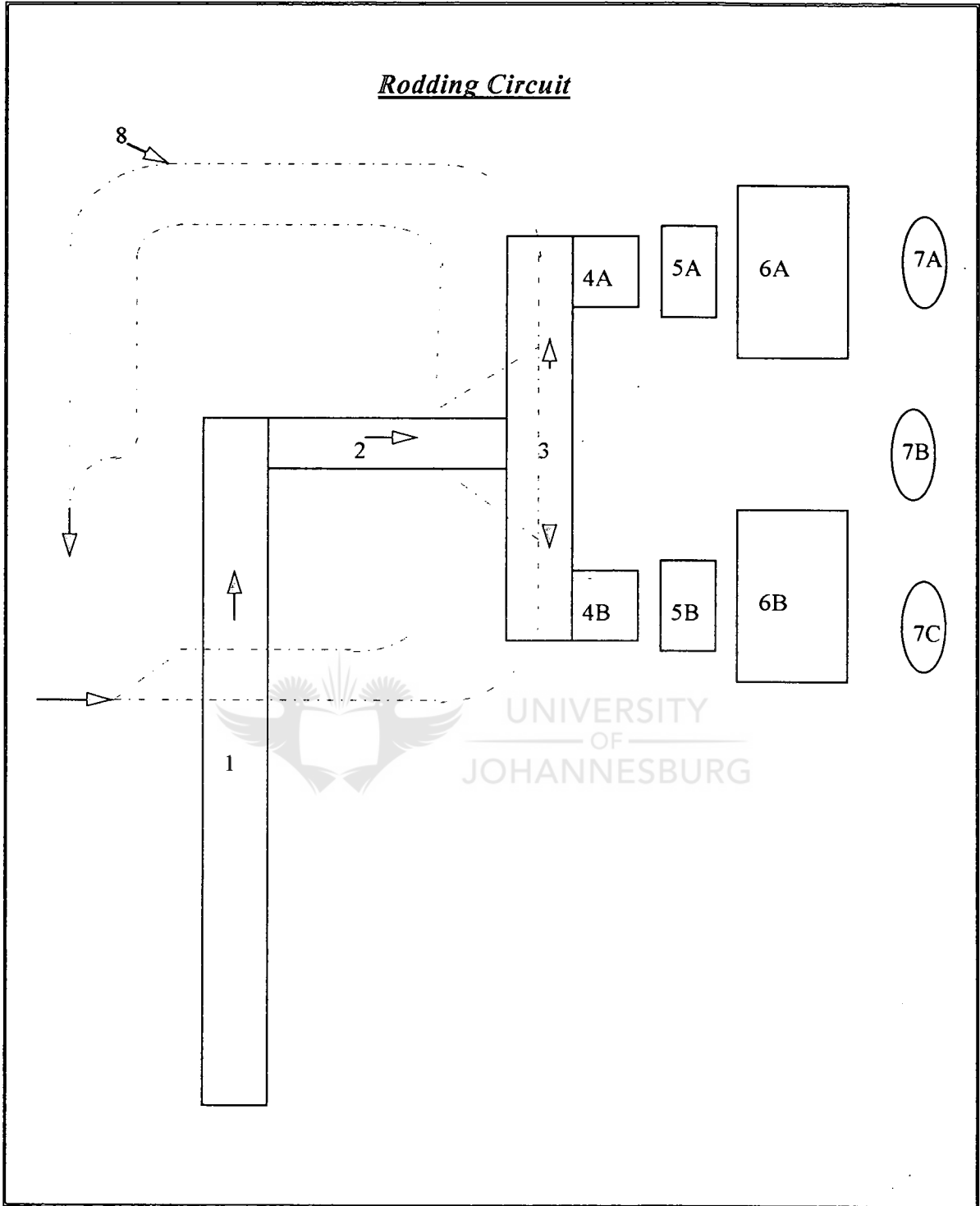
2.5 THE RODDING SHOP

The rodding shop consists of two main circuits, namely the rodding circuit and the spent anode stripping circuit. The main functions of the two circuits will be discussed below.

2.5.1 The rodding circuit

The rodding circuit (figure 2.3) matches the stems to the anodes and attaches them together by means of liquid cast iron. The baked anodes enter the rodding shop from the storage area. Items 1, 2 & 3 in figure 3 are the roller conveyers bringing the anodes in from the storage area. The baked anodes are stored in this area after being baked in the baking furnace. A prematching station centers the pins in the anode holes to ensure compatibility between the anodes and the stems (figure 2.3 [4A & 4B]). The matched pair is then transferred to the casting table (figure 2.3 [5A & 5B]).

FIGURE 2.3: Rodding circuit



Source: Adapted from Hillside Smelter engineering drawings

A casting machine (**figure 2.3[6A & 6B]**) pours melted cast iron into the holes, assuring attachment. The casting machine gets the liquid cast iron from three induction furnaces (**figure 2.3[7A, 7B & 7C]**). The end product obtained after this process is called an anode assembly [see figure 2.2]. The anode assemblies are taken to the storage area and then to the potroom.

The overhead power and free conveyer (**figure 2.3[8]**), introduce the stems to the matching station. Once the anodes and the stems have been attached, the overhead power and free conveyer evacuate the anode assemblies from the matching station.

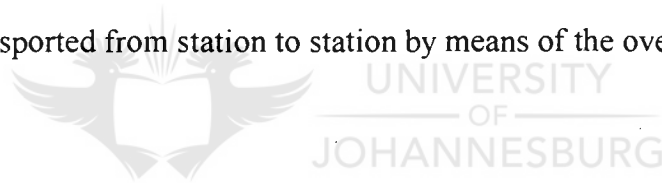
2.5.2 Spent anode stripping circuit

The anodes in the anode assembly are partially used in the pots. About 20 cm of the total height remains after usage. This can be effectively recycled, resulting in a substantial saving. The path which the anodes follow can be described in figure 2.4 as follows:

1. *Hooking station*. (**figure 2.4[1]**). The spent anode assemblies are hooked on to the overhead power and free conveyer. They are transported to the hooking station by means of a pallet transporter.
2. *Bath precleaning station* (**figure 2.4 [2A & 2B]**). These machines remove the primary bath accumulated on top of the anodes. Figure 2.1 illustrates the bath on top of the anodes. These stations use a mechanical method to insert large pins into the bath on top of the anodes to remove it.
3. *Finishing machine* (**figure 2.4 [3A & 3B]**). This is the secondary bath cleaning machine. Brushes ensure that the last pieces of bath are removed from the top of the anodes.
4. *Inspection station* (**figure 2.4[4]**). If any bath remains after the primary and secondary cleaning, it is manually removed by a jackhammer.

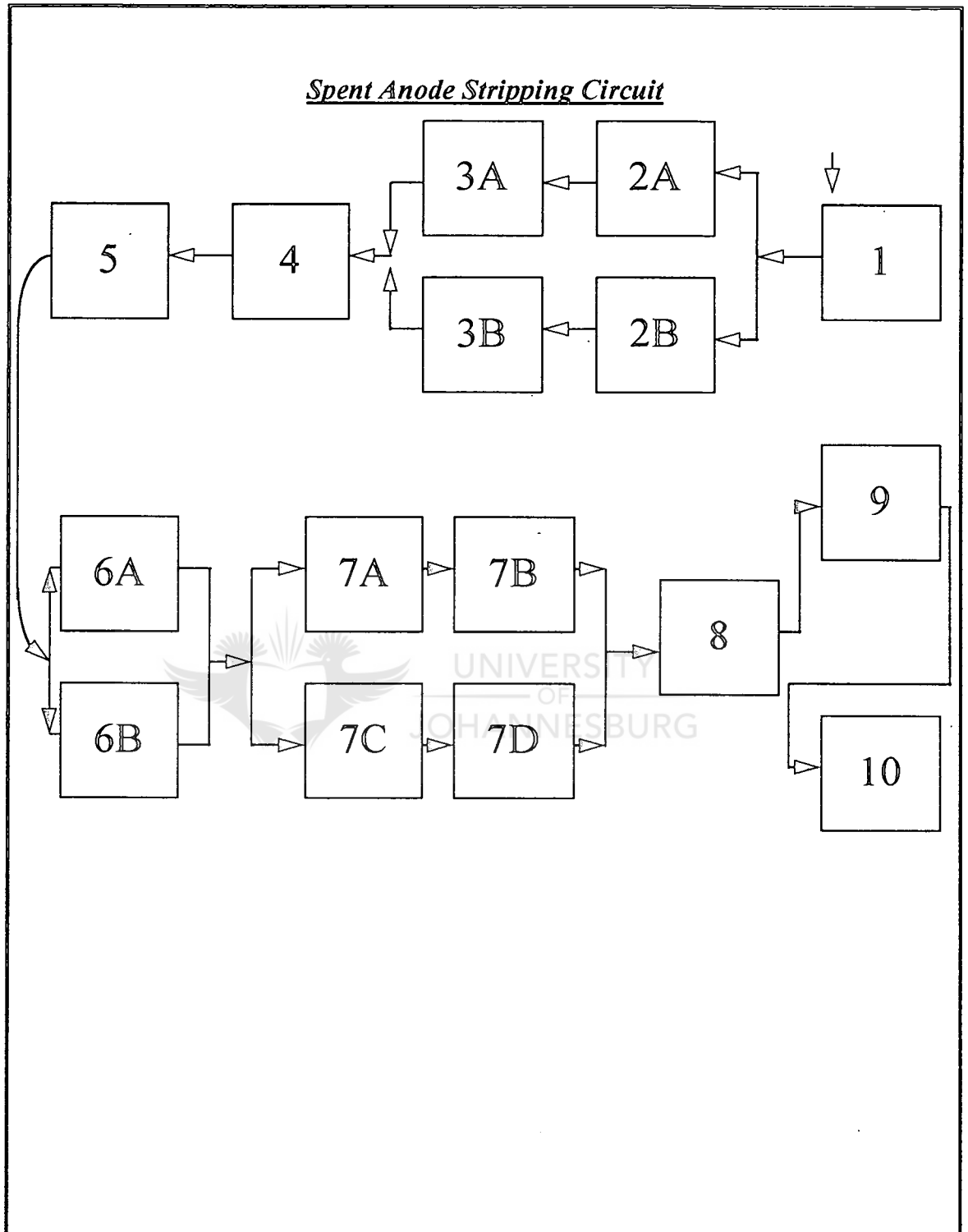
5. *Shotblasting (figure 2.4 [5])*. Shotblasting cleans the small pieces of bath which were not removed by the previous methods.
6. *Carbon stripping machine (figure 2.4 [6A & 6B])*. The 20 cm carbon left over is removed at this station.
7. *Thimble stripping (figure 2.4 [7A, 7B, 7C & 7D])*. During this operation, cast iron used to attach the anodes to the stem pins is removed from the pins.
8. *Stem inspection (figure 2.4 [8])*. If the stems are damaged, they are removed from the system and repaired before usage.
9. *Stem brushing (figure 2.4 [9])*. The used stems are cleaned from oxidation, bath and alumina. Brushes are used. The stems must be clean to ensure that they are good electrical conductors.
10. *Graphite coating (figure 2.4 [10])*. The pins are coated with a graphite coat to ensure effective attachment to the cast iron. This step also ensures that there is no molecular bonding between the stem pins and the cast iron.

The stems are transported from station to station by means of the overhead power and free conveyer.



The functions described above, are the broad functions of each subfunction in the carbon department. An in-depth discussion of the functions falls outside the scope of this study.

FIGURE 2.4: Spent anode stripping circuit



Source: Adapted from Hillside Smelter engineering drawings

2.6 PROBLEM ORIENTATION

During the construction of Hillside, two main parties were present. They are ALPROM (Alusaf Project Management) and AOT (Alusaf Operational Team). The former was responsible for constructing the plant and presenting it in a working condition to Alusaf's operational team, the workers who are going to be employed at Hillside.

Hillside as a whole was purchased from an external supplier, and Alusaf project management are only involved in the construction and commissioning phases. Alusaf's operational team have no way of knowing if the systems have an optimal logistical support plan. It is of vital importance to optimize logistical support, and it was therefore decided to evaluate the plan, and identify and correct the problem areas.

This study will focus on the logistical support of the carbon department only, specifically the rodding shop. The rodding shop is the interface between the carbon department and the rest of Hillside. The service they provide, will to a large extent be used as a barometer to judge the performance of the carbon department as a whole.

The rodding shop consists of a wide variety of equipment, the largest portion being mechanical equipment controlled by automation techniques. More than one supplier was used for the construction of the rodding shop. Each supplier has his or her own interpretation of logistical support. Hillside has its own requirements as far as logistical support is concerned. The supplier's perception needs to be married to Hillside's requirements and deficiencies need to be identified and sorted out. If the logistical support is not optimal for Hillside's unique requirements, this will result in substantial amount of unnecessary financial wastage.

There are approximately 100 pieces of main equipment in the rodding shop itself. This varies from roller conveyers, hydraulic power units to induction furnaces and other big

mechanical machines. The challenge to optimize the supportability for their equipment is vital for the successful operation of the carbon department.

2.7 SUMMARY

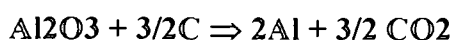
Alusaf is one of the 10 largest producers of primary aluminium in the world. Alusaf consists of Bayside Smelter and Hillside Smelter. Hillside is currently being constructed and will have the newest and most modern aluminium production technology in the world.

Hillside will produce 466 000 tons of primary aluminium per year by the end of 1996, while Bayside produces 174 000 tons per year.

Alusaf and Escom have an agreement to link the price of electricity to the London metal exchange price of aluminium, giving Alusaf a competitive advantage over its competitors.



The production of aluminium is done on the basis of electrolysis. The simplest form of the aluminium reaction can be described as follows:



The carbon (C) ingredient in the reaction is supplied by the carbon department. The carbon department supplies the carbon by means of anodes (large blocks, rich in carbon).

The carbon department is one of the subfunctions of Hillside, and consists of the following:

- *The paste plant.* Here coke and pitch are mixed in the correct mixture. The mixture is then compacted into a green anode.

- *The baking furnace:* The baking furnace bakes this anode to make it electrically conductive and to increase the mechanical properties. The end result is a baked anode.
- *The rodding shop.* In the rodding shop these anodes are attached to stems so that they can be insert into the pots to join in the above-mentioned reaction and make aluminium .

This study will be conducted in the rodding shop. Because this shop consists of equipment purchased from different suppliers it is of vital importance to determine the gap between the supplier's view of supportability and Hillside's requirements for supportability. To optimize the rodding shop, it is necessary to determine these differences and rectify them.



CHAPTER 3

CRITICAL AREAS OF EVALUATION

3.1 INTRODUCTION

In order to evaluate the logistical support system at a satisfactory level, the following aspects of logistical support will be evaluated in depth:

- reliability.
- maintainability.
- vendor supportability.
- data.

Each area will be researched, and the important aspects documented in this chapter. The following paragraphs highlight the importance of logistical support.

According to Wilson (1992: 33-40) if logistics is to become a source of competitive advantage, the service offered must be more appropriate than that offered by competitors. This would mean having a good understanding of the logistical requirements of the company, and striving for the optimization of the requirements. Alusaf finds itself in a situation in which its product's price is determined by the London Metal Exchange (LME). The only variable Alusaf can control to improve its profit is to reduce its operating costs. Total tonnage per year is fixed and the product price is not under Alusaf's control. If Alusaf can improve its logistical support, it will have an edge over its competitors because its operating costs will be reduced (Alusaf Employers Report 1994-1995). Alusaf will feel less strain when the aluminium price starts to decline.

According to Calberg (1994:23-24), " One of the great challenges facing corporate management today is the need to clarify for their employees, in a simple and instructive way, a number of fundamental economic facts that have a direct influence on

profitability.” The importance of logistical support needs to be emphasized and its should be made clear to everybody. Alusaf faces tremendous challenge firstly to identify all the problems in its logistical support, and secondly to ensure that all employees are aware of the benefits.

Research has shown that the perception that logistical executives or support service providers have of the importance of logistics service will affect what type and which levels of service will be offered (Novac et al 1994: 113-152). It is therefore important to obtain management support if a successful logistical support system is to be implemented.

Byrne et al (1993: 41-45) makes a powerful statement about logistical support: “An effective logistics process is a competitive necessity for a leading company”. Alusaf has the best technology in the world and it would be a tragedy if the competitive advantage given by this were to be neutralized by an ineffective logistical support system.

In a recently released Canadian study involving their top 10 companies, it was shown that there is a correlation between top performance and the implementation of a quality improvement programme focused on the logistics process (Byrne & Patrick 1993: 41-49). This study verifies that logistical support awareness among managers is crucial. Before any other area of logistical support is considered, management’s approval and corporation must be obtained.

The improvement of logistical systems is a worldwide phenomenon. European companies have reported an increase in logistical productivity of about 12 percent (Byrne & Patrick 1992: 45-50). Alusaf is the only producer of primary aluminium in South Africa, and will therefore have to compete in the international marketplace. Europe is a big producer of aluminium. If Alusaf wishes to keep the competitive edge, it must not only equal its

competitors but also beat them. This means improving logistical support at a faster rate than that of its competitors.

3.2 RELIABILITY

According to Blanchard et al(1981:326) a typical reliability plan should consider the following topical areas:

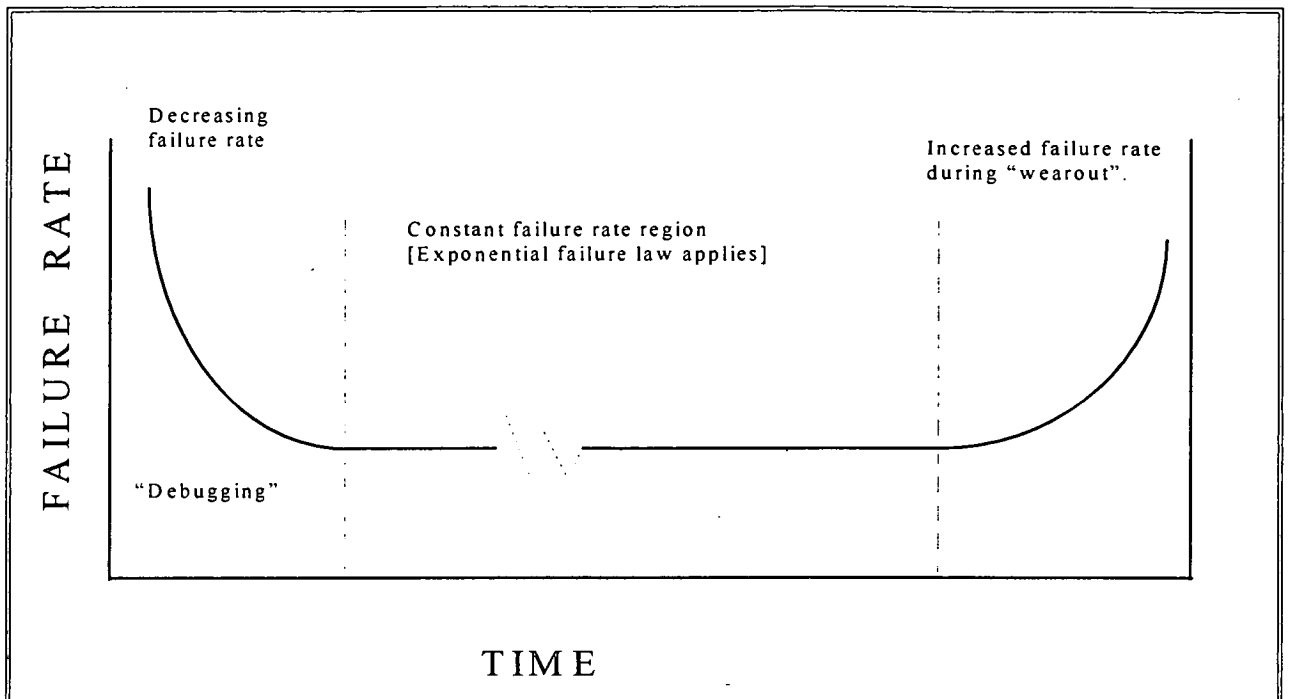
- reliability quantitative and qualitative requirements for the system, the generation of block diagrams and allocation or apportionment of reliability requirements to the subsystems and beyond (as appropriate) (figure 3.3).
- critical useful life analysis.
- failure mode and effective analysis and criticality analysis (FMECA).
- reliability predictions and assessment.
- stress, strength analysis.
- reliability tests and evaluation.
- data collection, analysis and corrective actions.

The system lifecycle will typically have hazard rate distribution, as shown in figure 3.1 (Billinton & Ronald 1987: 135).

Figure 3.1 illustrates the importance of being able to predict the wearout phase, and by means of preventive maintenance lengthening the constant failure rate region. Preventive maintenance will have to be scheduled to such an extent that an acceptable probability will exist for the system to be able to survive for a certain period of time.

The debugging period must be kept as short as possible. This can mainly be achieved during precommissioning and commissioning. The whole reliability module must be designed to minimize the debugging and wearout phases.

FIGURE 3.1: Hazard rate distribution



Source: Billinton & Ronald 1987: 135

The systems must adhere to a specified availability rate. The availability rate (inherent availability) can be defined as follows: (Alusaf Hillside specifications 1994):

$$A(i) = \frac{\text{Mean time between failure}}{\text{Mean time between failure} + \text{mean time to repair}}$$

A(i) = The probability that a system or equipment, when used under stated conditions in an ideal support environment (ie, readily available tools, spares, maintenance, personnel etc.) will operate satisfactorily at any point in time as required. It excludes preventive maintenance actions, logistical delay time and admin delay time. (Blanchard et al 1981: 337).

MTBF = Mean time between failure.

MTTR = Mean time to repair

Mean time between failure can be divided into categories to identify most frequent problem areas, for example:

- manual defects.
- operator and maintenance defect.
- dependent failures.

Analysis of the classifications can provide a good indication of the sources of the most frequent breakdowns.

A progressive reliability block expansion diagram has to be developed for the rodding shop as a whole. This diagram will be broken down into the smallest unit. The true reliability will be computed and it can be seen if the required reliability is actually met (Blanchard & Fabrycky 1981: 340). This concept is shown graphically in figure 3.3.

3.2.1 Quantiyative and qualitative requirements

System quantitative requirements must be defined. These will typically include specifications such as $R(t)$ [reliability], MTBF[mean time between failure], MTBM [mean time between maintenance] and λ [hazard rate].

A typical evaluation will be conducted as follows: the required quantitative factors will be specified for the system as a whole. This will come from the design specifications. Each block in the progressive reliability block diagram will be quantitatively defined. Evaluation will determine if the integration of all the blocks gives the required specification (figure 3.3).

As a rule, the specified requirements for the system as a whole will be known. These will be the requirements of LEVEL I (figure 3.3). The true reliability of the system components will be computed from the lowest level (LEVEL V). Using progressive computation, the true system reliability will be known and a comparison can be drawn.

3.2.2 Critical useful life analysis

According to Blanchard & Fabrysky (1981: 353), critical useful life items are items that cannot fulfil their functional requirements if corrective or preventive maintenance is not performed on them. A good example is the sparkplug in a motor vehicle. If the sparkplugs are not properly maintained, the car will soon be unable to perform its functional duties. An optimal preventive maintenance plan for these systems is essential.

The rodding shop also needs a preventive maintenance plan. If machinery is operated until breakdown, effective planning is impossible. Preventive maintenance must be scheduled in such a way that machinery operates from shutdown until shutdown. This can only be done with a carefully planned preventive maintenance plan. A critical useful life analysis needs to be done to ensure that all the equipment in the rodding shop operates from shutdown until shutdown.

3.2.3 Failure mode, effect and criticality analysis (FMECA)

Failure mode, effect and criticality analysis determines the ways in which equipment can fail and the effects of such failure on other elements. Failure mode, effect and criticality analysis will typically include the following (Blanchard & Fabrycky et al 1981: 353):

- an identification of each item that is likely to fail.
- a description of the failure modes (this will typically include how the equipment will fail, under what operating conditions, ect).
- the causes of failure.
- possible results of failure, for example complete equipment destruction or partial system operation, (to what extent does this failure hinder the successful completion of the system mission?).
- Probability of assurance.

- criticality of failure, which can be classified as minor failure, major failure, critical failure and catastrophic failure.
- possible corrective actions or preventive measures to be taken.

As mentioned in chapter 2, Alusaf purchased the technology from an overseas supplier. In the purchasing contract, it was stipulated that specialists from different aluminium smelters throughout the world will assist Alusaf operations during the commissioning phase.

It is crucial for Alusaf to ensure that the failure mode, effect and criticality analysis phase are completed before these specialists finish their contract and return to their respective plants. They have the knowledge to make the failure mode, effect and criticality analysis extremely easy and complete.

3.2.4 Reliability predictions

Once the system becomes operational, its true reliability will have to be evaluated. This will indicate the probability of a device achieving its purpose adequately for the period of time intended under the operating conditions encountered (Billinton & Ronald 1987: 2). Miller & Freund (1985) add to the above definition in saying that the limits within which the system operates should also be defined. If the system operates for a period of time under specified conditions but outside its limits, one can expect it to be less reliable.

This reliability will be evaluated against the specified reliability. The evaluated reliability will drive the maintenance plan and will also indicate the quality of maintenance that needs to be done on a particular system.

The importance of an accurate reliability evaluation will be twofold:

- to determine if the system is as reliable as specified.
- to determine a maintenance plan that will optimally integrate with the performance of each system.

3.2.5 Stress, strength analysis

Components can either be used to their full designed potential (or above) or well below its potential. In the case of the former components are more likely to fail and not complete their functional task. If they are used under their designed capacity, they will be far more reliable and likely to complete their mission.

Another form of overdesign is redundancy. This is a situation in which there is more than one component able and ready to perform the task. If the operational component fails, the redundant component takes over. Billinton & Ronald (1987: 490) point out that a system with redundant components will have a higher reliability than one without redundancy.

Redundancy and overdesign both leads to higher financial investment. A balance has to be achieved. If a component fails unexpectedly because of overusage, the financial losses incurred by production loss might be so great that use of a component well below its potential is a better and safer situation to be in.

3.2.6 Reliability test and evaluation

Before the system is accepted, a performance test has to be conducted to ensure that the specified functional performance can be met. After testing, the system will fall into one of the following three categories

- rejection region.
- continue testing region.

- acceptance region (see figure 3.2).

The results obtained will determine the course of action specified in figure 3.2. Before a system is accepted, it must meet the requirements specified in the acceptance region. If systems that do not meet these requirements are accepted, then the specified availability, production rates and general performance specifications will not be met.

3.2.7 Data collection, analysis and corrective actions

Data collection, analysis and corrective actions entail an ongoing process. During operation, data are captured and converted into useful information. Problematic areas are evaluated and corrective action taken. The reliability factors must be monitored constantly. If an unacceptable value is shown, corrective action must be taken.

3.3 MAINTAINABILITY

Maintainability refers to the ability of an item to be maintained in the least amount of time at the lowest cost. According to Blanchard & Fabrycky (1981: 371), maintainability is the ability of an item to be maintained, whereas maintenance constitutes a series of actions to be taken to restore or retain an item in an effective operational state.

3.3.1 Measures of maintainability

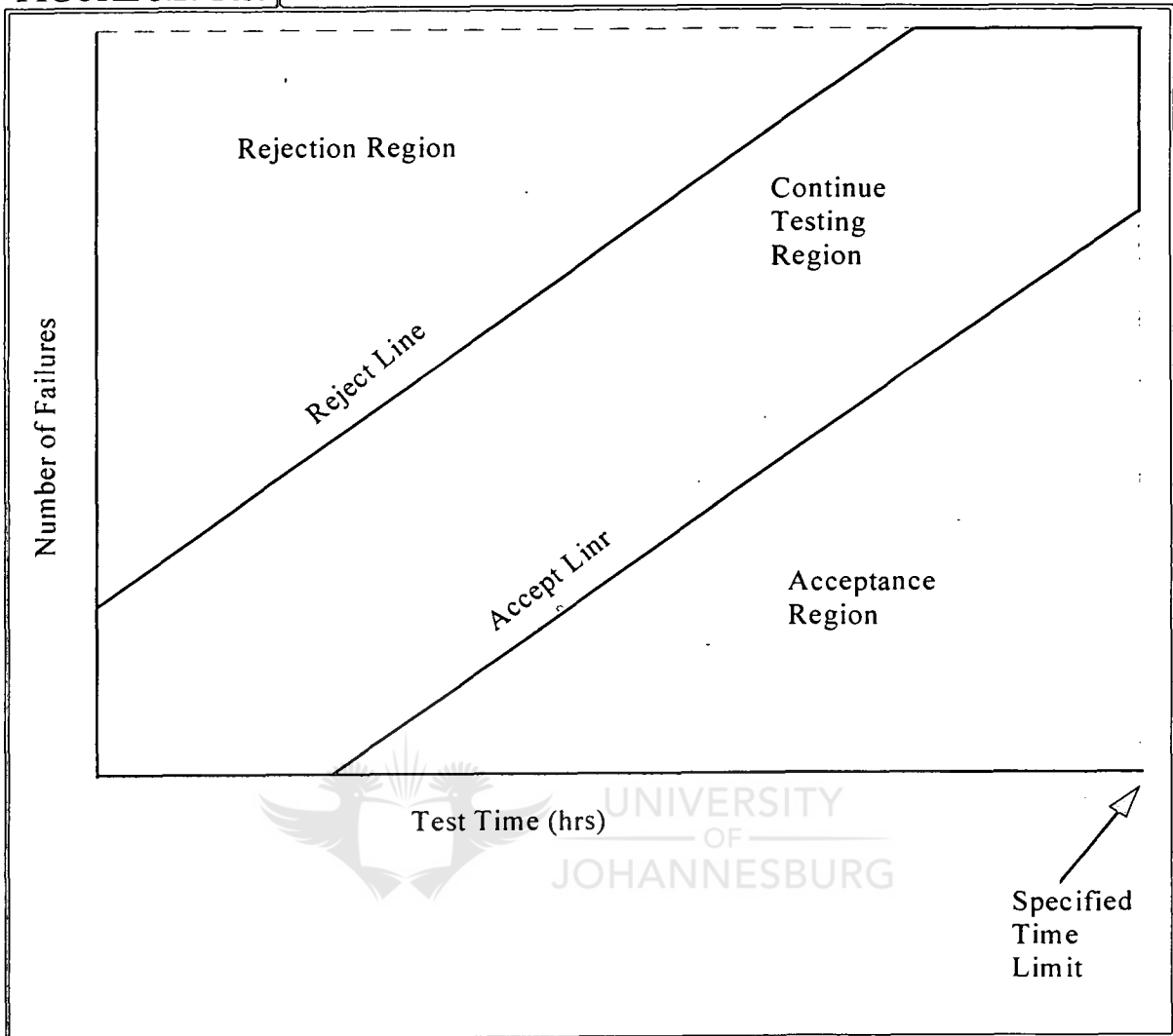
Blanchard & Fabrycky (1981: 375-385) define maintainability and identify good measures of maintainability as follows:

Maintainability is the ease and rapidity with which a system can be maintained and is measured in terms of the time required to perform maintenance tasks.

Good maintainability indicators:

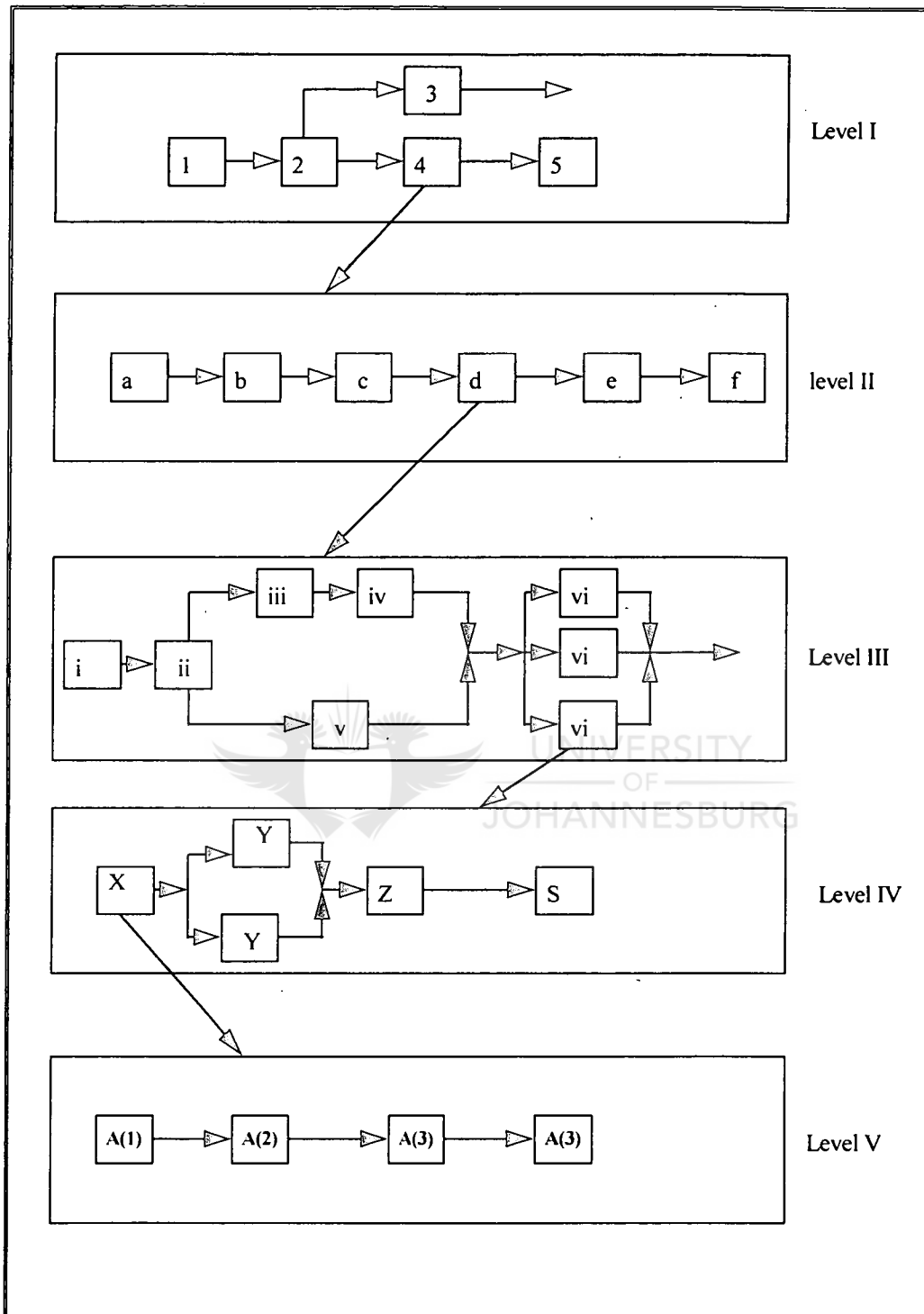
1. Mean corrective maintenance time (mean time to repair) (Mct). This value includes only the active maintenance time, and excludes the logistical and administrative delay times. It is a measurement of the system's availability seen in isolation. It does not take into account the maintenance environment in which the system operates. If the maintenance response times are slow, or the lead time for spare parts is sub-standard, then mean corrective maintenance time will not be influenced. This is a good measurement to use when a system's performance is measured for the purpose of accepting or rejecting the system.
2. Mean preventive maintenance time (Mpt). This is a controllable parameter used to control other parameters. It might be decided to increase this time in order to lengthen the mean time between failures.
3. Mean active maintenance time (M). This parameter includes maintenance times for corrective and preventive maintenance. Analysis of this figure provides a good indication of the total maintenance cost of a system.
4. Logistical delay time (LDT).
5. Administrative delay time (ADT).
6. Maintenance down time (MDT). This includes logistical delay time, administrative delay time and mean active maintenance time. Identifying logistical delay time and administrative delay time can provide an indication of the effectiveness of the maintenance service department. If these times are constantly high for a particular system, this could be an indication that the specified stock level is not sufficient. An investigation might highlight the problem and reduce these times substantially. Another important feature of maintenance downtime is that it integrates the effectiveness of the system with the effectiveness of the maintenance environment in which the system operates. At the end of the day, it is maintenance downtime that keeps the system out of

FIGURE 3.2: Test plan



Source: Blanchard & Fabrycky (1981: 359)

FIGURE 3.3: Progressive block diagram



Source: NAVAIR 00-65-502 (1968)

production, and this time needs to be minimized as much as possible. Byrne & Patrick (1992: 169-180) emphasize this point. They realize that the logistics process weaves together all major operational functions of the business to meet customer requirements. Firms are starting to use cycle time performance to evaluate the performance of their logistical support functions.

3.3.2 Maintenance frequency factors

There is a close link between maintenance and reliability. Mean time between failure and failure rate is the key indicator of reliability. It can be argued that mean time between failure is an indication of corrective maintenance. If mean time between failure is improved, corrective maintenance will be reduced.

Preventive maintenance is usually induced to improve system reliability (improve failure rate). It should be noted that preventive maintenance can be a very costly and timeconsuming exercise. It is therefore essential to optimize the amount of preventive maintenance to keep costs as low as possible.

The cost of production loss, might justify a higher degree of preventive maintenance. Equipment that is vital for the completion of the primary mission will generally receive more preventive maintenance than support systems.

Mean time between maintenance takes into account the time between corrective and preventive maintenance. This figure will indicate the overall availability of a system. If a system never fails but requires frequent preventive maintenance, then it will reduce the mean time between maintenance. A system that has a long mean time between maintenance, is a well-designed system because it requires little preventive maintenance. It is very reliable because it has a low failure rate and will require little corrective maintenance.

3.3.3 Maintainability in system/product design

3.3.3.1 Maintainability requirements

The ultimate measure of system's success, is to measure its ability to fulfil its mission. Maintainability contributes significantly to this ability. If maintainability is difficult, the system's performance will decrease and hence its ability to perform its mission.

For the system to be defined as maintainable, it is necessary to pay attention to the following factors during system design (Blanchard & Fabrycky (1981: 390) :

1. system performance factors, (during commissioning, performance tests will be used to verify the design specifications).
2. analysis of the conditions under which the system will be used, (the system should be designed accordingly).
3. definition of the system support concept:
 - anticipated level of maintenance.
 - responsible persons/installations for maintenance.
 - prime elements of logistical support for each level of maintenance (eg spare parts, facility, etc).

The foregoing factors determine to what extent and what maintainability characteristics should be incorporated to ensure the specified system availability.

If the system's specified availability is, say 95 percent and its reliability is relatively low, then a high degree of maintainability is required to ensure the specified availability.

Conversely if the reliability is high, the maintainability requirements will be less.

Keeping the foregoing requirements in mind, quantitative requirements need to be defined for the system. This will entail elements such as mean time between failure, mean time between maintenance and mean time to repair.

Another factor that should be studied, is the failure rate of the system. This rate can be used to determine the allocated maintenance time (preventive maintenance) per system. If the system's anticipated failure rate is relatively high, the preventive maintenance allocated to that system will be higher compared to a system with a lower failure rate.

By keeping an accurate record of all maintenance actions, the actual failure rate can be computed, and one can see where excessive preventive maintenance time has been allocated, or where insufficient time has been allocated. By optimizing these allocations, money and time can be saved and production losses due to breakdowns can be reduced.

3.3.3.2 Maintainability analysis

To illustrate how maintainability analysis can evaluate alternative repair policies, logistical plans, etc Blanchard (1978) presents the following example:

An existing system needs to be replaced. Three alternatives are being considered. The availability, mean time between failure and estimated mean repair time are illustrated in table 3.1 . All three alternatives satisfies the specifications. A decision has to be made as to which system will be the best.

As can be seen in table 3.1, alternatives A and C have the best availability. Alternative A, however, has a good mean time between failure but a relatively bad mean corrective maintenance time. Alternative C on the other hand has a good mean corrective maintenance time, but a relatively bad mean time between failure.

Research has shown that increasing investment in research and development will result in a lower operational and maintenance cost. Optimizing all the costs, will give a good indication of the most feasible alternative. Refer to table 3.2 for the analysis and the indication of the optimal alternative.

TABLE 3.1: Alternatives

Alternative	Availability	Mean Time Between Failure	Mct
Existing	0,961	125	5
Alt. A	0,991	450	4
Alt. B	0,990	375	3,5
Alt. C	0,991	320	2,8

Source : Blanchard (1978)

TABLE 3.2: Evaluations

Category	Alt A	Alt B	Alt C	Remarks
R and D cost				High reliability parts, packaging, accessibility
◦ Reliability design	R 17 120	R 15 227	R 12 110	
◦ Maintainability design	R 2 109	R 4 898	R 7 115	
Investment cost manufacturing (200 systems)	R3 422 400	R3 258 400	R3 022 200	R-17 112/Equipment A R-16 292/Equipment B R 15 111/Equipment C
Operational and maintenance cost				12 800 Maint.actions/equip A
◦ Maintenance personnel and support	R1 280 000	R1 536 000	R1 800 00	15,360 Maint. actions/equip A 18,000 Maint. actions/equip A
◦ Spare/repair parts.	R 342 240	R 325 840	R 302 220	
TOTAL	R5 063 869	R5 140 365	R5 143 645	

Source: Blanchard (1978)

This example illustrates that alternative A satisfies the specifications at the lowest cost. It is thus important to keep the financial aspect in mind when making maintainability decisions.

According to Lahiri (1992: 75-80), the logistical decision-making process in a real-life situation can be substantially improved by developing and implementing a decision-support modelling system which incorporates and integrates both quantitative and qualitative factors in a logical and consistent manner. The type of example indicated above, can be computer modelled to improve the decisionmaking process even further.

Cooke (1994: 64-68) supports this point of view when he says that companies in the USA are benefitting noticeably in their logistical support efforts by means of efficient information technology.

3.4 VENDOR SUPPORTABILITY (SUPPLY SUPPORT)

Vendor supportability and supply support are the ability of the vendor to supply on time, the correct spare part in the specified working order. Supply supportability also refer to the maintenance department to supply repaired parts at the right time in the correct working order. If one of the above mentioned fails, the logistical support chain is broken, and consequently, suboptimal logistical support is given.

According to Byrne et al (1992: 45-50), logistical excellence can be used to achieve total supply quality chain. Strong links and mutual trust need to be present between the company and his supplier.

The optimum level of stock needs to be identified to support the system at the defined level. If maintenance time is analyzed and it is clear that the administrative and logistical

delay times are very high compared to other maintenance actions, this could mean that the defined stock level is unacceptable. It may be necessary to redefine the item stock level.

It would however, be financially unwise to keep items in stock for very long periods of time. The holding costs will be a waste of money. If the particular equipment is an integral part of the system's ability to complete its primary mission, and loss in production due to breakdown is larger than the holding costs, it may be necessary to overdefine stock levels to ensure that breakdown does not occur with production.

The **probability of mission completion** with the defined stock level is a crucial important indication of overall logistical efficiency. As illustrated in figure 3.1, between the debugging and wearout phases, the constant failure rate region is found. What is important in this phase is that the system operates from shutdown to shutdown. If it fails between shutdowns, then a spare part must be available. Miller et al (1985: 455) defines failure time distribution as the distribution of time to the failure of a component. If this failure time distribution is integrated with stock levels, then one can compute what stock level is needed (for a given failure time distribution) to maximize the probability of mission completion.

A typical calculation would determine the probability of a system completing an X-hour mission with a known failure rate. The calculations will be handy in situations where definite equipment shutdown is scheduled for maintenance. The probability of a system completing the time between shutdown without failure can be computed. If this probability is acceptable, it is a good indication that the stock level integrates well with the scheduled maintenance shutdown.

Another indication of spare part effectiveness is the determination of the amount of spare parts needed for optimal protection. Billinton & Ronald (1987: 277) point out that at a certain level of spare parts there will be no further gain. It is important to determine this

limit because this will indicate (with a given number of spare parts), how close the system availability is to the theoretical limit. It is thus logical to say that the optimal protection level will coexist with the level which there will be no further gain for the system.

It is important to distinguish between different philosophies behind spare part determination. Determining the spare parts for primary mission equipment critical for the success of a system, will be handled different from a system that merely supports the prime mission equipment. High cost items will be treated differently from low cost items and so forth.

The following list will be used to evaluate vendor (supply) supportability (Blanchard 1976: 497):

1. Have the distribution channels and inventory points for spare/repair parts been established?
2. Are the types and quantity of spare/repair parts compatible with the system maintenance concept, the logistical support analysis and level of repair analysis data?
3. Are the types and quantity of spare/repair parts designated for a given location appropriate for the estimated demand at the location? Too many or too few spares can be costly.
4. Are spare/repair part's provisioning factors (eg replacement frequencies) directly traceable to reliability and maintainability predictions?
5. Are the specified logistics pipeline times compatible with effective supply support? Long pipeline times place a tremendous burden on logistical support.
6. Have spare/repair part requirements been minimized as far as possible?
7. Have test and acceptance procedures been developed for spare/repair parts? Spare/repair parts should be processed, produced and accepted on a similar basis to their equivalent components in the primary equipment.
8. Have the consequences (risks) of stock-out been defined in terms of the effect on the mission requirements and cost?

9. Has an inventory safety stock been defined?
10. Has a provisioning or procurement cycle been defined (procurement or order frequency)? Have economic order quantities been defined?
11. Has a supply-availability requirement been established (the probability of having a spare available when required)?
12. Are spare/repair parts completely interchangeable with comparable elements of primary mission equipment which they must support? Have the spare/repair parts been modified to incorporate the applicable changes made in the primary equipment?

According to Chase & Aquilano (1992: 854), just in time (JIT) purchasing is an extremely effective and economical way of purchasing consumable and high volume products. The relationship with the suppliers needs to be of a high quality and trust and continuity of service are vital. To ensure effectiveness in this system, the following aspects are essential:

1. reduced lot sizes.
2. frequent and reliable delivery schedules.
3. reduced and high reliability in lead time.
4. consistently high quality levels in the supplied products. Because the philosophy of just in time is followed, the reject rate must be as close to 0 percent as possible because only the necessary is ordered.

Byrne (1992: 66-67) is convinced that the emerging demand of just-in-time and quick response inventory replenishment and electronic data interchange will force companies to identify requirements and define offerings faster and more frequently.

The end objective would be to have a single reliable source for each product. One should bear in mind that risk is involved in this kind of single supplier concept. If the supplier were to experience a problem with his supplies, one's production could be badly hampered because supply continuity is stopped. What would typically happen in such a

agreement, is that the supplier would agree to the following being introduced in the contract: *If the supplier cannot deliver the correct amount of goods at the right time to the customer, the customer can buy the product at any vendor, and the difference in price will be for the supplier's bill.*

The supplier accepts this kind of agreement because he is assured of a profitable and long-term contract from the customer. This is obviously a win win situation for the customer and supplier.

3.5 DATA PLANNING

Whitten et al (1989: 51) distinguish between data and information. They define the difference as follows:

Data:

Data are raw facts in isolation. Data describes the business. These isolated facts convey meaning but generally are not useful by themselves.

Information:

Information is data that has been manipulated to be useful to someone. In other words, information must have value, or it is still data. Information tells people something they don't already know or confirms something they suspect.

These definitions are extremely relevant in the design of data/information valuable to the business. The important elements that are key performance areas in organizations should closely be monitored. These readings/results will typically be data describing the business. These data would then have to be "transformed" into information in order to absorb the data and take actions accordingly. In the rodding shop, this is a crucial aspect because from the outset, relevant data need to be analyzed, and appropriate information needs to be extracted from them in order to make data planning successful.

Maintenance historical times should also be accumulated. This will help to compute all the maintainability measurements as discussed. Correctly identifying the formats of what information is needed, will ensure correct calculations. The trend's over specified periods of time can be examined to track progress in areas such as availability, maintenance down time et cetera.

These data will assist in identifying the root of the problem. Abdul-Rahman (1993: 20-30) indicates that most control techniques do not identify the root of the problem. The information gathering process must focus on the cause and not the effects of the problem.

IBM uses the accurate data capturing technique to drive *their defect preventive process (DPP)* (Kaplan et al 1993: 51-52). IBM's defect preventive process originally involved three steps, namely:

1. determine the causes of the defect.
2. determine what will prevent the defect from accuring in the future.
3. implement preventive actions.

This defect preventive process can be tailored to the needs of a specific company. IBM take the following steps to make full use of the defect preventive process:

1. form a casual analysis team.
2. use a action team.
3. hold a kickoff meeting.
4. use centralized data collection and storage tools.

Modifying data capturing to suit and solve the problems in the organization is a vital part of any business.

Another aspect of data design, is procedural planning and design. The following checklist can be used to evaluate this aspect of data design (Blanchard 1976: 498):

1. Have system/product operating and maintenance procedure requirements been defined for life cycle?
2. Has the necessary been prepared?
3. Are operating and maintenance procedures compatible with logistic support analysis data? This pertains particularly to the logic troubleshooting flow diagrams, task sequences and support requirements.
4. Are operating and maintenance procedures as brief as possible without sacrificing necessary information?
5. Are operating and maintenance procedures adequate from the viewpoint of presenting simple step-by-step instructions, including appropriate use of illustrations and tables for presenting data?
6. Are operating and maintenance procedures compatible with level of activity performed at the location where the procedures are used? Depot maintenance instructions should not be included in manuals used at the intermediate level of maintenance. The maintenance procedures should be compatible with the level of repair analysis and the maintenance concept.
7. Do the operating and maintenance procedures specify the correct test and support equipment, spare/repair parts, transportation and handling equipment and facilities?
8. Do the procedures include special warning notices in areas where safety is a concern?
9. Are the designated operating and maintenance procedures used in system/equipment test programmes?
10. Are all the procedures adhered to?

3.6 SUMMARY

In order to effectively evaluate the critical aspects of the rodding shop's logistical support, the following topics will be evaluated:

- reliability.
- maintainability.
- vendor supportability.
- data.

For a company to become internationally competitive, it is vital to optimize that logistical support system. Each of the above topics will be evaluated and the important aspects pointed out.

Reliability evaluation will take place under the following headings:

- reliability quantitative and qualitative requirements for the system, the generation of block diagrams & allocation or apportionment of reliability requirements to the subsystems and beyond (as appropriate) (figure 3.3).
- critical useful life analysis.
- failure mode and effective analysis and criticality analysis (FMECA).
- reliability predictions and assessment.
- stress, strength analysis.
- reliability tests and evaluation.
- data collection, analysis and corrective actions.

Maintainability can be described as the ability of an item to be maintained in the least amount of time at the lowest cost. The main criteria for maintainability are as follows:

- measures of maintainability.
- maintenance frequency factors.
- maintainability in system/product design.

Vendor supportability is the ability of the vendor to supply the right product, on time and in the correct condition. Vendor supportability will be evaluated against a 12-point checklist covering the most important points of vendor support.

Data planning comprises mainly the following topics:

- the data needs to be accumulated.
- the way in which these data should transfer into information so that they can be presented in the best possible manner.
- a evaluation of all the procedures that maintenance should have prepared to optimally carry out their function, (this part of data planning will be evaluated against an eight point checklist).



CHAPTER 4

ALUSAF HILLSIDE SMELTER : LOGISTICAL SUPPORT EVALUATION

4.1 INTRODUCTION

The rodding shop is not fully commissioned hence many of the systems are not finished. In cases where the systems that were not fully commissioned were evaluated a forecast was made based on the system's capabilities after commissioning. The systems are evaluated according to their forecast capabilities. This will ensure that systems with good logistical support after commissioning will not be penalized because they are still in an unfinished state.

4.2 RELIABILITY

4.2.1 Quantitative and qualitative factors

The specified reliability (availability) for all the systems in the rodding shop is known. (table 4.1). This is the availability which vendors must ensure their equipment adheres to. Reliability will be tested during performance testing. If the performance testing indicates that the true reliability of level 1 (figure 3.3) is substandard, action will have to be taken. In the rodding shop, the progressive block diagram analysis for each system have not been conducted, and there is no scheduled planning for the analysis. The equipment in the rodding shop is therefore not analyzed to the lowest level. The true reliability of the system is tested by performance testing and not by a progressive block diagram. This is a relatively good procedure for testing the end result, but it is not effective in the sense that it does not show if any of the parts in the lower levels are of a substandard reliability. It generally tests the result and not the cause. If during performance testing, the system does

TABLE 4.1 : The rodding shop's specified availabilities

<i>FUNCTION</i>	<i>SPECIFIED AVAILABILITY %</i>
Hooking / Unhooking station	≥ 92
Bath cleaning stations	≥ 97
Inspection station	≥ 97
Shot blasting	≥ 95
Carbon stripping stations	≥ 90
Thimble stripping stations	≥ 93
Inspection station	≥ 97
Stem cleaning station	≥ 97
Anode pin graphite coating station	≥ 97
Rodding circuit	≥ 90

Source: Adapted from Alusaf Hillside Operational Specifications 1994.

not perform according to its specified reliability, it will be fairly difficult to pinpoint the exact cause of the substandard performance.

PROPOSAL

A progressive block diagram analysis for all the systems in the rodding shop should be conducted. The computed reliability (by means of a progressive block diagram) must be compared with the specified reliability. If there is a deviation, it will be easy to pinpoint areas in the system in which a substandard reliability element is used.

This analysis will assist the rodding shop to identify possible areas in which a system is not designed according to specifications. The progressive block diagram will also help to indicate elements of the system in which failures could occur because a substandard part is used.

4.2.2 Critical useful life analysis

All the systems in the rodding shop need preventive maintenance to meet their functional requirements. Preventive maintenance is scheduled once a week (Thursdays). The whole rodding shop shuts down for preventive maintenance. Because it is impossible to do preventive maintenance on all the equipment, scheduling is done to concentrate maintenance's attention on certain equipment.

PROPOSAL

In the future, systems should be analyzed and monitored to determine actual mean time between failures. It is impossible to attend to all the equipment in the rodding shop every week. Preventive maintenance should be planned in such a way that systems function without or with as few breakdowns as possible between scheduled preventive maintenance periods. Preventive maintenance should be planned according to the information gathered. If maintenance is scheduled on the basis of "*which equipment gave the most problems in the previous week*", then the rodding shop's maintenance schedule will be determined by the equipment instead of being optimally scheduled.

Some equipment might require preventive maintenance once every four weeks, and other equipment once every week. If preventive maintenance is scheduled optimally, then all the systems will receive preventive maintenance at a frequency that corresponds to their performance. This will eliminate a situation in which a system breaks down because of insufficient preventive maintenance. It will also reduce maintenance costs because too much preventive maintenance is done on a particular system.

4.2.3 Failure mode, effect and criticality analysis (FMECA)

The rodding shop has the resources to complete a very accurate and comprehensive failure mode, effect and criticality analysis. As mentioned in chapter 3 (section 3.2.3), specialists are available on a 24hour basis to assist Alusaf operations. The aim is for the specialists to assist Alusaf operational staff and to ensure that the systems are commissioned effectively. A comprehensive failure mode, effect and criticality analysis is being conducted to a large extent. However the problem is that it is done on an informal basis. Specialists may mention a possible failure, the cause thereof and the consequences. The specialist may mention the problem to someone else who does not understand it completely at that stage or because the failure is not relevant at that stage the warning may not be taken seriously or may even be ignored.

Specialists sometimes know about possible failures, but because they have not yet occurred, they do not bother to mention the possibility to anyone. Much information is lost because of this.



The comprehensive failure mode, effect and criticality analysis process needs to be formalized to the extent that all the specialists make a special effort to identify possible breakdowns, their consequences and possible preventions. Alusaf operations need to document all possible problems, their consequences and possible solutions and should become fully aware of each possibility, analyze the severity of the consequences and take appropriate action.

A comprehensive failure mode, effect and criticality analysis will help the rodding shop in its preparation for emergency/breakdown situations. If the rodding shop is prepared when the situation occurs, this save time and money and ensure a safer working environment.

4.2.4 Reliability prediction

Plans are currently in place to design and carry out performance tests. However, Alusaf operations is planning to perform these tests too soon, for the following reasons:

1. The systems are generally going through their debugging phases. The failure rate is higher than normal and the results obtained in performance testing will indicate the results of a wrong region - debugging instead of a steady state.
2. Many of the systems are not yet operating under full load. The results obtained from testing will once again give readings of a system operating under only part of its design load. It will be easier for the system to perform well under such conditions than under full load.

PROPOSAL

Alusaf operations need to identify when a system is out of the debugging phase and in the steady state. The system must also be under full load. Only then should performance tests be carried out. The reliabilities obtained during debugging will indicate that the system is less reliable than during steady state. If performance tests are carried out during debugging, the systems will be rejected because reliability indicators are too low. The real problem is the scheduling of performance tests.

The results obtained from performance testing can be used as a basis for preventive maintenance scheduling. Preventive maintenance should be scheduled according to the results obtained from performance testing. System performance should be monitored according to the scheduled preventive maintenance and adjustments should be made accordingly.

4.2.5 Stress strength analysis

Alusaf is in the unique situation in that by far the largest component of its product's cost (primary aluminium) is electricity and alumina (65 percent) (Alusaf Employee Report 1994 - 1995). Furthermore, the pots should not be stopped because the anode supply is insufficient. This would create a most expensive and very undesirable situation.

The fact that the pots must not stop because the anode supply is insufficient, means that a system can be designed to handle a bigger load than it would actually handle - an oversized system. If oversized would ensure that the failure rate is minimal and that the pots would not stop because of insufficient anode supply, then it would be financially feasible to oversize a system.

Designing a system to handle a load less than it can actually handle (undersize), is an extremely dangerous situation. If the systems in the rodding shop are undersized, then the risk of performing substandard (not producing the required number of anode assemblies) is great because the system was not designed to perform at the specified load. This will lead to an insufficient anode supply to the pots and subsequently the stopping of the pots. This will be a very expensive and undesirable situation.

Alusaf has a very extensive and capable maintenance department. Identifying undersized situations has already taken place and an important focus of the department is to ensure that Alusaf does not accept any system with undersized components in it. During precommissioning and commissioning, a great deal of attention will be paid to identifying undersized systems and components of systems.

4.2.6 Reliability test and evaluation

The tests designed for the rodding shop are of a high standard. They are comprehensively designed and contain all the elements of a good performance test, namely

- rejection region.
- continue testing region.
- acceptance region.
- time frame.
- comprehensive technical specifications.

Table 4.1 indicates a typical performance test. For each of the systems in the rodding shop, a test similar to the one in table 4.1 is available.

4.2.7 Data collection, analysis and corrective actions

Alusaf has a highly detailed computer system to capture all data related to maintenance (SAP system). This system captures all failures on all systems and computes specified values such as mean time between failure, availability and any other specified value.

The SAP system cannot function by itself. In order to make the SAP system efficient, every breakdown and maintenance action performed in the rodding shop needs to be recorded. The rodding shop's maintenance personnel do not record all the breakdowns and maintenance actions performed. When a breakdown occurs, and maintenance is notified, they correct the problem (especially if it is not a major one) and do not record it. When the reports for the systems are generated, not all the values are included and a report that is not 100 percent correct is generated.

Information is also lost when breakdowns are corrected by nonmaintenance personnel. Operators may have the knowledge to correct the problem but each time they

correct a problem and do not record it, valuable information is lost. Fixing recurring problems might become part of the operator's routine. He will start to consider it as part of his job and the system will function continuously with a defect.

PROPOSAL

All breakdowns must be recorded. All system breakdown recordings need to be analyzed and action must be taken in order to fully optimize the recordings. Specific vital parameters (eg mean time between failure and availability) must be identified and these parameters must be recorded. If the values fall below the specifications, corrective maintenance must be taken or designs must be improved.

The importance of breakdown and maintenance action recording should be emphasized for all maintenance personnel. Each maintenance action performed on a system and captured on SAP is booked against the system. The time spent on that system, manpower and parts are then accumulated and the maintenance cost of the system determined.

To utilize the SAP system effectively, it must be ensured that all maintenance and production personnel are made aware of the importance of data capturing. All maintenance and production personnel must also be trained to effectively utilize the SAP system.

TABLE 4.2: Performance test

PERFORMANCE TEST			
SYSTEM DESCRIPTION : RODDING CIRCUIT		PREPARED BY:	H VENTER
SYSTEM NUMBER : 3-3820-12			
DATE FROM:			
DATE TO:			
OBJECTIVES:			
1 Verifying the specified cycle time and speeds			
2 Verifying the specified production capacity and quality specifications			
3 Verifying availability			
PREREQUISITES			
1 2 200 baked anodes in stock.			
2 Induction furnace availability.			
DESCRIPTION			
OBJECTIVE 1 & 2			
The east and west casting station/machine/ladle preheaters will be evaluated separately.			
The test will be done over a 10day period.			
Five days for east and 5 days for west.			
Over a 5day period the stations will produce for 2 consecutive shifts and rest for the third shift.			
Each shift will produce for 4 consecutive hours per shift (1/2 of shift).			
Cycle times will be taken twice per shift (5 measurements each).			
Averages and standard deviations will be computed and compared with specs.			
OBJECTIVE 3			
Over a 1 month period, the system availability will be evaluated.			
Keep record of all the breakdowns. Assign the actual repair time to each breakdown. (Just time maintenance spent on repair action). Compute time between failures. Compute availability.			
SPECIFICATIONS TO BE MET			
No	CATEGORY	DESCRIPTION	CRITERIA
OBJECTIVE 1			
1	Hole drying	Time between 2 consecutive batches of 3 double anodes	162 secs
2	Pre-matching station	Time between 2 consecutive anode ass.(including time for unhooking)	98 secs
3	Rodding station	Casting table rotation	10 secs
4	Anode hooking station	Total time between two consecutive anode assemblies including time for hooking to overhead P&F	108secs
5	Throughput time	Cycle consists of rodding 10 anode assemblies Includes --Casting machine aux. handling operations --Ladle filling --Traveling to and from induction furnace --Traveling to ladle preheating --Skimming Excludes --Ladle preheating [The cycle time can be tracked via level 2] L1 PREV CYCLE L1 CUR CYCLE L1 AV CYCLE	22,6 min
6	Travel time	From position receiving CI to ready to pour (from closest furnace)	25 secs
7	Pouring	Total time to pour 1 anode hole (from start of one hole to start of next)	14 secs
8	Time to rod	Total time to rod one anode assembly (from cross travel parked position to return to parked position and ready to pour next ass)	108 secs
SPEEDS			
1	Long travel		0,83 m/s
2	Cross travel		0,2 m/s

OBJECTIVE 2									
1	Anode assemblies	Measures the average production per shift over 10 shifts							55 assys per shift
		[This can be tracked via level 2]							
		L1 PREV THRGH L1 CUR THRGH							
2	Quality	Average rejection rate per shift. Measured as per quality attachment.							0.50%
		[Matching station rejection can be tracked via level 2]							
		L1 ANOD RJ PV L1 ANOD RJ CR							
OBJECTIVE 3									
1	Casting machine availability							93%	
2	Rodding circuit availability							90%	

Source: Alusaf Hillside Performance Testing Specifications

4.3. MAINTAINABILITY

The rodding shop is a totally automatized environment. Human intervention and human operations are reduced to the bare minimum. Maintenance plays a crucial role in the success of the rodding shop's performance.

Equipment needs to operate at a high level of reliability. This is achieved through effective preventive maintenance. In order to schedule effective maintenance, accurate and reliable indication measurements should be used.

PROPOSAL

The rodding shop is in a unique situation in that it is a new shop being commissioned. The failure rate distribution during the systems' life cycle will take on a hazard rate distribution curve as stipulated in figure 3.1. Maintenance must keep this in mind when evaluating measurement figures and must realize that the figures obtained during the debugging phase will indicate higher preventive maintenance frequencies. It is therefore of vital importance to determine when a system is out of the debugging phase and in the steady state. Continuous updating of preventive maintenance scheduling is of vital importance.

4.3.1 Measures of maintainability

A general value is used to determine the performance of a system. A system is accepted as in the specifications if its availability is at an acceptable level.

No distinction is made between availability during commissioning and availability during the steady state.

PROPOSAL

Clear maintainability measures needs to be identified. A decision must be taken about which values (as in section 3.3.1) are going to be monitored and evaluated.

Availability is an integral indication of an equipment/systems performance. Because of Alusaf's the unique situation (debugging phase versus steady state), it needs to identify two types of availability. The one type of availability needs to take into account the value of mean corrective maintenance time. This value should be monitored during performance testing. This value excludes logistical delay time and administrative delay time - hence the performance of the system on its own will be evaluated. The effectiveness of the environment in which the system operates will not be taken into account. This makes sense because we want to evaluate the performance of the system alone to decide if we want to accept or reject it. Maintenance personnel are still learning the technicalities of the system, and because optimal stock levels have not been defined, we will not penalize the system for these inefficiencies on Alusaf's part.

During the steady state, however, we must compute availability based on mean down time. This will take into account the whole environment in which the system operates. Breakdowns and the reason for breakdown must be recorded. This will enable us to identify the main reason why systems are unavailable and give us the opportunity to rectify the situation.

A decision must be taken as to the cutoff time when the switch will be made from one availability to the other. This will typically be when commissioning on that system has been completed and when normal production starts.

4.3.2 Maintenance frequency factors

Actual operating performance data on each system are not yet available. It is therefore very difficult to schedule preventive maintenance. Every Thursday, the rodding shop shuts down for maintenance. It is impossible to attend to all the equipment in the rodding shop every week. The way preventive maintenance is scheduled is that equipment that posed the most problems during the week will be looked at. During the initial phase, this is the only way to attempt and optimize preventive maintenance. Because maintenance is determined by the system's performance during the previous week, it can be argued that this is not preventive but corrective maintenance.

The cost of preventive maintenance needs to be considered. The rodding shop is in a unique position in that it supplies the potroom with anodes. If the potroom receives a subamount of anodes, the pots will stop and huge sums of money will be lost. It is vital to ensure that the rodding shop keeps supplying rodded anodes. The above reason could lead to decisions of excessive preventive maintenance. If excessive preventive maintenance will ensure that the rodding shop supplies the potroom with sufficient anode assemblies, then it will be financially justifiable. The cost of excessive preventive maintenance will never be bigger than the cost of stopping the pots.

PROPOSAL

When reliable indicators are available, the rodding shop needs to schedule preventive maintenance in accordance with those values. The computer system that Alusaf uses (SAP), will provide accurate indications about the defined values that will be used to

schedule preventive maintenance. If the rodding shop uses the right values then this area should function at a very satisfactory level.

The importance of using the correct indicators, correctly computing them and reacting to them will to a large extent determine the performance of the systems.

Reliability is a vital indicator in the rodding shop. The rodding shop production rate was designed according to a specific reliability. If reliability falls below a certain value, then the rodding shop will not be able to perform to specification. It is also important to correctly compute the reliability. If reliability during the steady state is computed using mean corrective maintenance time, then the system indicators will indicate that the system performs better than it actually does. This will lead to wrong decisions being taken about preventive maintenance. Acting according to the indicators is of crucial importance. It is no use having these indicators and only acting according to them when they indicate a substandard value.



4.3.3 Maintainability in system/product design

4.3.3.1 Maintainability requirements

Maintainability requirements is an aspect that has received a great deal of attention to date. The maintenance department was very much involved in the above. Throughout, aspects were identified that could improve the system's maintainability. Table 4.2 illustrated the phases that each system went through/will go through before it reaches **industrial completion** (when the system is finally handed over to Alusaf operations).

TABLE 4.3: Maintenance involvement

PHASE	AIM DURING PHASE	MAINTENANCE INVOLVEMENT	EXAMPLE
1 System inspection	<ul style="list-style-type: none"> ◦ To identify all visual defects of the system. ◦ Identify possible areas of improvement. 	<ul style="list-style-type: none"> ◦ Evaluated maintainability possibilities of system. 	The gearbox of a particular motor weighs 300kg. The gearbox is located at the top of a 50m silo and no assistance is provided in taking out the gearbox and transporting it to the workshop for repairs. A lifting beam was installed above the gearbox to improve maintainability.
2 System demonstration	<ul style="list-style-type: none"> ◦ To determine if the system operates as specified. ◦ To determine if the system adheres to all safety interlocks. ◦ Identify possible areas of improvement 	<ul style="list-style-type: none"> ◦ Evaluated system operation during demonstration. 	During the demonstration it appeared that the hydraulic system operated with unnatural jerks. This resulted in the mechanical components wearing out. The operation was smoothed out. This improved maintainability.
3 System commissioning.	<ul style="list-style-type: none"> ◦ To determine system performance under designed capacity. ◦ To determine all defects that occur during operation. ◦ Evaluating system performance according to specifications. ◦ Identify possible 	<ul style="list-style-type: none"> ◦ Evaluated all recurring and underdesigned problems. 	During the commissioning phase, a particular gearbox failed twice in the space of 10 days. The problem was identified as one of automation. This was sorted out, and the gearbox's life span was stretched to specification. This improved maintainability.

	areas of improvement <ul style="list-style-type: none"> ◦ Monitoring spare/repair stock requirements and using it as a basis for stock optimization. 		
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Source: Adapted from Alusaf Hillside's Precommissioning/Commissioning tasks

PROPOSAL

One problem that surfaced during the whole process of commissioning, was the procedure of accepting the system. Although maintenance were very involved during the commissioning phases, they were not involved in the determination of system acceptance. The production superintendents advised production managers for systems acceptance. In some instances, systems were accepted without Alusaf being in the possession of all the drawings. Maintenance should become more involved in determining the acceptance of a system.

Careful comparisons need to be drawn between preventive maintenance and failure rates. This is one of the indicators to determine the effectiveness of preventive maintenance scheduling. If the failure rate is unacceptably high, then preventive maintenance needs to be looked at. It could be that a system does not receive the correct amount of preventive maintenance.

4.4 VENDOR SUPPORTABILITY (SUPPLY SUPPORT)

Alusaf Hillside has a large procurement department. The function of this department is to optimize vendor supportability by means of:

- vendor audits.

- order expediting.
- stock level optimization.

The rodding shop thus has a limited responsibility towards vendor supportability.

However the areas in which they can make a positive contribution are :

- identifying possible suppliers.
- assisting with optimal stock level.
- giving feedback on product quality.

It is on this basis that vendor support will be evaluated according to the list in chapter 3.

1. Because the equipment has been purchased from overseas contractors, most of the vendor distribution points of those spare parts are in the country of origin. Alusaf is currently in the process of identifying local suppliers for spare parts. In some cases this is difficult because the equipment is very specialized and only overseas suppliers can supply it. If local suppliers are approached, they need to develop the part, and that tends to be expensive. In the long term, however it would be cost effective to have local suppliers, even if this means that they have to develop the part. The logistical and administrative delay time would also be optimized.
2. Because a detailed logistical support analysis has not been conducted, it is impossible to evaluate the systems against these criteria. During commissioning and the early operational phases of the systems, it has frequently happened that stock was not available during breakdowns. As the system life cycle matures and more data become available, this aspect of **supply supportability** will be optimized.
3. An optimum spare part analysis has not been conducted. As stated earlier, the rodding shop is in a unique situation in that it supplies rodded anode assemblies to the pots, and if it supplies insufficient anodes, it will stop the pots. This would be a very expensive operation. It is better to have too many items in stock rather than too few.

PROPOSAL

The rodding shop should follow the optimal spare part philosophy with high cost parts. Many of the parts are very expensive and need to be optimized (the minimum quantity to ensure the maximum availability of spare parts). As the system life cycle matures, relevant information will become available, and this aspect of supply supportability will be optimized. With low cost parts, bulk quantities can be purchased.

4. There is a definite shortcoming in this area. Replacement frequencies are not compatible with stock availability. This is partly because the systems have performed far below expected and specified indicators. As the underdesigned areas are eliminated, this area is being optimized. The rodding shop is on the right track in that it is looking at the cause (design problems) and not the consequence of the problem.
5. Because many of the suppliers are in overseas countries, the logistical pipeline times are very long. Some local suppliers are being investigated in an effort to determine compatibility.
6. The primary concern at the moment is starting the plant. Optimizing will follow. However, this may be very costly if all cost aspects are ignored.

PROPOSAL

The rodding shop needs to evaluate all its consumable items to see where optimization can be accomplished. Accurate consumption levels need to be defined and surplus levels need to be reduced. Where possible, a just in time philosophy must be followed. This will reduce inventory.

It is essential to optimize from the start. Much time and money can be saved if a optimum system is introduced from the outset. People will also start to use the optimal procedure from the start. A lot of time and effort can be saved if employees are trained the right way from the start.

7. Spare and repair parts are tested in actual production. There is no pre-installation procedure to determine if a spare/repair part is acceptable or not. If a spare/repair part that is not acceptable is installed, then it will fail in actual production. Because this is mainly a maintenance function, the rodding shop is mainly concerned about receiving a workable spare/repair part.

PROPOSAL

Maintenance should install procedures to precheck equipment before it is installed. Some of the systems being used are extremely bulky and therefore have bulky parts. In some instances it is difficult or sometimes impossible to verify this equipment. Where possible spares should be preverified and procedures developed for this purpose.

8. As stated earlier, the rodding shop supplies the pots with rodded anodes. Stockout would result in the following:
- pot standstill and therefore no production.
 - possible damage to equipment.
 - restart of the pots which is a time-consuming business and entails large financial losses for Alusaf, (this point has been clearly defined by management).
9. Identifying a inventory safety stock is a procurement function.

PROPOSAL

The rodding shop could supply procurement with initial estimates to assist them in determining safety stock. As the system life-cycle commences, more reliable information will be made available and more accurate levels can be determined.

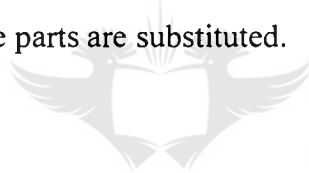
10. It was not possible to define a provisioning and procurement cycle and economic order quantity. As the life-cycle commences, this phase will be optimized.
11. Supply-availability requirements are an area in which definite improvements can be made.

PROPOSAL

The rodding shop must keep accurate records of the elements defined in maintainability measurement. This would allow determination of the probability of having a spare part available, given a specific failure rate and a specific availability rate. The higher this probability, the better the supply support for that particular system is.

Supplier supportability can also be improved by substituting local suppliers for overseas suppliers. Local supplier will reduce the lead time for spare parts compared to overseas suppliers, and consequently improve supply availability.

12. There have been some problems in cases where spare parts have not been fully interchangeable with elements of primary mission equipment. The reason is because many suppliers come together and integrate their equipment in a particular system. During commissioning, parts that are not interchangeable are identified and interchangeable parts are substituted.



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4.5 DATA PLANNING

Data planning will be evaluated according to two criteria:

1. *Specific data capturing.* In order to evaluate the performance of the Rodding shop, critical key performance data needs to be captured in order to determine if the systems are performing to specifications.
2. *Checklist as in chapter 3 (section 3.4 - Vendor Supportability) to evaluate procedural planning and design.* Procedures need to be available for each maintenance action. The checklist will determine the quality, availability and feasibility of these procedures.

4.5.1 Specific data capturing

In order to manage maintenance, specific data capturing is necessary. We have all the tools to effectively capture all the data, transform them into useful information and follow a defect preventive process. Many data are lost because not all maintenance actions are recorded. Also, many data are captured - never to be transformed into useful information.

All the data and information needed to monitor key performance areas have been identified. Means of accumulating these data have also been identified, nearly all of which have been designed.

PROPOSAL

All maintenance actions should be recorded to be able to accurately compute the values used to measure maintainability. Operations that appear too small to record, should in fact be recorded because each failure impacts with the availability values.

Unnecessary data that are not transformed into useful information need to be eliminated. Eliminating unnecessary data will streamline the data-capturing process and ensure that important aspects are highlighted. The reason for the presence of unused data is that when the data were needed, they were captured and used for a period of time. Thereafter, the originator never initiated a termination procedure. Some of these data are still being captured, but never used.

All information should be presented in such a manner that it can be easily understood and that the important aspects are highlighted. Information that is difficult to understand, does not have the same value as information that can be easily and quickly understood.

4.5.2 Evaluating procedural planning and design

1. System maintenance procedures were defined for the maintenance on each system.

PROPOSAL

Maintenance must be defined for the specific phases of the life cycle. There is a procedure for each system, but no specific reference is made to different types of maintenance during different stages of the product life cycle. Differences should be made between corrective, preventive, major/minor et cetera. The maintenance shutdowns are planned, but no distinction is made between major or minor maintenance.

When a system is scheduled for maintenance, an action plan must be available to guide maintenance. Records should be kept of the frequency of specific maintenance on a system. It may be necessary to change a particular part once every six months. Hence it would be a waste to perform this action every month, when it is only necessary to do so once every six months.

2. Seventy percent of the defined procedures have been prepared. There has simply not been enough time to prepare everything. In time, all the required procedures will be prepared.
3. A detailed logical troubleshooting flow diagram was prepared . Tailormade flow diagrams were prepared for mechanical, electrical and general troubleshooting and isolation procedures.
4. Alusaf Hillside has a standard procedure format. This is aimed at getting the most information to the used in the briefest possible format. The rodding shop also adheres to all these procedures. Furthermore, because the technical specifications for each system are readily available, the most important information can be gathered.
5. Generally, the procedures are adequate. Sometimes the user does not fully understand some of the procedures. When this happens, it is obvious the person was not properly

trained. In time all personnel will be properly trained and all procedures understood and applied.

6. Maintenance procedures are compatible with the level of activity. Maintenance at a level other than in the field itself or in the carbon workshop does not fall under rodding shop maintenance. The procedures for this maintenance are therefor designed, developed and used at that level.
7. All relevant test equipment is not always specified.

PROPOSAL

Procedures should include sets procedures to be carried out after a maintenance action. This will ensure that production receives equipment in a working order. Time will not be lost due to equipment being handed back to production that is not in good working order.

8. Safety is an important factor at Alusaf. One of its core values is a safe working environment. In each procedure, all the safety areas are specified.
9. Adherence to procedures is the main problem. Although all these procedures have been designed, they are seldom used. Maintenance personnel tend to work on the equipment without applying the appropriate procedures.

PROPOSAL

There should be a drive towards motivating everybody to make use of all the procedures available. One of the major problems is that the procedures are not readily available or users do not know how to apply it.

Procedures should be easily available and understood they should also be updated frequently to ensure that the best techniques are used.

Applying procedures ensures consistency. If everybody follows the same procedure, then the systems will function better.

4.6 SUMMARY

Four subjects were evaluated to determine the logistical support of the rodding shop. The rodding shop controls three of the subjects directly, and the procurement department controls the fourth. The three aspects that the rodding shop controls directly are reliability, maintainability and data planning. Vendor support is controlled by procurement.

The reliability of the rodding shop was evaluated under the following headings:

- Reliability quantitative and qualitative requirements for the system - the generation of block diagrams and allocation or apportionment of reliability requirements to the subsystems and beyond. Each subsystem in the rodding shop has a specified reliability it has to adhere to.
- Critical useful life analysis. All the systems in the rodding shop need preventive maintenance to function according to specifications.
- Failure mode and effective analysis and criticality analysis (FMECA) need to be conducted in a formal way to ensure that the rodding shop gets the most value out of the analysis.
- Reliability predictions and assessment. The rodding shop must realize and be certain when the system is out of the debugging phase and in a steady state.
- Stress, strength analysis. Situations in which underdesign occurs must be identified and corrected. Overdesign may be feasible if it can be financially supported.
- Reliability tests and evaluation. All the systems in the rodding shop have a detailed performance test designed for them.
- Data collection, analysis and corrective actions. The rodding shop must ensure that all relevant breakdowns and maintenance actions performed on all systems are captured on its SAP system.

Maintainability in the rodding shop largely determines its success. In order to determine the maintainability of the rodding shop, it was evaluated against measures of

maintainability, maintenance frequency factors and maintainability in system/product design.

Vendor supportability is a procurement function. The rodding shop can, however, assist in certain aspects of supportability. It can identify possible suppliers, assist with optimal stock level and provide feedback on product quality. Procurement optimizes vendor supportability by vendor audits, order expediting and stock level optimization.

Data planning was evaluated according to general data capturing and procedural planning and design. **General data capturing** is aimed at measuring key performance areas. In order to evaluate the performance of the rodding shop, critical key performance data needs to be captured to determine if the systems are performing according to specifications.

Evaluation of procedures that maintenance should have prepared to optimally carry out their function. This part of data planning will be evaluated against an eight point checklist.

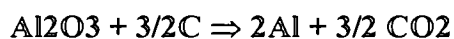


CHAPTER 5

SUMMARY

Alusaf is one of the 10 biggest producers of primary aluminium in the world. It consists of Bayside Smelter and Hillside Smelter. Hillside produces 466 000 tons of primary aluminium per year and Bayside 174 000 tons per year.

The production of aluminium is done on the basis of electrolyses. The simplest form of the aluminium reaction can be described as follows:



The carbon ingredient in the reaction is supplied by the carbon department, which comprises the following:

- the paste Plant.
- the baking Furnace.
- the rodding Shop.



This study was conducted in the rodding shop. The gap between the supplier's view of supportability and the requirements of Hillside need to be determined.

In order to effectively evaluate the critical aspects of the rodding shop's logistical support, the following topics were evaluated under the headings mentioned:

1. Reliability

⇒ Reliability quantitative and qualitative requirements for the system. The generation of block diagrams and allocation or apportionment of reliability requirements to the subsystems and beyond (as appropriate) (figure 3.3). Each

subsystem in the rodding shop has a specified reliability that it has to adhere to.

- ⇒ Critical useful life analysis. All the systems in the Rodding shop needs preventive maintenance to function according to specifications.
 - ⇒ Failure mode and effective analysis and criticality analysis (FMECA) needs to be conducted in the rodding shop on a formal basis to get the most value out of the analysis.
 - ⇒ Reliability predictions and assessment. The rodding shop must determine when the different systems are out of the debugging phase and in the steady state.
- Stress, strength analysis. Situations in which underdesigning occur must be identified and corrected. Overdesign may be feasible if it can be financially supported.
- ⇒ Reliability tests and evaluation. All the systems in the rodding shop have a detailed performance test designed for them.
 - ⇒ Data collection, analysis and corrective actions. All relevant breakdowns and maintenance actions performed must be captured and analyzed.

2. **Maintainability.** Maintainability in the rodding shop largely determines its success. To determine the maintainability of the rodding shop, maintainability was evaluated against the following measurements:
- ⇒ measures of maintainability.
 - ⇒ maintenance frequency factors.
 - ⇒ maintainability in system/product design.

3. **Vendor supportability.** Vendor supportability is a procurement function. The rodding shop can, however, assist with certain aspects such as identifying possible suppliers, assisting with optimal stock level and providing feedback on product quality. Procurement optimizes vendor supportability by vendor audits, order expediting and stock level optimization.

⇒ Vendor supportability will be evaluated against a 12point checklist covering the most important points of vendor support.

- Data

⇒ What data need to be accumulated, and how should they be converted into useful information to present it in the best possible manner?

⇒ Evaluation of maintenance procedures that will assist them to optimally perform their functions. This part was evaluated against an eight-point checklist.



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