THE DESIGN OF A PAPER WASTE HANDLING SYSTEM

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DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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Tenth day of August 1993

ABSTRACT

The design of a waste handling system is closely related to the functioning of the manufacturing system that it serves. The study considered the design of a waste handling system at the factory Printpak Gravure in Industria. The system in use was considered cost inefficient. The system was examined, operating variables were determined. A model of the system was constructed so that the effectiveness of alternative systems could be compared. The replacement system selected reduced machine downtime and resulted in a lower yearly operating cost.

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1. INTRODUCTION

A production system in a factory may be comprised of various machines. Primary production machines are served by secondary server systems. A Typical secondary system could consist of materials handling equipment between or after the production machines.

Production may cease due to inadequacies in the server system (e.g. the waste handling system). The cost of this failure includes all the factory overheads allocated to the production machine for the period of the failure.

The influence that a waste handling system design has on the surrounding production system must be considered in equipment selection. The disruption of the production system must be minimised. Installing the handling machinery should be justified by the removal of production disturbances or increased efficiency of the overall production system.

2. PROBLEM DEFINITION

2.1 Problem Outline

The waste handling system in the company Printpak required attention. The system was not effective, large periods of machine downtime occurred. Management was also of the opinion that the cost of running the system could be reduced.

The student was restricted to alterations within the waste handling system. The production system was to be treated as a separate, independent entity. Changes to the production system (i.e. schedule changes) were not allowed. The paper collection operation (i.e. the disposal of the waste paper) was however negotiable and could be altered if deemed necessary.

2.2 Objectives

The objectives were set after insight into the production process was attained. The objectives listed below were the direct desire of the decision makers involved in the study. The responsible engineer was interviewed to validate the choice of the objectives. The objectives concerned the waste handling system only. The production system was not to be altered by the changes to the system.

2.2.1 To eliminate or substantially reduce production machine downtime caused by the waste handling system.

2.2.2 To reduce the direct cost of the waste handling system.

2.2.3 To control the income derived from paper waste.

2.3 Constraints

The constraints were defined by two aspects of the production process. Firstly the wishes of management and secondly physical constraints within the factory.

2.3.1 Factory floor area.

2.3.2 Machine positions in factory to remain as is.

2.4 Criteria

The criteria for the system to be designed was the 'wish list' of management. These criteria were considered important aspects for the system to be installed. If at all possible these criteria were to be met. Some of the criteria could be associated with cost (e.g. waste spewage) while others were 'non- quantifiable criteria (floor area kept to a minimum, the future use of the floor area was not known- the cost was therefore unquantifiable).

2.4.1 Convey all the paper waste produced in the factory in the most cost effective manner available.

2.4.2 Utilise the current factory layout, i.e do not move machines from any of their positions.

2.4.3 Floor area used must be kept to a minimum.

2.4.4 Non disruption of current traffic patterns and the activities of the factory floor.

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2.4.7 The number of waste containers and the space utilised by them must be reduced.

2.4.8 Optimise the waste collection schedule, and improve the efficiency and regularity of the collection function.

2.4.9 Recycle all the waste possible, i.e. ensure that all the waste that is not recyclable cannot be recycled in any conceivable way.

2.5 Outline Of Study

A study of the waste handling system was undertaken to determine the variables that were within the realm of the decision makers. The systematic approach of the operations research method was taken. The literature survey undertaken served a dual purpose: To outline operations research methods that were applicable to the study and to give an overview of waste handling systems available on the market.

This project report is subdivided into distinct areas. The introduction serves to familiarise the reader with the problem and outlines the steps within the study. The following three chapters deal with an overview of material in the literature survey. The material listed was used in the study. The next chapter details waste handling system in use. An economic model of the system is constructed for comparative reasons. Thereafter alternatives are considered. The alternative systems considered were compared and the most effective system selected.

3. OPERATIONS RESEARCH

The original use of operations research was in the second world war. Complex military decisions were made based on quantative models engineered by mathematicians, engineers, psychologists, physicists and others recruited by the military. After the war operations research found application in industrial operations research. Operations research can therefore be seen as 'the application of the scientific method to problems arising within the management process embracing integrated systems of men, materials and machines' Fabrycky, et al [12].

Operations research is a process that can be divided into specific steps.

3.1 Problem definition

The problem to be defined will consist of four major components; the environment, the decision maker, the objectives and the alternative solutions.

The environment may be described as the frame ork within which the organised activity is purposely directed to achieving the organisation goals. This will include physical, social and economic factors which may bear on the problem at hand. As an example the safety regulations within a factory environment will form part of the environment.

The decision maker is the second important factor in the problem. Implied in this is the desire of an individual or group of individuals to achieve a set of organisational objectives.

Facts upon which to base the decision will form a part of defining the problem.

Organisational objectives are a third important factor in the problem. Organisational objectives can be detected by noting the organisational activity.

Alternatives are the final part of the problem requiring definition. Those variables that significantly affect the effectiveness by which the objective may be defined are defined. The variables subject to direct control by the decision maker are separated from those that are outside his influence.

3.2 Formulating the model

The first step in defining an appropriate model is taken when the problem is defined. Models are useful in choosing from a set of alternatives; they serve to illustrate the effect of the decisions made.

A body of quantitive relationships has been defined to assist operational researchers in constructing the models. These relationships assist in illustrating how decisions made will affect the process modeled. The researcher may be in a position to use standard relationships to define the specific problem or a customised model (specific to his problem) is used. The obvious by-product of constructing a model is the individuals improved understanding of the problem under review.

Decision and game models are specifically geared to assist in the selection between a variety of options. Uncertainties associated with the various choices will be included in these models. Within decision models the following point was noted by Fabrycky, et al [13] 'unquantifiable nonmonetary factors may be significant enough to outweigh calculated costs or profit differences among alternatives'. Furthermore it was noted that certain factors could often not be incorporated in monetary terms. Fabrycky, et al [13] further noted that 'valid qualitative comparisons may be made when the quantitative outcomes cannot stand alone or when the outcomes are non quantitative'. An intuitive approach to decision making based on those facts that cannot be included within the effective function of the model form part of the decision process.

3.3 Manipulation of the model

The manipulation of the model seeks to obtain optimum values for those variables under the control of the decision maker. A model that accurately represent the actual circumstances encountered will yield a good indication of possible outcomes when the variables in the model are manipulated.

The decision models will allow the decision maker to choose the optimum solution. The effectiveness function of the model may be based on an economic optimum, or other factors that are important within the model (e.g. safety factors).

3.4 Making the decision

Models of operations are essentially means for taking the decision maker to the point of decision. They offer a quantitative basis for evaluating the operations within his concern. The model in itself will not be a duplication of the actual outcome, but will however give the decision maker important information needed in his decision.

The quantitative approach to decision making will ensure that the decision made will include the majority of variables important to the decision.

4. ECONOMIC MODEL DEVELOPMENT

4.1. Introduction

Present day decision makers place large emphasis on the financial effectiveness of their decisions. 'The selection of a specific alternative is usually straight forward if the available alternatives are reduced to a common economic base for comparison' Fabrycky et al [13]. In this process all the factors included within the alternatives are reduced to the common economic basis. Reliability, as an example, will be converted to cost (the cost being dependent on replacement frequency and replaced component costs).

Economic equivalence implies that the alternatives are reduced to a common economic basis (i.e. aspects of each alternative are converted to monetary values). Furthermore the economic values of the various alternatives are manipulated so that they become directly comparable. In this step the time value of money formulae are used to ensure that the various options may be referred to a common basis.

4.2 Cost considerations of machinery

Purchasing new machines, or comparisons of costs between alternative machines requires accurate assessments of all the costs involved in running the machinery. The costs fall into one two categories: Capital purchasing costs or operating costs.

4.2.1 Capital Purchasing cost

'The initial outlay of capital required before the machine is operational is considered as the capital purchasing cost' Humphreys, et al [1]. Costs included in this category would be anything ranging from the purchase of the machine to the commissioning of the machine. Purchasing costs may also include any of those costs related to the development of the machine. Installation costs would include all alterations needed to the factory floor to accommodate the new machine. The physical transportation and labour involved in installing the machine would be included too.

In making capital cost assessments various procedures could be carried out. The literature could be consulted to determine the cost of similar installations, these costs are then extrapolated to the required situation. This procedure is used for larger as well as smaller projects. Large projects are subdivided into smaller components, the cost of each component subsequently determined.

An alternative method of costing would be to obtain direct quotes for the machinery. This is normally carried out for systems that are not complex and have technological requirements that are easily assessed.

4.2.2 Operating costs

'Operating costs are those costs sustained when maintaining and running machinery' Humphreys, et al [1]. Maintenance costs are based on the average figures for machinery of this type. 'Maintenance estimates are considered on a preventative basis, machinery maintained can then be considered 100% reliable' Jelen [2]. Costs for maintenance include any downtime on production lines related to the repair of the machinery.

Estimates for labour usage at new machine installations are based on work carried out at each machine. The complexity of the work and the duration thereof determines the labour requirement.

A certain degree of uncertainty exists in the labour requirements at a work centre. People may react to work circumstances in different ways, some workers will be more productive than others.

4.3 The time value of money and equivalent values

The value of money is dependent on time. Invested money accumulates interest. Yearly compounding of invested money allows accumulated interest to be compounded further. The effect that the interest rate i and the number of years have on invested money is shown in equation 1 below.

$$s = p(1+i)^n \quad \ldots\ldots 1$$

s: sum of money

p: amount invested

i: compound interest rate

n: number of periods

In an engineering economy a year is usually taken as a unitary period of time. Compounding may, however, occur more than once annually. In this instance equation 2 may be applied to determine the accumulated value of money

$$s = p(1+i/m)^{m.n} \quad \text{..............................2}$$

s: sum of money

P: initial investment

i: interest rate

m: number of compoundings per year

n: number of periods (years)

The value of m determines the number of compoundings to occur in the period considered. This may be bi-annually (m=2) quarterly (m=4) or monthly (m=12). The increase in the monetary value of an investment per period is known as the rate of return or effective rate of return.

accumulated value = original value (1 + i effective)

'Compound interest calculations are normally considered when investments are made over a time period of more than one year' Humphreys [1]. Simple interest calculations are made for an investment period of less than a year. Using simple interest calculations over a single year period as opposed to compound interest calculations induces a small error (0.5% of invested value).

A sum of money received at a future date is worth less in real present day terms. This is due to the effect that interest has on invested capital. Equation 3 quantifies the present worth of a sum of money received n years in the future

p=s(1+i)^-n..................................3

p: present worth

s: future amount received

i: interest rate

n: number of periods

The actual sum received at some future date is reduced by the above factor. This is known as discounting.

A continuation of the present value of money principle is the determination of the present day value of an annuity based investment. The value of regular payments or receipts of money may be determined by using equation 4 below. The equation illustrates the importance of accumulated interest and the effect of inflation. It applies to payments as well as receipts of money. The value of the money is less than the simple arithmetic sum.

$$p = \left((1+i)^{n-1} / (i(1+i)^{n}) \right) r \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Equation 4 is known as the unacost factor (annuity), the inverse (1/p) is known as the capital recovery rate and is given in equation 5 below.

$$r = p\,(\,(1+i)^{(n-1)} / \;(i(1+i)^{n})\,)^{-1} \ldots\ldots\ldots\ldots\ldots 5$$

r: annual payment

p: initial sum invested

n: number of years (periods)

i: interest rate of investment

Thus an annual payment of r has to be made to recover the initial investment P. The sum of annual payments r can be derived by the combination of the previous equations and is given by the equation below.

$$s = r((1+i)^{n-1})/i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

s: sum of the annuity

r: payments made per period

i: interest rate for the period

n: number of periods of the investment

4.4 Cost comparisons

The economic model for each option available to the decision maker ensure that a valid comparison can be obtained between the alternatives.

All the aspects within each alternative are comparable within the economic framework. From the above discussions it becomes clear that costs such as labour, reliability of machinery and the cost of possible machine downtime can all be included within the same economic basis.

5. RELIABILITY OF MACHINERY

5.1 Introduction

The economic model discussed in the previous section would require all the uncertainties within the alternatives to be quantified. Machine reliability is one such uncertainty that needs quantification. Maintenance may be subdivided into one of three activities: Improvement maintenance, Corrective maintenance and Preventative maintenance. Improvement maintenance embodies maintenance undertaken to improve the operating conditions of the machine, e.g. placing self lubricating equipment at inaccessible places. Corrective maintenance entails the repairing of faults as they occur. Preventative maintenance is an all encompassing technique whereby the maintenance requirement of the system is quantified, a proactive approach to maintenance is taken.

5.2 Preventative maintenance

'Preventative maintenance means all actions intended to keep durable equipment in good operating condition and to avoid failures' Patton [14]. The basis of a preventative maintenance scheme is the reduction of the cost of machinery failure. The cost of maintaining the machinery in an operating condition (planned maintenance) is compared to the cost of replacement at failure (i.e. the cost of preventative maintenance is compared to the cost of corrective maintenance).

Machinery in a production environment will be comprised of numerous sub-components. The maintenance requirements of each machine system will therefore depend on the maintenance requirements of components within the system. As an example, the bearing within an electric motor may have an infinite life (say 20 years), if lubricated regularly. If on the other hand lubrication is neglected then the life span will be reduced drastically. The cost of the maintenance program in this case will be the cost of regular inspections and lubrications of the bearing. This cost must then be compared to the cost of an unexpected failure (machine downtime, technician cost, etc.).

Probability of failure of the sub-components within a machine system will be important in planning the preventative maintenance program. The preventative maintenance scheme in use can be represented by an economic model. This model is included within the overall economic model of the system to be installed.

5.3 Probability of failure

Every component within a machine system is prone to failure at some point in time. The length between failure is a function of the environment surrounding the machine system [14]. The different components will have different life span characteristics within the same environment. Standard components (e.g. V-belts, Bearings, Electrical contactors and fan blades) have clearly quantified lifespans (manuals quantify these lifespans) [15], [16], [17], [18]. Data in these manuals is based on historical statistical data.

The lifespans of components within a system will yield the required maintenance scheme. The scheme is evaluated by comparing costs between alternative maintenance schemes.

6.0 PRINTPAK WASTE HANDLING SYSTEM

6.1 Factory floor layout

Figure 6.1 illustrates the factory floor layout, the waste production centres are at:

6.1.1 Trimming machine A

A roll of printed paper is trimmed down to size, the paper may be recyclable or non-recyclable (wet wrap). The weight is 80-100 gsm (grammes per square inch). The width of strip produced ranges from 0.5cm to 1cm. The machine produces from 2.4 to 3.0 m^3 uncompressed paper per 8 hour shift (max production rate).

6.1.2 Trimming machine B

A roll of printed paper is trimmed down to size, the paper may be recyclable or non recyclable (wet wrap). The weight is 80-100 gsm and the width of the strip produced ranges from 0.5cm to 1.0 cm. The machine may produce up to 3.0 m^3 of paper in an eight hour production shift.

6.1.3 Thrissle machine C

The Thrissle machine is used primarily in colouring the reel. The paper is rewound and no waste is produced (80 % of production time). When the stamping operation is used on this machine (hingelids, 20% of production), the machine produces between 80 and 90 kg of waste per hour. A paper density of 220 gsm yields volumes of between 0.8m^3 and 0.9 m^3 per hour. Chip size lies between 1.5 and 2.0 cm^2.

6.1.4 Zerand machine D

The Zerand machine is run to produce paper chips of 200 gsm (displays) or chips of 220 gsm (hingelids). The 200 gsm paper chips are typically 4 to 5 cm^2 while the 220 gsm paper chips range from 1.5 to 2.0 cm^2 in area. The waste production rate ranges between 100 and 120 kg per hour. This corresponds to 1.0 to 1.2 m^3 per hour.

6.1.5 Stripping machine E

This machine produces non-recyclable paper strip. Paper density ranges from 80 to 100 gsm and waste production rates 0.8 m^3 per hour. The waste consists of a continuous strip.

6.1.6 Stripping machine F

This machine produces non recyclable continuous strip and short strips. The operation normally runs on wet strand paper for the production of beer labels. Production rates are 0.8 m^3 per hour. Paper density normally between 80 - 100 gsm.

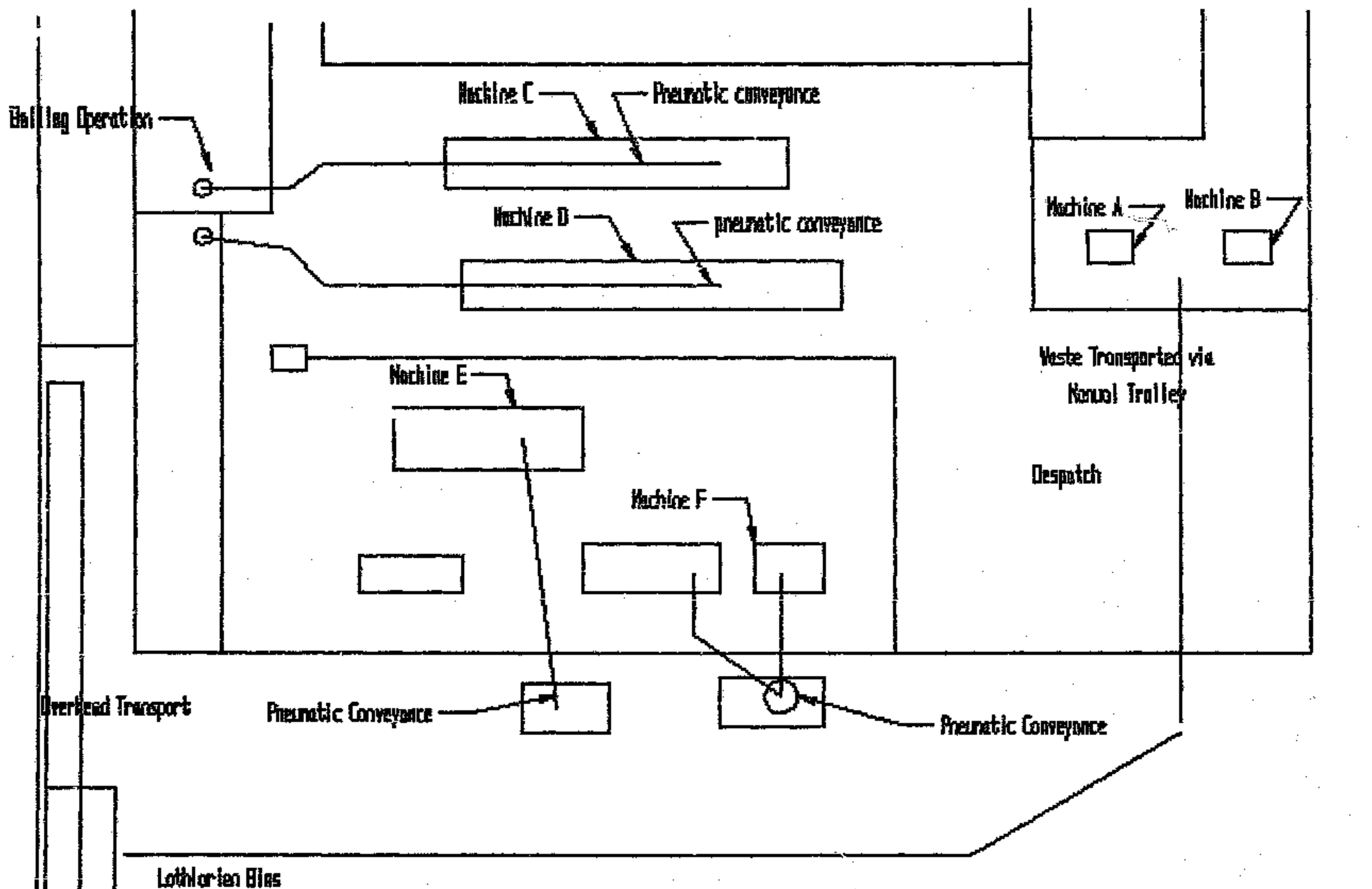

Fig. 6.1 Factory floor layout with positions of machines producing paper waste

6.2 Operating costs of handling system

The operating costs for the systems in use included the following categories of costs:

Power consumed

Labour utilisation

Machine downtime due to failure

Maintenance

Costs at the various centres were referred to the same periods so that a valid comparison could be made. The 5 and 10 year periods were chosen as these were considered a reasonable period for equipment life, by maintenance personnel.

The yearly cost for the maintenance would include all failures that were likely to occur within the system. This assumption was valid as the equipment considered (primarily electric motors) was used in a relatively clean environment. The operating conditions of the equipment (as stated by the company electrician, based on experience) was such that the motors were expected to last for a period of 10 to 20 years. The electrician mentioned that the motors were running at between 70 and 80% of rated capacity.

Maintenance estimates that were included within these economic models were based on the information of standard component programs. The annual shut-down period was utilised to carry out the required maintenance. The maintenance cost was estimated for the individual machinery (based on actual costs). The cost allowance in the company accounting system did not record specific maintenance for each cost centre. The maintenance allowance made included the maintenance on the production machinery (this comprised the largest portion of the allowance). The preventative maintenance values calculated in Appendix C were assumed a reasonable estimate for the machinery currently in use.

6.2.1 Machine A

Paper waste is directed into boxes at the machine. Box size 0.8 m^3. These boxes are transported manually to the Lothlorien containers. Three boxes are transported per day, 3 minutes per box at R9 per hour amounts to R297 per year (220 working days). The machinist has an assistant who is responsible for moving the carton when full. A small fan unit (1.5 kW) is used to blow the paper into the box. The cost of the power consumed by this system is R1.8 per day (8 * 0.15 * 1.5), R396 per year. The fan unit must be maintained, yearly maintenance for a small unit is R212 (Appendix C).

Power:	R396
Maintenance:	R212
Labour:	R297

Total yearly cost: R905

Based on an annuity type payment, the present value of the costs incurred over five and a ten year period is as follows:

Cost for 5 years: R3031

Cost for 10 years: R4525

6.2.2 Machine B:

Paper waste is directed into a box, the box is manually transported to the waste bin containers. Box size is 0.8m^3. The box transport is carried out by the machine operator's assistant. Three boxes are transported per day, 3 minutes per box at R9 per hour amounts to R297 per year (220 working days). The paper strip runs directly off the machine and collects on the floor in front of it. The paper is then scooped up and placed inside the box. There is no power cost associated with the handling.

Labour: R297

Total yearly cost: R297

Based on an annuity type payment the costs for 5 and 10 years are as follows:

Cost for 5 years: R994

Cost for 10 years: R1485

6.2.3 Machine C:

Waste produced at C is transported via a pneumatic conveyance to the bailing room at position 4. The pneumatic conveyance consists of a 6 kW fan unit and a 11 kW booster unit blowing into a cyclone. The paper then drops into the bailing room where it is bailed by two labourers. The extraction system on the Thrissle machine is in use for 20% of the year. The direct power costs associated with the handling of the paper are R898 per year (R20.4 per day * 220 * 0.2). Four labourers are permanently employed in the bailing room to handle the paper, the labour is allocated to both the Zerand and the Thrissle machines. The yearly labour cost allocated to the Thrissle machine is R12000 (R1500 * 4 * 12 * 0.2/1.2). The system components need to be maintained. The system consists of a low pressure fan unit, a high pressure fan unit and a rotary valve. The associated maintenance costs R212, R241, and R212 respectively (Appendix C). The yearly maintenance cost for the Thrissle waste system is R133 per year ((R212 + R212 + R241)*0.2)). When bailed the paper is transported with a manual trolley and an overhead crane to the waste containers. The sisal bags used in the bailing operation are supplied by the contractor collecting the paper. Additional cost associated with this system is possible downtime that may occur. The pneumatic conveyance may block up, due to operator inattentiveness or system break down. Hourly cost of fixed overheads for the machine (i.e. cost when machine is down) is R599. A down time of 6 hours costs the factory R3594 in lost production.

Power:	R898
Maintenance:	R133
Labour:	R12000
Machine downtime	R3594
	___

Total yearly cost: R16625

If this amount is paid every year then the actual value, based on an annuity type payment is as follows:

Cost for 5 years: R55693

Cost for 10 years: R83125

6.2.4 Machine D:

Paper is produced at the machine centres on all the production runs and then handled via a pneumatic conveyance to the bailing room. Two Fan units are used (6 kW and 11 kW) which transport the paper into a cyclone unit which then deposits it in the bailing room. The system consists of a low pressure fan unit, a high pressure fan unit and a rotary valve. Power consumed by the system amounts to R4488 (power R20.4 per day, 220 days per year). The associated maintenance costs are R212, R241, and R212 or a total of R665 per year (Appendix C). The bails are collected and transported with the overhead crane to the bins. Labour at this machine amounts to R60000 per year ((1 - .2/1.2) x R1500 x 12 x 4). The Zerand waste system costs R1313 per hour. A downtime of 6 hours costs R7878 per year.

Power: R4488

Maintenance: R665

Labour: R60000

Machine downtime R7878

Total yearly cost: R73031

Costs extended over a 5 and 10 year period based on annuity payments are as follows:

Cost for 5 years: R244653

Cost for 10 years: R365155

Machine C and D combined

Total yearly cost: R89656

Total cost after 5 years: R300346

Total cost after 10 years: R448280

6.2.5 Machine E:

Paper is transported via pneumatic conveyance and overhead pipes to the containers. The conveyance system uses a small fan unit (4 kW). This fan unit blows into a venturi orifice forming a negative pressure which then draws the paper away from the machine. The yearly maintenance cost associated with this system is R212 (low pressure fan unit, Appendix C). The paper is transported as a continuous strip. It is deposited in a bin and collected. No further handling is required. Power consumed by the system is R4.8 per day, R1056 per year (4 * 0.15 * 8 * 220). A loss in production occurs with the changeover of the bins. One hour of production is lost every 2 weeks. Yearly 24 hours of production are lost. The hourly cost rate of the waste system for this machine is R318, yearly cost of lost production R7632 (R318 * 24).

Power: R1056

Maintenance: R212

Machine downtime R7632

Total yearly cost: R8900

Based on yearly annuity payments the present value of running the system over a 5 and 10 year period are as follows:

Costs for 5 years: R29815

Costs for 10 years: R44500

6.2.6 Machine F:

A pneumatic conveyance is used to transport the paper to the containers outside. The system consists of a 6 kW blower unit which routes the paper into a cyclone. The paper drops into a bin after moving through the cyclone. The continuous strip is chopped by the blower before moving into the container. Power costs associated with the fan unit are R7.20 per 8 hour shift, R1584 per year (6 * 0.15 * 8 * 220). Maintenance costs associated with the low pressure fan unit at the cyclone are R212 per year. The container is collected by the outside paper company. Additional energy is spent cleaning the area around the container as the container is not entirely enclosed. A loss in production is suffered at the changeover of the containers. One production hour is lost fortnightly. The hourly cost rate of this machine is R400, therefore R9600 is lost every year.

Power: R1584

Maintenance: R212

Machine downtime   R9600

Total yearly cost: R11396

Based on an annuity payment the present value of running the system for 5 and 10 years is as follows:

Cost after 5 years: R38176

Cost after 10 years: R56980

Machine E and F combined

Cost after 1 year: R202296

Cost after 5 years: R67991

Cost after 10 years: R101480

6.3 Paper collection system

The company G.B. Waste in Pretoria has entered a contract with Printpak to collect the paper waste. G.B. Waste has in turn taken an agreement with Lothlorien paper waste to collect the paper. The basis of the collection contract was for Printpak to place the paper in sisal bags supplied by the collection company, Lothlorien. All the waste, i.e. the non recyclable strip waste, the recyclable strip waste, the paper chips and the finished product (Lexington cigarette boxes) would have to be supplied in bales. Lothlorien supplies an independent contractor with the non-recyclable waste which is used as packing material. The white paper grade, the Lexington grade and the paper chips are used to manufacture paper pulp which is used by the paper industry (Carlton tissue).

John Zima a labourer at Printpak signals Lothlorien when a bin is full. This is problematic as the bins are often too full for the trucks, i.e. the bins supplied are to heavy when they are filled to the brim. To eliminate this problem Lothlorien attempts to regulate the collection system by sending their trucks whenever they consider the bins to be full enough. The trucks normally travel under capacity.

Printpak does not have extensive control over the collection of the bins. If the truck arrives at ten o' clock then the machine will have to be stopped to accommodate this. A lack of collection schedule between Lothlorien and Printpak is evident. The machines affected by this system are machines E and F. They are dependent on a bin being present beneath the collection system. There is also a lack of coordination between planned production of waste and produced waste.

Lothlorien also undertakes to collect the paper chips produced when manufacturing cigarette boxes. Lothlorien requires that the chips are supplied in bale form. In June 1993 they are moving to larger premises and have undertaken to accommodate the possibility that the paper chips will no longer be in bale form when supplied to them. This will be an obvious advantage to Prinpak as they will no longer have the labour intensive procedure of bailing the loose paper chips.

The waste paper collection market on the Witwatersrand is largely a monopoly between a few large companies. Lothlorien have an undertaking with Mondi paper waste that Lothlorien exclusively collect the higher grade paper while Mondi collects the lower grade paper (cardboard). Nampak paper was approached too, however, they were unwilling to consider the collection of Printpak waste. Printpak must therefore negotiate with Lothlorien to improve its waste collection system.

The initial contract negotiations between G.B. Waste and Printpak involved the collection of mixed waste paper (cork tipping), printed label paper (e.g. Chromolux paper), white off cuts of board (chips), Printed board (lexington), unprinted white board (reel ends) and cores. Currently Printpak is being paid for Lex, White chips, reel ends, White (unprinted reel ends). No money is received for corktipping. The paper type Chromolux is currently lumped together with corktipping and being invoiced as waste to Printpak. A test was carried out on the paper by Lothlorien. According to Lothlorien the paper is pulpable, however not useable in their process due to the low reflectivity. The reflectivity test run by Lothlorien contradicts the findings of the quality department of Printpak. Nampak paper was approached for recyclability tests of the paper, the paper was found to be unuseable. Based on these test results the abovementioned grades were considered non-recyclable and the handling system was subsequently designed for that case.

7.0 MATERIALS HANDLING SYSTEMS

7.1 Introduction

Materials and manufactured components are normally transported over short distances in a manufacturing concern. The loads are conveyed inter departmentally or between subsequent manufacturing processes. Transport of the loads involves the shifting of the load as well as loading and unloading at the different stations.

Materials handling falls into one of three groups, viz. hoisting, conveying or surface conveying. Hoisting equipment is primarily concerned with the lifting and lowering of materials, conveying of materials is the movement of materials along a fixed plane, while surface conveying transports the loads along differing paths, i.e. no fixed path.

Loads may be classified as bulk or unit loads. Bulk loads are loads transported in a continuous fashion, i.e. no single mass increments (unit loads).

The choice of handling equipment is dependent on equipment design, the operational characteristics as well as the economic viability of the scheme used. Loads moved should be synchronised with manufacturing activities, i.e. removed or supplied from the manufacturing activities as required. The handling system should not induce any constraint on the manufacturing process. The performance criteria of the handling system will prescribe the effectiveness of the overall production system.

The capital cost as well as operating cost is included in the machine choice. Included in capital costs are installation costs, transportation costs and cost of equipment. Running costs include maintenance, power and lubrication costs. A machine meeting all technical requirements may require too large a capital investment for it to be a viable alternative.

7.2 Bulk materials

The nature of the bulk solid is an important factor in selecting transport equipment. Empirical equations governing the flow of bulk solids in various conduits are readily available in the literature. These equations relate physical properties of the solid to the flow characteristics in the conduit.

Physical properties would include particle size, inter particle coefficients of friction, densities, levels of aeration in the media, friction factors and the moisture content of the solid. This empirical information is utilised by manufacturers of conveying equipment. It was used as a guide line in selecting the systems.

7.3 Gravity flow of bulk materials

The oldest form of material conveying is by the utilisation of gravity. Two important factors are required for this form of transport; sufficient potential energy and horizontal space. The cost of installing a pure gravity slide is low, R500 for a 6 metre slide is common.

The limiting factor in selecting gravity systems is the height required to allow the material to move freely. The repose angle (angle at which the paper just begins to slide) for paper and mild steel lies between 40 and 45 degrees from the horizontal. A slide length 20 metres will require a vertical height of at least 13 metres. Longer conveying distances render these systems (gravity slides) impractical as the average factory building is only 6 meters in height. The effective use of the gravity principle over distances that are greater than 6 meters require the installation of intermediate lifting stations.

7.4 Pneumatically assisted gravity slides

A refinement of the gravity slide principle is a pneumatically assisted gravity slide. This system consists of a slide with a perforated sliding surface through which air is blown. The air forms a cushion of lift reducing the friction between the bulk material and the slide walls. The reduction in friction reducing the angle needed to force movement into the material. From empirical standards in handbooks the repose angle for paper in this application was between 6 and 10 degrees. For a distance of 20 metres a vertical height of 3.5 metres was needed.

The power consumed by the transport system is dictated by the weight and degree of aeration of the material. A 20m slide may only consume 2 kW of power at a time, i.e. 0.1 kW per metre length of slide is required. The cost of a gravity slide is low, a 20m length with aerating fan unit costs R1500 (2.0 kW unit) (The cost is that of material and the fan unit). The price is misleading, these systems only work when the transported material has potential energy. Any material transported must be lifted to attain this height. A hoisting system must be used at the start of every section of the slide. A typical system would include a bucket elevator driven by a 0.5 kW motor. For a potential height of 3.5m an installed elevator would cost R3500. An elevator would be required after every 20m section of gravity slide. This increases the cost of as well as the complexity of the system. High maintenance requirements and low reliability do not promote the use of this system.

Gravity conveyors have the added disadvantage that they must be closed conduits when used in an outside environment. Moisture penetrating such a conduit may lead to blockages. Sealing a conduit increases the cost of the system.

7.5 Pneumatic conveyors

The pure pneumatic conveyance consists of air channelled through a pipe at high speed. The paper is picked up in the high velocity air stream and conveyed through the pipe. An advantage of this system is its flexibility, the pipes may be directed through bends without a loss in system performance. The system is simple with few moving components. A disadvantage is that the initial installation of the system is more expensive than conventional systems (gravity). The system also has a higher specific power consumption per kilogram of material moved (air must be moved with the paper). A typical fan unit with ducting may cost anywhere between R5000 and R15000 while its power consumption is 11 kW for a 40m length of pipe transporting paper (100 kg per hour).

7.6 Belt conveyors

The belt conveyor is a well known method of transporting bulk loads and unit loads. The system has the advantage that it requires a low specific power consumption. A Disadvantage is the lack of flexibility in its application, i.e. any change of direction requires a change over point between two belts. If the belt has to move through many turns, various belts have to be employed. Each different belt requires a different drive system. A belt with a drive motor and running gear costs R4000. For every turn made an additional drive motor with running gear is needed. The capital outlay required to obtain the needed flexibility would not promote the installation of such a system. Furthermore these systems are problematic when employed in an outside environment. Paper tends to blow off the belt. When used outside the belt must be enclosed, causing it to be prone to blockages.

7.7 Mechanical conveyors

Mechanical conveyors include such devices as screw conveyors, bucket conveyors, overhead rail systems and conveyor trolleys. These systems were not considered as they were not cost effective if used to transport material over longer distances. The systems were also inflexible. The capital outlay and the inefficient use of space by these systems was too high, eliminating them from the list of possible options considered.

8.0 SOLUTION REQUIREMENTS FOR WASTE SYSTEMS

8.1 Requirements for machines A and B

Machines A and B required the waste to be manually collected in boxes at the machine. This was labour intensive (although not expensive) and space consuming. The transport system for the paper had to be cheap (low power consumption).

8.2 Requirements for machines C and D

The waste handling system of machines C and D was expensive (4 labourers) and unreliable. Downtime would occur on the two most costly machines of the factory. Substantial cost savings stood to be made here. Any system installed would have to eliminate a portion of the labour and machine downtime to be cost effective.

8.3 Requirements for machines E and F

Machines E and F were dumping their waste into the containers at F and G respectively. The waste handling system caused machine downtime on machines E and F with every bin changeover. The solution's requirement would therefore be to remove the production loss.

In all the systems the reliability of any installed machinery was considered. If a system appeared to be unreliable steps were taken to improve the reliability. This included the use of back up systems and preventative maintenance schemes. The cost of the back up system or preventative maintenance scheme was included in the cost of the machinery. A standard economic model was used to compare the installations. This model was based on the variables that were important to each system. Unquantifiable variables (such as noise levels, dust, safety of operator and ease of use) were considered. The economic model served as a final selection, the initial selection was based those factors that weren't included within the economic model.

9.0 ALTERNATIVE SYSTEMS CONSIDERED

9.1 Zerand and Thrissle machines C and D

The collector company Lothlorien was unable to handle the paper chips in unbailed form. They were moving to larger premises in October of 1993, from this date onwards they were willing to consider receiving paper in unbailed form. The following systems were considered in the event that Lothlorien would decline from accepting paper in unbailed format.

Paper was bailed after separation in the cyclone. The system would block when a lack of supervision caused paper to build up above the bag. The blockage would extend to the cyclone and cause paper to spew from the by pass pipes onto the premises. This usually occurred when the machines were running at full production and an unscheduled downtime was least welcome. The bags had to be monitored constantly as the paper fell into them in an uncompressed state. Labourers periodically removed the bags from beneath the chute to 'compress' the paper.

The effective operation of the conveying system on the Zerand and Thrissle production machines depended on the workers of the bailing operation. The efficiency of the system could be improved by eliminating the need for constant supervision. The bailing operation was not continuous, the labourers were responsible for compression of the paper into the bags.

9.1.1 Alteration A1 (Zerand and Thrissle)

The first possibility considered was to allow the flow of paper through the pipe to be continuous, i.e. to eliminate the buildup of paper when the labourers were forcing the paper into the bags. This was achieved by placing a screw conveyor in the pipe line. The conveyor would act as a compactor. In figure 9.1 below an illustration is given of the equipment layout required. The required screw conveyor was of the type that was designed for the compaction of materials. These were not manufactured in South Africa but could be imported. Cost comparisons with locally manufactured conveyors (non compaction types) indicated an initial expenditure of R6000, ex works. The alarm system installed above the conveyor cost R750 per unit while the associated ducting with the conveyor amounted to R750 per line. The total capital outlay for this system amounted to R7500 (R6000 + R750 * 2) per line.

With the use of the screw conveyor as compactor fewer labourers would be required. A single labourer would be redundant with the installation of the conveyors (it was no longer necessary to have constant supervision of the bailing operation). The annual labour saving would amount to R18000. R3000 allocated to the Thrissle machine and R15000 to the Zerand machine. An additional maintenance cost of R277 per year was allocated to maintaining the screw conveyor (Appendix C).

Power consumption for the Thrissle machine amounted to R1162, an additional R264 (5kW * 0.15 * 8 * 220 * 0.2) per year (Waste handling system of the Thrissle machine runs 20% of production time). Maintenance amounted to R188 per year (R133 + 0.2*R277). Yearly labour saving on the Thrissle line was R3000. It was assumed that 80% of the machine downtime was prevented with the installation, i.e. R2875.

Yearly operating cost of Thrissle machine

Initial installation cost: R7500

Yearly power consumption: R1162

Yearly labour cost: R9000

Yearly maintenance: R188

Machine downtime: R718

Total cost for 1 year R18568

Total cost for 5 years R42567

Total cost for 10 years R60829

The power consumption of the handling system on the Zerand machine is R4488. The additional cost of power for the screw conveyor is R1320 per year (5 kW motor running continuously, 8 hours per day, 220 days per year). Additional maintenance costs for Zerand line is R252 per year (Appendix C). It was assumed that 80% of current machine downtime would be prevented, R6302.

Yearly operating cost of Zerand machine

Initial installation: R7500

Yearly power consumption: R5808

Yearly labour cost: R45000

Yearly maintenance: R942

Machine downtime: R1575

Total cost for 1 year R60825

Total cost for 5 years R184128

Total cost for 10 years R272114

Costs for Zerand and Thrissle combined

Total for 1 year R79393

Total for 5 years R226695

Total for 10 years R332943

An allowable tax reduction for depreciation was included for the first five years. A 20 % annual depreciation was used. After five years depreciation correction ceased and annual running costs were merely referred to present day values. All the costs represented were the present day values of amounts paid in the future.

The installed system was to be something entirely new in its application in this country. The suppliers of screw conveyors do not specialise in this application and have no technical knowledge of these type of conveyors. The time taken to obtain such a conveyor was therefore difficult to determine. The effectiveness of such a conveyor once installed was not definite and could not be quantified. The economic justification of this system was obtained from the removal of machine downtime and labour savings.

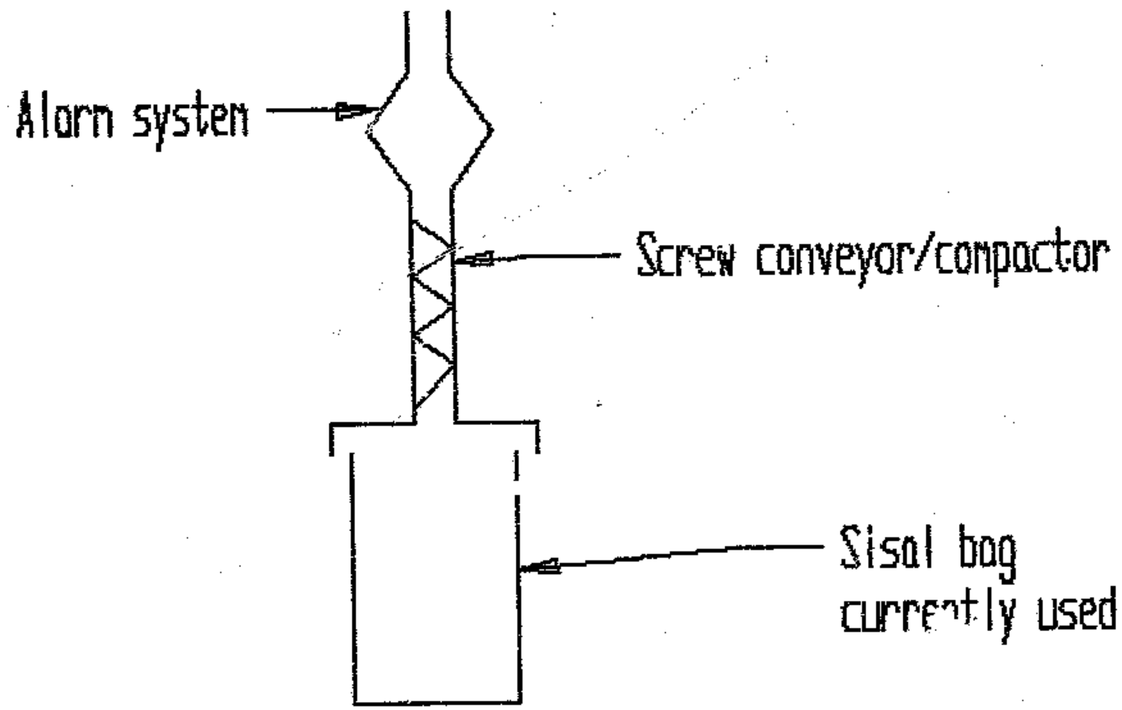

Fig. 9.1. Screw conveyor acting as a compactor, with an alarm

9.1.2 Alteration A2 (Zerand and Thrissle)

The system in figure 9.2 below was offered to eliminate machine downtime on the Zerand and Thrissle lines. In the diagram the pipes in the bailing room had been shortened to the roof. At the roof of the bailing room an infra red sensing device was placed to detect the paper level. A buffer bin was placed below the opening of the pipe. Further sensing devices were placed along the inside of the buffer bin to warn the labourer of the bin level. The sensing device was connected to a flashing light and an alarm. The alarm would signal when the bin filled beyond a certain point. The alarm would call a foreman into the bailing room to investigate the reason for the state of the bin level. The bailing room employees would ensure that the alarm did not sound.

In addition to increasing the buffer above the bin more bag trolleys would be made to assist the labourer in filling the bags. When changing the bag the labourer had to ensure that another trolley was available to replace the one he removed. If a few more of these trolleys were built, then a trolley could always be placed beneath the bin, eliminating the need to close off the bottom of the bin when stamping the paper into the bag. This would further assist the work becoming a one man operation.

The cost of the bin installation amounted to R500 per bin. The signalling devices each cost R750. They were infrared triggering devices which were triggered when the beam was broken for more than a set period of time (this could be adjusted on the device, say 10 seconds). The device triggered when paper remained in front of it. (e.g. when the bin fills and a pile of paper collects in front of the unit). The triggering mechanism closes a switch to which any form of alarm could be wired.

This system should eliminate at least 50% of the machine downtime. The operators were made more aware of the importance of the work carried out by them.

Yearly operating cost of Thrissle machine

Initial installation cost: R1250

Yearly power consumption: R897

Yearly labour cost: R12000

Yearly maintenance: R138

Machine downtime: R1797

Total cost for 1 year R16083

Total cost for 5 years R50605

Total cost for 10 years R75079

Yearly operating cost of Zerand machine

Initial installation: R1250

Yearly power consumption: R4488

Yearly labour cost: R60000

Yearly maintenance: R690

Machine downtime: R3939

Total cost for 1 year R70362

Total cost for 5 years R232456

Total cost for 10 years R346956

Total cost for the Zerand and Thrissle machines combined

Total cost for 1 year R86445

Total cost for 5 years R283061

Total cost for 10 years R422035

The paper remained in an uncompressed state and still required the attention of four employees. The combined alarm system and the bigger buffer above the bags eliminated 50% of machine downtime. The alarm system would act as a feedback to other employees in the factory. Employees on the main production lines (Zerand and Thrissle) were responsible for keeping the production line running, this included reacting to any alarm signals from the bailing room.

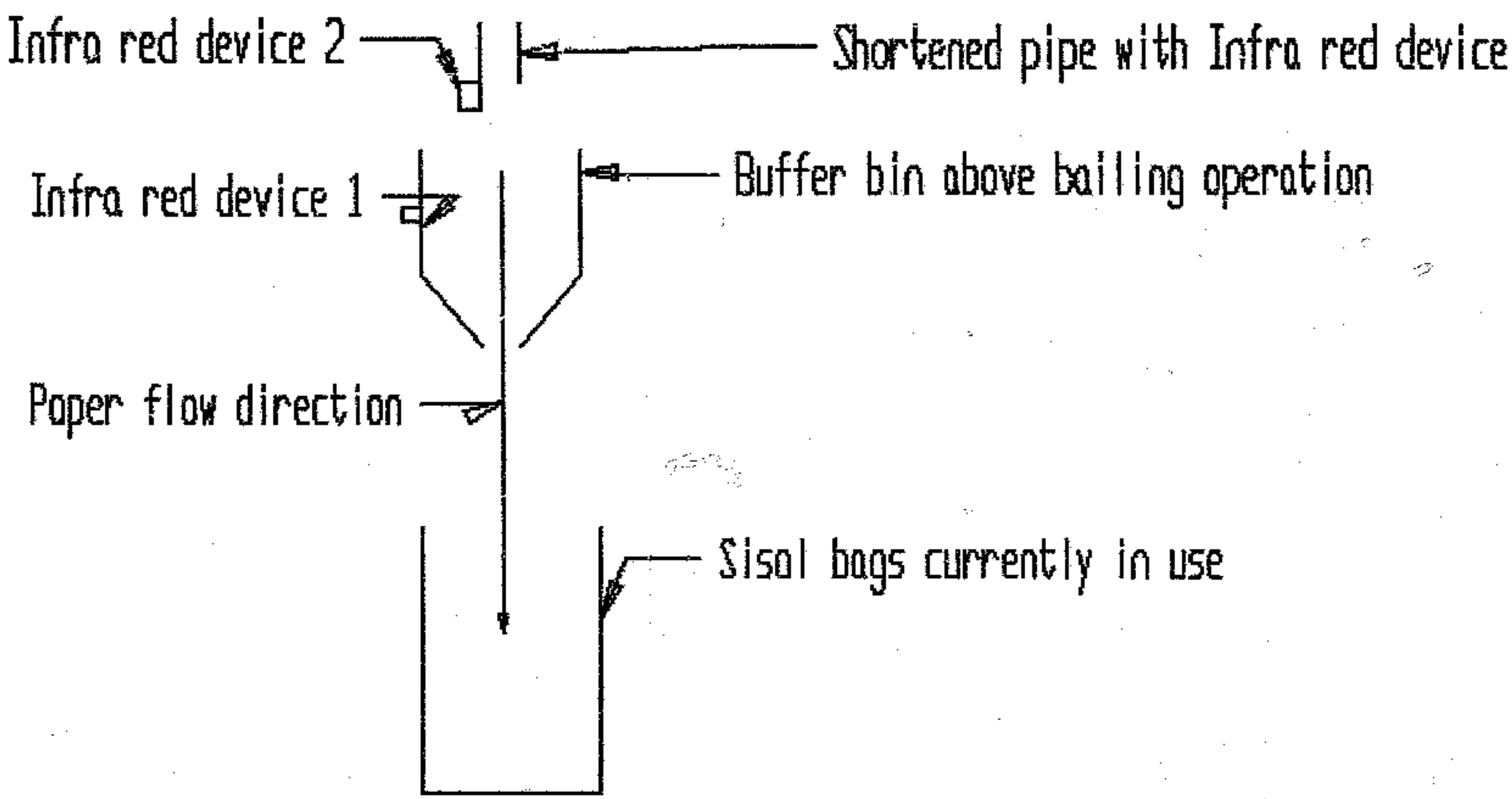

Fig. 9.2 Bailing operation utilising a buffer bin and alarm systens to signal blockages

9.1.3 Alteration A3 (Zerand and Thrissle)

Figure 9.3 below illustrates a conveyor belt placed below the opening of the cyclone. This system was aimed at removing blockages caused by operator inattention. The belt ran continuously and deposited paper in the lower hopper. Should the bailers be slow to remove the bag from beneath the hopper the hopper would begin to overflow. The pipe underneath the cyclone thus remained unblocked while spillage of paper into the bailing room occurred. As an added safety precaution an alarm system was fitted in the pipe below the cyclone to detect blockages. The installed cost of a belt conveyor was R5500. The cost of the alarm system was R750. Additional maintenance costs were R252 per year (Appendix C). The conveyor system was driven by a 4kW motor, the additional power cost was R1056 per year (8 hours per day, 220 days per year at R0.15 per kWh). The system no longer needed the constant supervision of a labourer. It was considered possible to reduce the number of employees in the bailing room. The cost estimate was however carried out for the same number of employees as before.

Yearly operating cost of Thrissle machine

Initial installation:	R6250
Yearly power consumption:	R1108
Yearly labour cost:	R12000
Yearly maintenance:	R188
Machine downtime:	R718 (80% eliminated)

Total cost for 1 year	R20264

Total cost for 5 years R51521

Total cost for 10 years R69039

Yearly operating cost of Zerand machine

Initial installation cost: R6250

Yearly power consumption: R5544

Yearly labour cost: R60000

Yearly maintenance: R942

Machine downtime: R1575

Total cost for 1 year R74311

Total cost for 5 years R232579

Total cost for 10 years R347162

Total cost for Zerand and Thrissle machines combined

Total cost after 1 year R94575

Total cost after 5 years R284100

Total cost after 10 years R424089

The system was feasible in that it was practical and easy to install. The installation of the system was of short duration and was to be scheduled during the lunch hour or after 4 pm. In addition to the conveyor and hopper installed, the number of bag trolleys were increased to help the labourer.

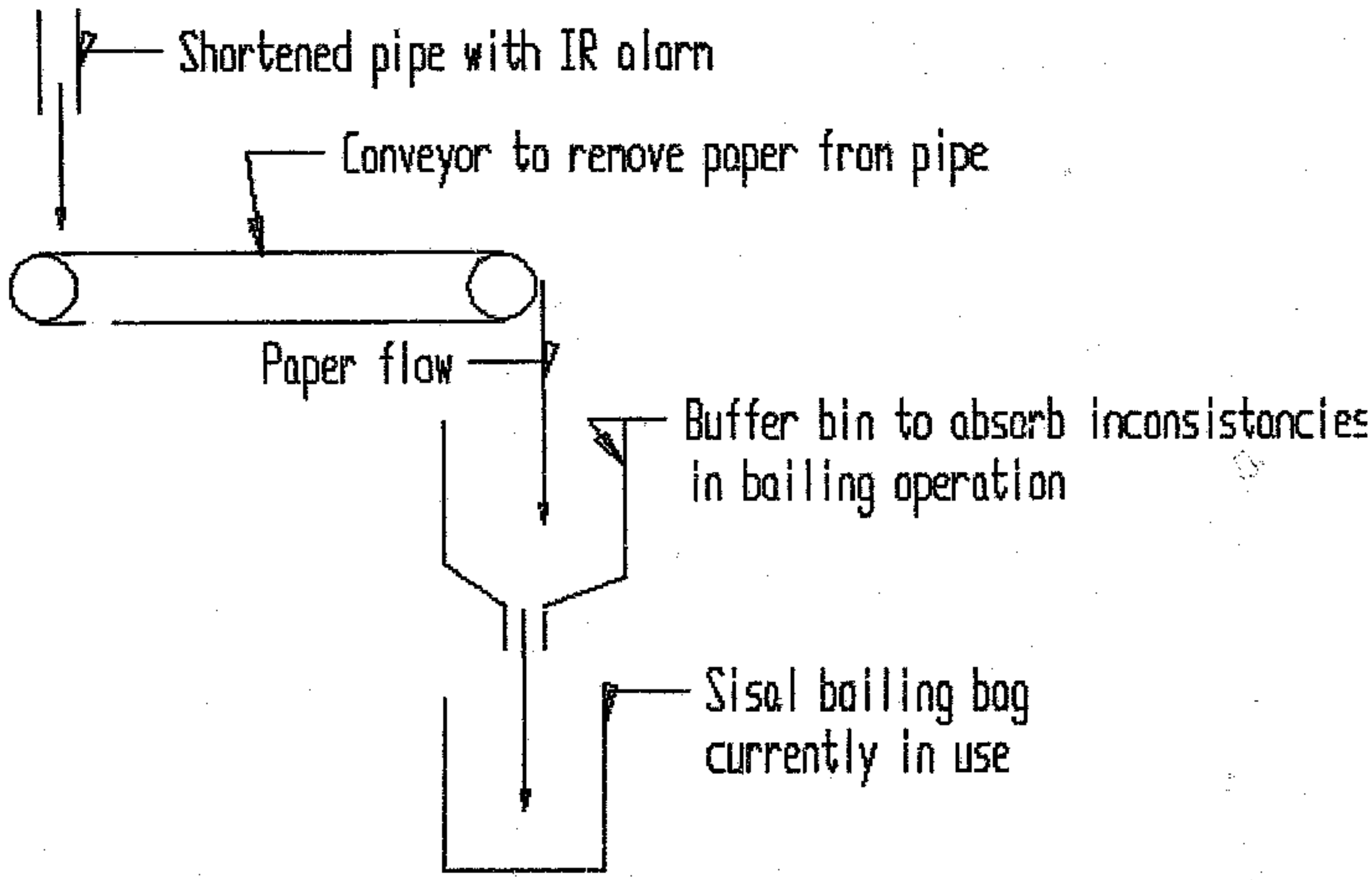

Fig. 9.3 Conveyor belt installed in bailing room to prevent pipe blockages

9.1.4 Alteration A4 (Overhead crane)

By considering the economic values of the abovementioned options the cheapest solution for the Thrissle machine was option A1 which cost R60829 for a 10 year period. A1 was also the least expensive solution for the Zerand machine at R272114 for the 10 year period. The difficulty of procuring a compactor type screw conveyor would have to be considered before using this system. Any of the systems (A1 to A3) may be installed for the Zerand or Thrissle machines, the operating costs of these systems were lower than the systems currently in use.

By making an alteration to the overhead crane guide it was possible to install a crane that could move in two axes as opposed to one. This enabled a single labourer to handle the crane. In the figure 9.4 below the alterations to the current frame with the new crane installed can be seen.

Cost of installation: R23500

Labour saving: R18000

Yearly maintenance: R636

If we combine this alteration with system A1 then the following yearly cost will be incurred for Thrissle and Zerand machines.

Yearly operating cost of Thrissle machine with crane modification

Initial installation cost: R11417

Yearly power consumption: R1162

Yearly labour cost: R6000

Yearly maintenance: R294

Machine downtime: R718

Total cost for 1 year R19591

Total cost for 5 years R35740

Total cost for 10 years R49227

Yearly operating cost of Zerand machine

Initial installation: R27083

Yearly power consumption: R5808

Yearly labour cost: R30000

Yearly maintenance: R1472

Machine downtime: R1575

Total cost for 1 year R65938

Total cost for 5 years R149989

Total cost for 10 years R198557

Total costs for the Zerand and Thrissle machines

Total cost for 1 year R85529

Total cost for 5 years R185729

total cost for 10 years R247784

The system was feasible if the calculated labour saving was accurate. The alteration of the crane was technically feasible. Further more it was possible to construct a walkway for the labourer to follow the crane. The drastic reduction in cost for the system was a direct result of the labour saving. The labour was eliminated as the bailing operation could now be a two man operation, one to watch the filling of the bags, and one labourer to handle the crane.

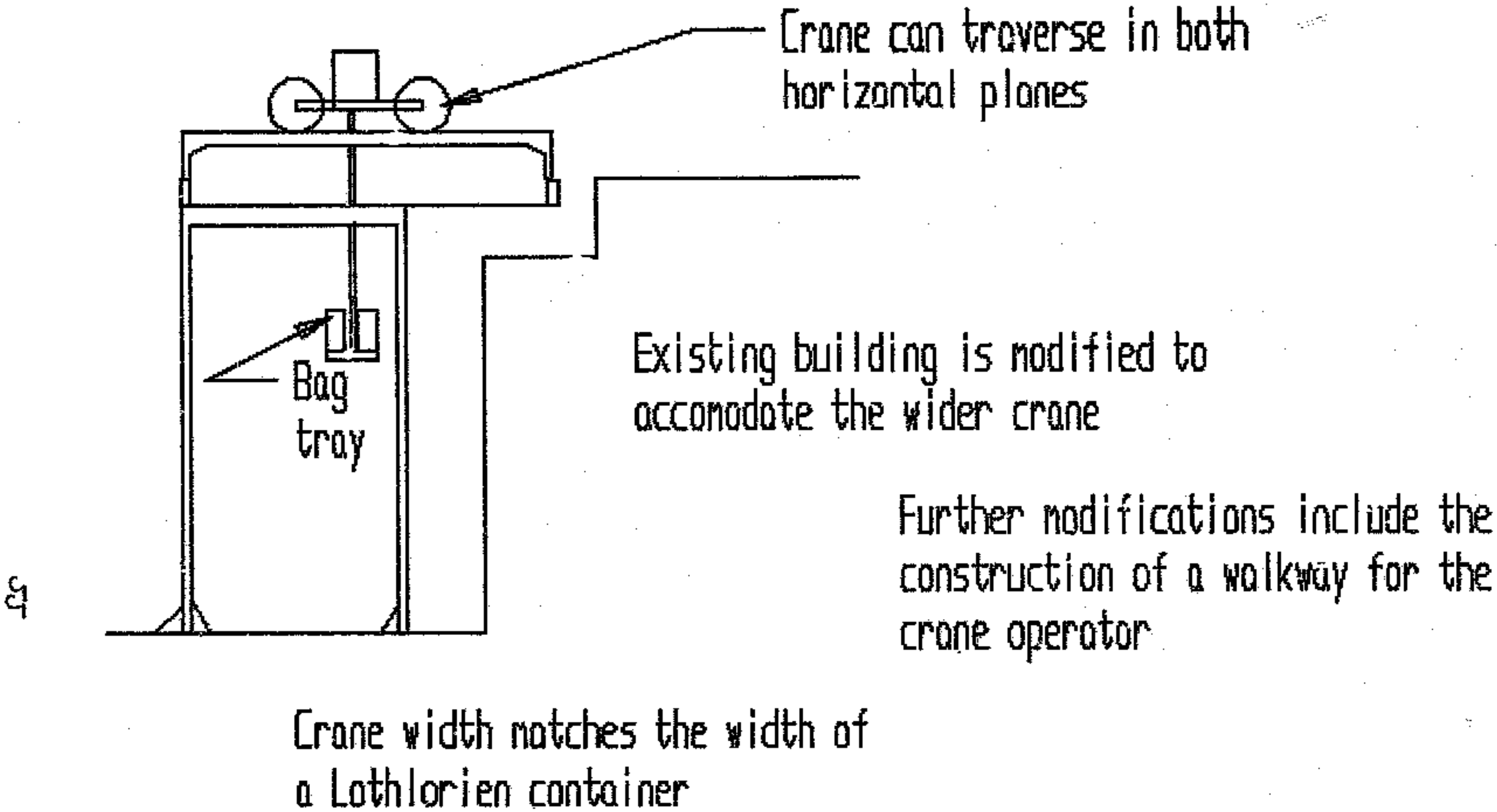

Fig. 9.4. Alterations to the overhead crane structure

9.2 Systems for the Zerand and Thrissle machines (C and D)

These system were considered for the possibility that Lothlorien consented to receiving paper in unbailed form.

9.2.1 Alteration B1 (Zerand and Thrissle)

The second alternative was to eliminate the bailing operation entirely and to automate the system. This required the cooperation of the contractor lothlorien to accept the paper in unbailed form. In figure 9.5 below the first alternative system is illustrated. The use of the compactor in conjunction with the smaller closed containers eliminated the need for supervision and the use of labour, except at changeover of the containers.

The automatic compactor could be set to any desirable cycle. Paper fell into the compactor from above, and was pushed into the closed bin. The degree to which the bin is filled could be predetermined by the pressure set on the compactor. When a certain compaction pressure is reached the ram of the compactor slides further forward into the container and pushes the paper beyond the opening of the container. At this stage in the cycle the bin would be manually released from the compactor and the cover placed over the opening. An empty bin would be placed before the compactor. As can be seen from the diagram the bins were placed on rails in front of the compactor. When a bin was filled another bin was wheeled in front of the compactor. The automated system required attention at the changeover of the bins. The time taken to fill a bin was dependant on the size of the bin selected. The manufacturer of the bins mentioned that the compactor was able to compress the paper of volume ratios 2 or 3 to one. A $10m^3$ closed bin container would be equivalent to a $20m^3$ container otherwise used. The bins were custom made to fit the type of transport used by the company Lothlorien. The compactor unit with bins and associated rails costs R69720 installed. It was driven by a 5 kW electric motor, annual cost of electricity was R1320 (8 hours per day, 220 days per year). A yearly maintenance cost of R444 was allowed for (Appendix C).

A cyclone was used to deposit the paper directly into the compactor. An additional hopper was installed above the compactor preventing machine downtime at changeover of the bins. If the system was placed alongside the building next to the existing cyclone unit for the blumer machine, existing fan and cyclone units could be used. If the system was placed at the current position of the paper chip bins then the additional cost of a cyclone unit and larger fan unit had to be included in the calculations.

Cost of the system alongside building:

Zerand and Thrissle machines both use same compactor

Cost of initial installation:	R69720
Cost of labour	R18000
Maintenance	R1272
Power	R6705
Machine downtime	R0
Total cost after one year	R95697
Total cost after 5 years	R138057

Total cost after 10 years	R170528

In position of containers:

Cost of initial installation:	R104720
Cost of labour	R18000
Maintenance	R1272
Power	R6705
Machine downtime	R0
Total cost after one year	R130667
Total cost after 5 years	R163677
Total cost after 10 years	R196148

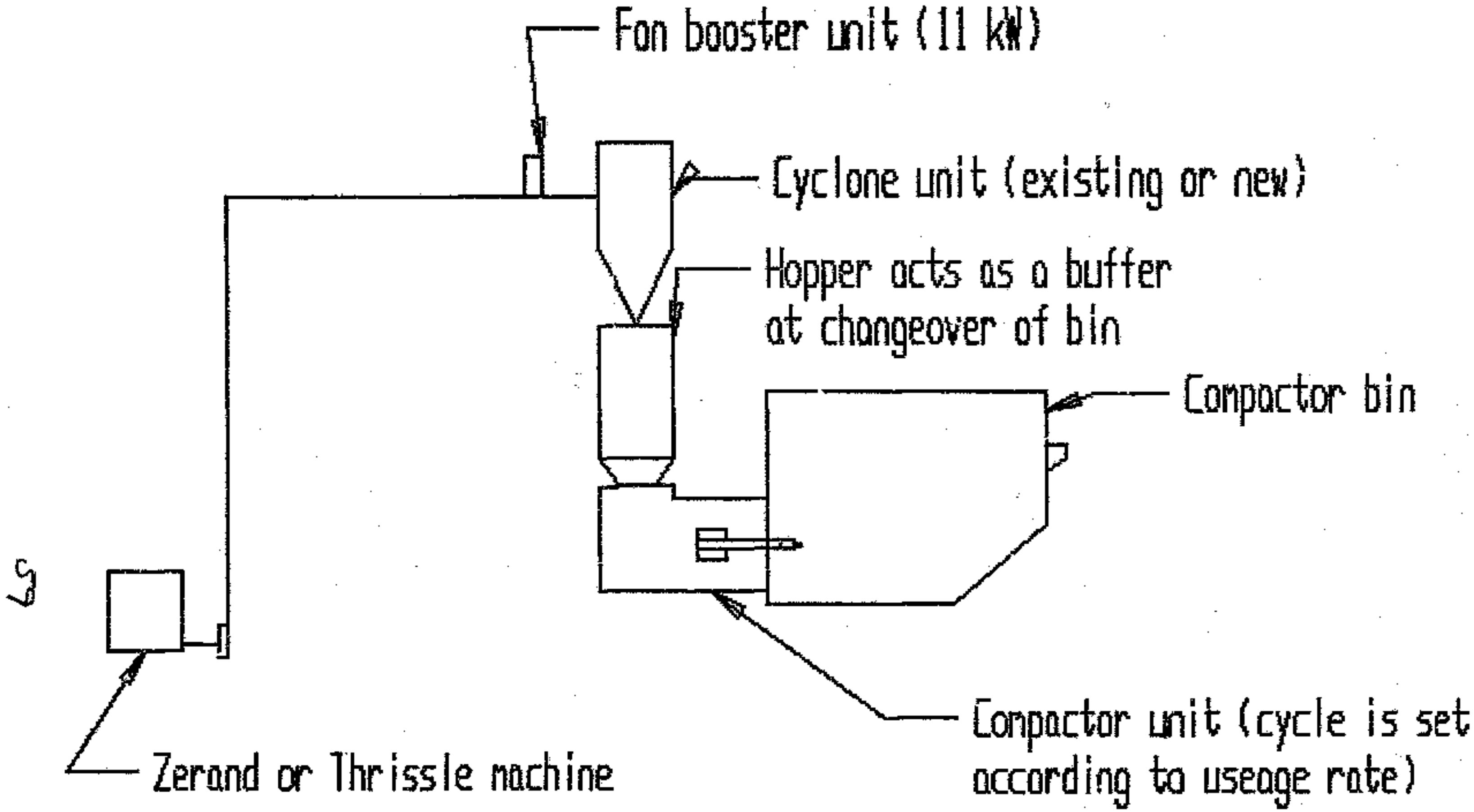

Fig. 9.5 Compactor used on Zerand and Thrissle machines

The system was technically and economically feasible. The installation need not cause any machine down time. The whole installation would fit next to the system currently in use. The system was completely closed and would therefore eliminate the possibility of paper spillage. The containers were custom designed. The labour usage of the system was minimal. Since the pressure of the paper in the container was set on the compactor it would further be possible to control the weight of paper being sold. The bin would not be collected until it had a certain pressure of compaction. This made it possible to give a better estimate as to the weight of material leaving the factory premises. The pressure of the compactor could be calibrated to the wei, . of the full bin with the assistance of the company Lothlorien. The system required the cooperation of the company Lothlorien in receiving paper chips in unbailed form.

9.2.2 Alteration B.2 (Machine C and D)

An alternative to using the compactor was to deposit the paper directly into the waste bin containers. In figure 9.6 below an alternative to the closed compactor/bin unit is given. The overhead cyclone had a bin below it to facilitate the changeover of the containers. The containers had to be modified to prevent the paper from spilling out of them. The super structure cost was R30000 installed as quoted by S.A.D.A.C. An additional R35000 would be needed to fund two Hp fan units and an accompanying fan unit. The power consumption of these units was assumed to be the same as units currently installed on the Zerand and Thrissle lines.

Alongside the building:

Cost of initial installation:	R30000
Cost of labour	R18000
Maintenance	R828
Power	R5385
Machine downtime	R0

Total cost after one year	R54213
Total cost after 5 years	R103073
Total cost after 10 years	R133339

At the position of the containers:

Cost of initial installation:	R65000
Cost of labour	R18000
Maintenance	R828
Power	R5385
Machine downtime	R0

Total cost after one year	R89213
Total cost after 5 years	R128693
Total cost after 10 years	R158959

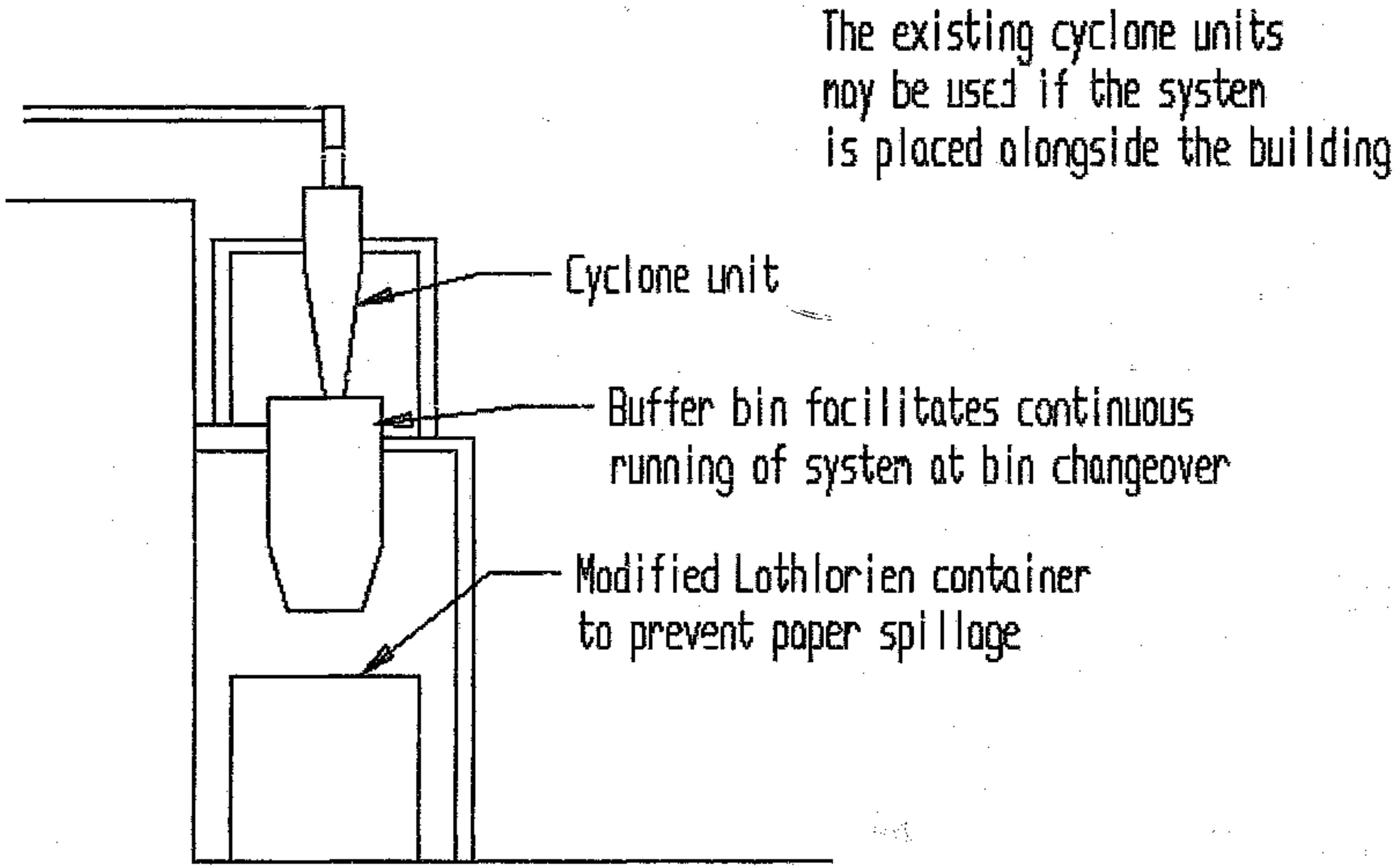

Fig. 9.6 Paper chips deposited directly into the Lothlorien container

The above system was sensitive to the inattention of a labourer. Stockpiling above the containers could occur. The responsible person had to ensure that stockpiling and the blockage of the cyclone did not occur. This problem could be eliminated with the installation of alarms. An additional cost was included in the above calculation to account for the elimination of this problem. This additional investment being justified by the saving in machine downtime.

9.3 Systems for the Blumer and Line cutter machines (E & F)

The system in use caused machine down time on the machines Blumer and the line cutter. The cost of the downtime was reccurrent and predictable. A by weekly down time of one hour occurred on each machine with the change over of the containers.

A further complication with the running of the handling system was the possibility of recyclable paper being amongst the non recyclable grades. At present the grades being used in these machines (indaba, chromolux,horse fly paper) were not recyclable. Tests were carried out by Lothlorien and by Nampak paper recycling. Nampak found that the wet strength of the paper was too high, i.e. the pulping operation took too long for the paper too be useful. Thus at present no recyclable paper waste was being produced by any of the trimming machines. In the event of paper waste being recyclable it would have to be separated from the non-recyclable grades. The additional equipment installed had to be economically justified by the revenue gained from the sale of the waste paper.

Lothlorien resells the cork tipping (non recyclable) to a company manufacturing packing material. It may be possible to derive additional income from the sale of packing material, this must be investigated. As it is not likely that paper used in the Printpak process will be recyclable in the foreseeable future, the justification of the system installed must arise from the fact that machine downtime is prevented on the production lines Blumer and the line cutter.

9.3.1 Alteration C.1

The current handling system was expensive due the long changeover times involved. The chip size transported by the pneumatic system was small and difficult to handle. The operation was messy and time consuming because of the large amount of time spent sealing the container into which the paper was transported. In the diagram below a system capable of handling the paper is illustrated. The existing cyclone unit was used, paper strip from all the machine centres was routed to the bin below the cyclone and into the horizontal compactor. The bin above the compactor had a capacity of 6 m^3. This would allow for a changeover time of at least one hour. Bin size on the compactor was 11 m^3. Each machine produced approximately 2.5 m^3 of paper in uncompressed state daily. Thus with a compaction ratio of 3 to 1 the bin would require emptying once every two or three days. The compaction system was driven by a 5kW motor. Additional power costs for the blumer and line cutter machines would therefore be R1320 per year (8 hours per day, 2 0 days per year). Additional maintenance costs would amount to R444 per year. The compactor unit with its buffer container cost R74820 installed.

The system was custom designed to the requirements of the customer, thus a completely closed system may be achiev ... he compactor was automated, the need to supervise the system was thus automatically eliminated. If this system was used in conjunction with the system on the Zerand and Thrissle production lines, the containers would be common. Fewer containers may therefore be used between the two production lines. In Figure 9.7 below, the system to be implemented. The bin containers to be used would be designed according to the requirements of Printp . In this application the bins would be designed to accommodate the small paper size in use (prevention of spillage).

Cost of initial installation	: R74820
Labour cost:	: R0
Machine downtime	: R0
Power	: R3960
Maintenance	: R868

Total cost for year 1	: R79648
Total cost for 5 years	: R70942
Total cost for 10 years	: R69032

The disadvantage inherent of this system was that the machines were centrally linked to a common handling system. Failure of the system would therefore be more costly.

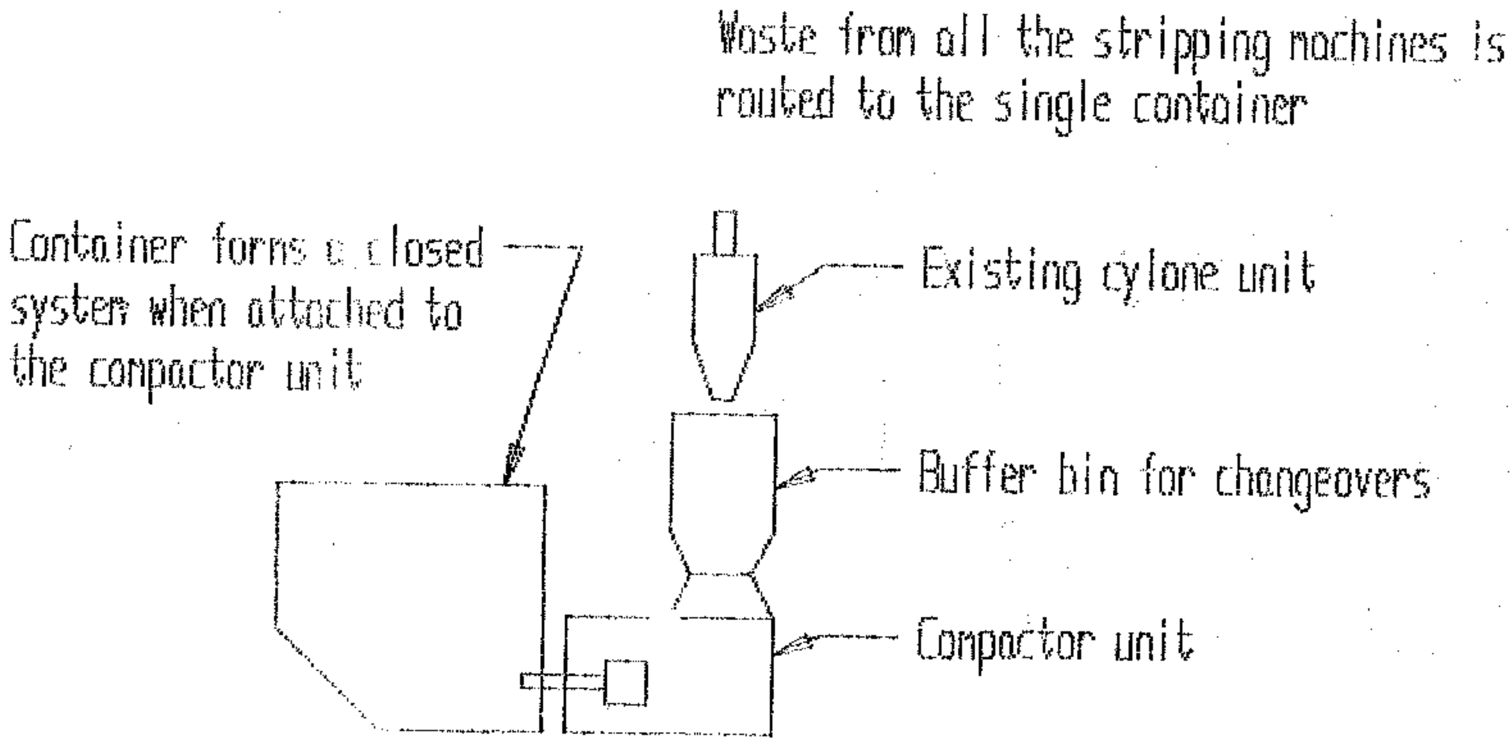

Fig. 9.7 Compactor system used on machines producing strip waste

9.3.2 Alteration C.2 (E and F)

The previous installation was expensive due to the compactor u nit used. The cost of the fan unit installed was also high as it was designed to serve all existing machines. Equipment used, i,e the Cyclone unit and the venturi extraction system on the line cutter may lower the cost of the system.

T his installation consisted of building a large support structure to accommodate the existing cyclone and a large buffer bin. The bin would prevent machine down time and collect paper from all the machines. The existing cyclone unit deposited paper into the bin, as well as the units serving the line cutter, slit1 (A) and slit2 (B) machines. This system can be seen in figure 9.8 below. The power consumptior for the relevant machines remained unchanged. Maintenance costs were as before. The cost of the bin installation was R31000. All machine downtime would be prevented.

In initial cost of installation	: R31000
labour cost	: R0
Machine downti me	: R0
Power	: R2640
Maintenance	: R424

Total yearly cost	: R34064
Cost after year 5	: R32956
Cost after year 10	: R33920

This system was feasible as it was relatively low cost. It incorporated the current machinery. The . stallation of the systems on the two slit machines (machine A and B) was not an economic necessity. These fan units were not justified in their cost as they were not needed to prevent machine downtime. The labour needed to prevent stockpiling of paper in the bin could can be signalled by an alarm system.

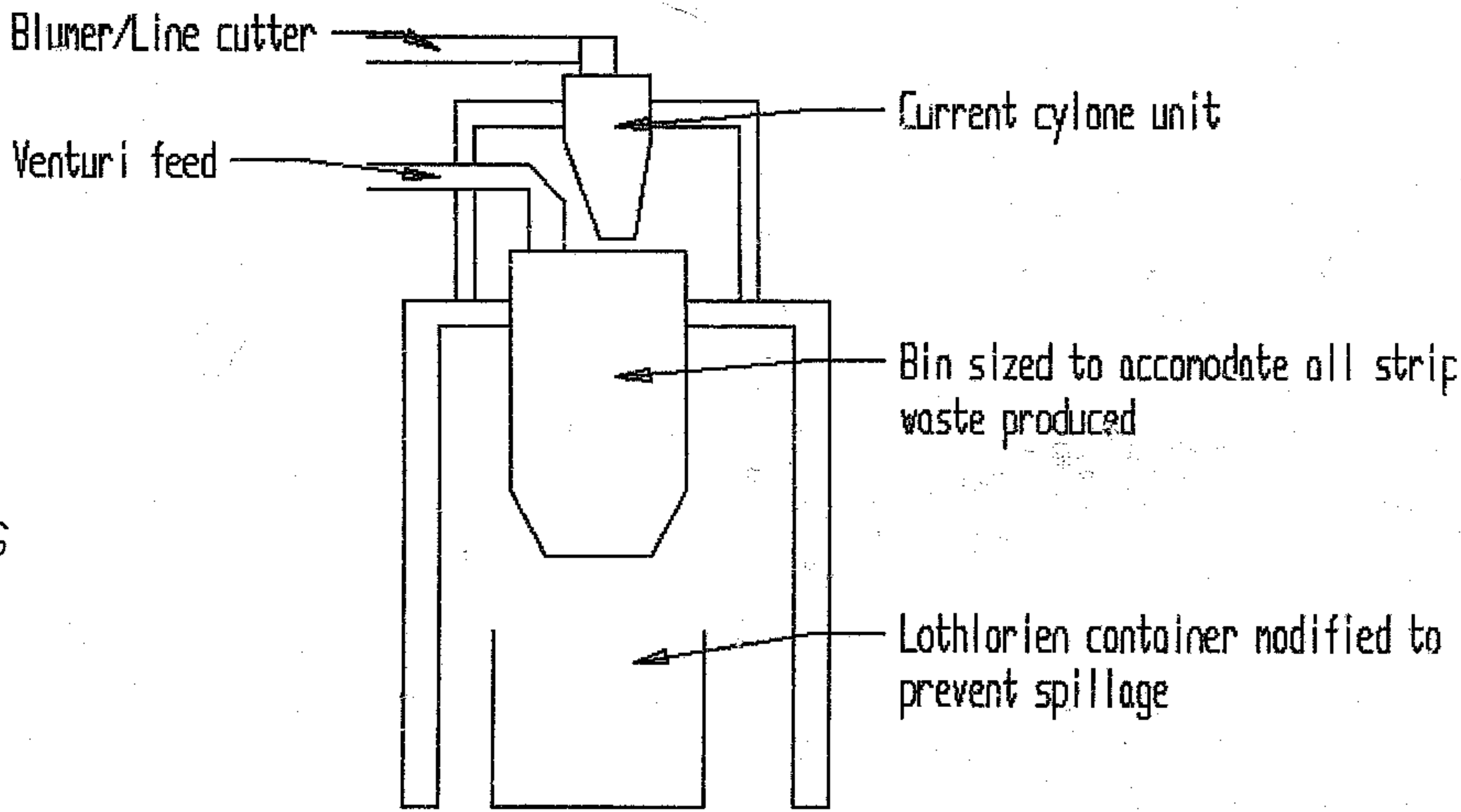

Fig. 9.8. Bin installation on machines producing strip waste

10 DISCUSSION AND CONCLUSIONS

10.1 Introduction

The final selection of the systems was based on the information yielded in the economic models. Selections were documented if the yearly operating costs were less than the cost of original systems. Systems selected for the Zerand and Thrissle machines would be dependent on Lothlorien co-operation to paper in unbailed form. The system selected were more effective than the systems currently in use. The effectiveness function was based on the economics of using each selection. The economic models used included all quantifiable costs, models displaying lower cost were considered more effective.

10.2 Systems for Zerand and Thrissle- paper in bailed form

If Lothlorien was unable to handle the paper in unbailed form alteration A4 was considered to be the most effective in reducing the cost of the system. The one year cost for this installation was R85529, this included the capital outlay for equipment. This compared favourably with the cost of the current system at R89656 for a single year period.

The cost efficiency of this selection increased over a long term period. For a five year period selection A4 would cost R185729 while the original system cost R300346, a 38% reduction in cost. For a ten year period the savings were similar magnitude. The system A4 cost R247786 while the original system cost R448280 a saving of 44%.

This increased reduction in cost was attributable to the capital cost being once off at the begining of the time of the investment. Tax savings every year, due to depreciation, further reduced the cost.

10.3 Systems for Zerand and Thrissle machines-paper in unballed form

If cooperation could be obtained from Lothlorien a less expensive system could be derived as an alternative to the abovementioned system. Selection B2 placed alongside the building would be the most cost effective solution. The operating costs for this system offered a substantial reduction on the original operating cost. For a single year period the system cost R54213, a 39% saving on the original expense over the single year period.

If the system was considered for a longer time span, then the saving would increase. The cost of the system over a five year period was R103073 as opposed to the original cost of R300346, a saving of 65%. Over a 10 time span the cost of system B2 was R133339 as opposed to the original cost of R448280, a saving of 70%.

The increase in magnitude of saving was due to a one off installation cost for the installed system, as opposed to a recurring labour cost for the original system. System B2 could be placed alongside the building without interfering w'.h the operating of the handling systems for the remaining machines. The system would fit, currently two containers were inuse alongside the building. With the use of the buffer bin as described, it would be possible to reduce the size of the container, thereby increasing the space av^il^bility and reducing the severity of the problem Lothlorien had with overloaded trucks.

10.4 Systems for the Blumer and Line cutter machines

System considered for the Blumer and line cutter machines were based on paper that was non recyclable. This was considered a valid assumption as various paper manufacturers were approached to test the paper, all tests indicated that the paper was not reusable.

System C2 was the least expensive for the two machines. The system cost insured a substantial reduction of the original operating cost. The first year cost for this system was R34064 as opposed to the original cost of R20296. Thus the system was not cost effective if considered over a single year period. The initial installation cost being large if compared with the saving of machine downtime.

The cost comparisons improve over a longer period. For a five year period the cost of system C2 was R32956 as opposed to the original cost of R67991, a 50% saving. Over a 10 year period system C2 had a cost of R33920 in comparison to the original cost of R101480 this was a saving of 66%. The increasing reduction in cost was due to the recurring cost of machine downtime on the original system.

10.5 Systems for machines A and B (slitting machines)

No systems were considered for these machines due to their low operating costs. The labour costs incurred were substantially lower than any alternative solutions. The interest lost or capital invested in machines, fans etc. was higher than the labour savings that stood to be made.

APPENDIX A: Hourly cost rates of cost centres

The costs of the factory, i.e. the factory fixed overheads are allocated to the various machines. With down time on any of the machines this cost is incurred, whether the machine is running or not.

Machine A: Slit 2

Hourly cost of machine - R129/hour

Annual cost of downtime (zero due to paper handling system)

Machine B: Slit 3

Hourly cost of machine - R88/hour

Annual cost of downtime (Zero due to paper handling system)

Machine C: Thrissle

Hourly cost of machine - R599/hour

Annual cost of downtime - R3594 (6 hours per year)

Machine D: Zerand

Hourly cost of machine - R1313/hour

Annual cost of downtime - R7878 (6 hours per year)

Machine E: Line cutter

Hourly cost of machine - R318/hour

Annual cost of downtime - R7632 (24 hours per year)

Machine F: Blumer

Hourly cost of machine - R399/hour

Annual cost of downtime - R9576 (24 hours per year)

APPENDIX B: Lothlorien consent to paper chips in unbailed form

The company Lothlorien was approached to obtain consent for the installation of a system handling paper chips in unbailed form. Lothlorien agreed to handle the paper chips if smaller bins were to be used. They agreed to consider the handling of paper in unbailed form if batches of between 4 and 6 tons could be delivered. They were willing to transport any form of container as long as the container was compatible to their trucks.

APPENDIX C: Maintenance estimates for the waste handling equipment

The selected systems will require maintenance. Maintenance considered included replacing worn components, general inspections of machinery and periodic lubrication of moving components. Machines would be checked on a regular basis, these inspections and lubrications would be carried out when production machines were not in use (e.g. during lunch hour). The extraction systems were comprised of different components, each component differed in level of complexity and cost of maintenance. The annual cost of the inspection was seen to be less than the cost of an unscheduled breakdown. From discussion with the engineer, a half hour of production was lost annually due to maintenance problems. This was a ball park figure that was mentioned based on experience. Proper staistical data of failures was not available. The maintenance of the handling system was not considered a problem but an unavoidable cost.

The following machines were used in the systems considered:

3 Phase squirrel cage motors

High pressure fan unit

Low pressure fan unit

Screw conveyor

Belt conveyor

Rotary valve

Overhead crane

Automatic compactor

Sensing devices

Maintenance of 3 Phase squirrel cage motors

GEC recommendations in the GEC catalogue from May 1980 states that when carrying out a scheduled maintenance, the motor is stripped down entirely, all defective components being replaced. The FAG catalogue suggests a bearing life of 10-15 years, normal operating conditions. The likelihood of an unexpected breakdown due to bearing failure is thus small 0.1% (FAG catalogue). A preventative maintenance scheme to prevent electric motor failure would consist of regular inspections (for unlikely accelerated component failure) and a scheduled overhaul period. The inspections would be carried out on a bimonthly basis and would check for the following:

* Unwanted Vibration, indicating bearing or shaft wear
* Belt tensions and general belt condition
* Security of fixing bolts
* Motor running temperature
* Operating current
* Motor electric terminals
* Corrosion or Mechanical damage
* Accumulated dirt

The inspection procedure carried out every two months would give adequate warning of an impending motor failure. The time taken for such an inspection would be 30 mins (based on discussions with maintenance personnel at motor manufacturers). At a technical labour rate of R40 per hour the cost would be R20 for every two months of motor usage. An annual cost of R120. The overhaul period for the motors could be determined for the specific duty that they perform. Electric motors lasting for more than 20 years are not unheard of. If the motors were overhauled every five years the cost would be R300 for every five years (R200 bearings and R100 for labour) of duty for a large motor (10 - 20kW) and R100 (R50 bearings and R50 labour) for a small motor (0 - 10 kW). R300 paid over a five year period (annuity) at a prime interest rate of 15% amounted to R44 per year, while R100 over five years was R15 per year. The total annual cost for large electric motors would be R164, small electric motors costing R135 per year.

High and Low pressure fan units

The fan units were coupled to the squirrel cage three phase motors with a belt and two pulleys. The fan units consisted of enlosed impellers that ran on two or more deep grove ball bearings. The plummer blocks of the fan bearings were supplied with grease nipples for lubrication. The impeller blades were enclosed in housings that could be opened for inspection. As the fan units were directly driven by the electric motors, they would be inspected when the electric motors were inspected. The inspection would cover the following details as specified by the manufacturers:

* Check for excessive vibration, indicating bearing impeller condition.
* Visually inspect the condition of the impeller blades.
* Check mountings, bearing fastening.

* Check belt condition and tension.

The inspection would add an additional 10 minutes onto the inspection time of the electric motors. An additional 10 minutes would cost R40 per year (R40 per hour, 6 10 minute inspections per fan per year). If the fans were overhauled every 5 years then the following cost would be added: R200 for bearings and R50 for labour. This amount paid by equivalent annuity at an interest rate of 15% would amount to R37 per year over a five year period. The yearly cost of maintaining both the high and low pressure fan units is R77 per year. If this cost was added to that of the electric motors then the following costs were incurred: low pressure fan units would cost R212 annually while high pressure units cost R241 annually.

The screw conveyor

The screw conveyor was driven by an electric motor with a belt drive. The spiral ran on oridinary deep groove ball bearings, the motor was a small three phase squirrel cage motor. The inspection of the conveyor, as specified by the manufacturer, would consist of checking the motor, the belt and ensuring that the spiral was running true (not damaged by blockages). The cost of checking the small electric motor and maintaining it would be R212. An additional R40 per year was added onto the cost to account for the replacement of the conveyor bearings after every 5 years. Total cost of conveyor maintenance amounted to R252 per year.

Belt conveyor

The belt conveyor consisted of a 3 phase squirrel cage motor (small) driving a roller with a belt. The roller engages the belt that transports the material. The inspection checked the electric motor (R212 per year) and aspects of the belt. The following points would be considered at the bi-monthly inspection:

* Rollers running true, are all rollers running
* Belt condition
* Conveyor belt tension

This inspection would take 10 minutes and would add an additional R40 per year onto the cost of maintaining the small electric motor. The total yearly cost for the belt conveyor would therefore be R252.

Rotary valve

The main wearing component of the rotary valve was the small electric motor that drives it. The yearly cost of maintaining a small electric motor was R212.

Overhead crane

The crane selected for installation was the electric version. It consisted of two electric motors driving the two planes of motion and a third controlling the lifting action of the crane. The cost of maintaining the crane would therefore be that of maintaining three small electric motors. Other wearing items of the crane (pulleys, hand held controls, and cables) were assumed to be included in the cost of maintaining the electric motors. The total cost would therefore be R636 per year.

Automatic compactor

The automatic compactor consists of an electric squirrel cage motor driving a hydraulic motor. The hydraulic motor forces fluid through valves, these activate an arrangement of hydraulic pressure cylinders. The cost of maintaining the electric motor is R212 per year. The same amounted was allowed for the hydraulic motor. The cylinders and valves are overhauled every five years. The system consists of 3 cylinders, five valves and 2 timing devices. The overhaul of the cylinders costs R40 per cylinder for labour (1 hour to overhaul 1 cylinder) and R10 for p[illegible]. The cost of maintaining the cylinders is therefore R120 every five years or R20 per year. The total cost of maintaining the system is therefore R444 per year.

Sensing devices and electrical contactors

The manufactures quote an unlimited lifespan for the solid state sensing devices (Infra red switches). It was assumed that the devices would have a limited lifespan of 10 years. If a replacement cost of R750 is incurred every 10 years, the annual cost would be R25 (based on an equivalent anuity at 15% interest and over a 10 year period).

Maintenance costs for machines currently in use

Machine A

Lp fan unit : R212

Total yearly cost : R212

Machine B

none

Machine C

Lp fan unit	: R212(*0.2)
Hp fan unit	: R241(*0.2)
Rotary valve	: R212(*0.2)

Total yearly cost : R133

Machine D

Lp fan unit	: R212
Hp fan unit	: R241
Rotary valve	: R212

Total yearly cost : R665

Machine E

Lp fan unit R212

Total yearly cost R212

Machine F

Lp fan unit R212

Total yearly cost R212

The maintenance costs considered were included in each system. Each system consisted of different combinations of the above machines. The cost of each installation is considered below:

Option A1:

This option was for the Zerand and Thrissle production lines. A screw conveyor with a sensing device was added to the system. The complete system costs for maintenance thus consisted of the following:

Thrissle machine

Lp fan unit @ R212 per year * 0.2

Hp fan unit @ R241 per year * 0.2

Rotary valve @ R212 per year * 0.2

IR device @ R25 per year * 0.2

Screw conveyor @ R252 per year * 0.2

Total yearly cost R188

Zerand machine

Lp fan unit @ R212 per year

Hp fan unit @ R241 per year

Rotary valve @ R212 per year

IR device @ R25 per year

Screw conveyor @ R252 per year

Total yearly cost R942

Option A2

An alternative to A1, alarms and buffer bins are installed below the current extraction system. The system thus consists of the following components:

Thrissle machine:

Lp fan unit @ R212 per year * 0.2

Hp fan unit @ R241 per year * 0.2

Rotary valve @ R212 per year * 0.2

Infra red alarm @ R25 per year * 0.2

Total yearly cost R138

Zerand machine

Lp fan unit @ R212 per year

Hp fan unit @ R241 per year

Rotary valve @ R212 per year

Infra red alarm @ R25 per year

Total yearly cost R690

Option A3

A belt conveyor is placed below the existing extraction system. The system for the Zerand and Thrissle machines thus consists of the following:

Thrissle machine:

Lp fan unit @ R212 per year * 0.2

Hp fan unit @ R241 per year * 0.2

Rotary valve @ R212 per year * 0.2

Infra red alarm @ R25 per year * 0.2

Belt conveyor @ R252 per year * 0.2

Total yearly cost R188

Zerand machine:

Lp fan unit @ R212 per year

Hp fan unit @ R241 per year

Rotary valve @ R212 per year

Infra red alarm @ R25 per year

Belt conveyor @ R252 per year

Total yearly cost R942

Option A4

System A1 is combined with an alteration to the existing crane system. If A1 is used with a more extensive crane system then the yearly cost of maintenance will be as follows:

Thrissle machine

Lp fan unit @ R212 per year * 0.2

Hp fan unit @ R241 per year * 0.2

Rotary valve @ R212 per year * 0.2

Infra red alarm @ R25 per year * 0.2

Belt conveyor @ R252 per year * 0.2

Overhead crane @ R636 per year * 0.2/1.2 (system is shared between Thrissle and Zerand machines)

Total yearly cost R294

Zerand machine

Lp fan unit @ R212 per year

Hp fan unit @ R241 per year

Rotary valve @ R212 per year

Infra red alarm @ R25 per year

Belt conveyor @ R252 per year

Overhead crane @ R636 per year *1/1.2 (system is shared between Zerand and Thrissle machines)

Total yearly cost R1472

Option B1

In this selection the bailing operation was not used. An automatic compactor was used in conjunction with the current systems. The cost of maintaining the system for both the Zerand and Thrissle machines was as follows:

Lp fan unit @ R212 per year * 1.2

Hp fan unit @ R241 per year * 1.2

Rotary valve @ R212 per year * 1.2

Infra red alarm @ R25 per year * 1.2

Compactor unit @ R444 per year * 1.2

Total yearly cost R1272

Alteration B2

Paper was dropped directly into the waste bin containers. A buffer bin was placed beneath the common cyclone of the Zerand and Thrissle lines. The maintenance costs for this system was calculated to be the combined maintenance cost of the Zerand and Thrissle lines for the year period.

Lp fan unit @ R212 per year * 1.2

Hp fan unit @ R241 per year * 1.2

Rotary valve @ R212 per year * 1.2

Infra red alarm @ R25 per year * 1.2

Total yearly cost R828

Option C1

The system uses a cyclone unit (lp) and an automatic compactor. The compactor is a common server of both tmachine E and machine F. The cost for maintenance of this systems is as follows:

Lp fan unit @ R212 per year * 2

Compactor @ R444 per year

Total yearly amount R868

Option C2

The compactor unit was excluded in this system. Existing equipment was used to drop the paper directly into the bins. The three existing fan units were used to drop paper directly into the bin. The cost of the systems were as follows:

2 Lp fan units: @ R424 per year

Total yearly cost R636

APPENDIX D: Companies supplying equipment prices

1. Bellambie mining and industrial: Electric crane capable of moving in two planes
2. SADAC: Fan units, Cyclones, Bins and ducting
3. Donkin fans: High pressure fan units for the Zerand and Thrissle lines.
4. Howden Safanco: High pressure fan units for the Zerand and Thrissle lines.
5. Nampak Paper recycling: tests to determine whether paper grades were recyclable
6. 52 Engineering: Quotes on fan systems installed for strip waste machines.
7. Akura: Automatic bailing machines
8. Duncanmec: Automatic compactor unit with bin.

APPENDIX E: Sample calculation of cost estimate

Machine lifespan determination

The basic lifespan of a machine is based on the replaceable components that it is made of. Prolonging the lifespan is achieved by increased maintenance. A early maintenance cost is calculated for each installation, machinery is considered to be replaced every ten years.

Cost/Income estimates

Once the lifespans for the machines are determined it is possible to estimate the cost and potential savings on each system. Costs are, capital investment, labour, power and maintenance. Income derived from the systems includes downtime prevention and tax benefits obtained from depreciation. Any machine purchased is costed for a one year, five year and a ten year period. A 20% depreciation factor is used, the machine depreciates to zero book value over a period of five years. Depreciation reduces the annual tax expense for the factory by a factor of 0.2 * 0.4 * capital outlay (if a 20% annual depreciation is considered). The costing for a machine is as follows:

5 year cost

capital + (annual running cost - 0.2 * 0.4 * capital) * 3.35

10 year cost

capital + (annual running cost - 0.2 * 0.4 * capital) * 3.35

+ (annual running cost) * (5 - 3.35)

where the factors 3.35 and 5 are the annuity based cost factors referring costs and income to present value. The value 0.4 is the current tax rate while 0.2 is the depreciation for the machinery.

Present value assessment

All the costs and income for each machine are referred to the present value using a 15% nominal interest rate (current bank interest rate). The different installations are then compared, the system with the highest current net value (lowest cost) is assumed to be the best option. Risk or probability of success factors are not included in the calculations as the systems are currently in use and therefore proven technology of low risk.

A sample calculation of the cost estimate for the installation A3 for the Thrissle is presented to clarify the method in calculating the yearly operating costs.

System A3 required the installation of a belt conveyor below the pipe outlets in the bailing room. An alarm was fitted to the pipe to detected possible blockages. The cost of the conveyor was R5500. The alarm systems were available at a price of R750 each. A power cost of R1056 was allowed for the running of the belt. Additional maintenance of R277 was allocated. Four labourers were still being used, at a cost of R72000 for boththe Zerand and Thrissle machines (R12000 for Thrissle and R60000 for Zerand machine).

Cost calculations carried out for the system on the Zerand machine were as follows:

Capital cost		R6250
Belt conveyor	R5500	
Alarm system	R750	
Power cost		R1108
Current usage	R897	
Additional usage	R1056*(0.2)	
Labour cost		R12000
current usage	R12000	
Machine downtime		R718
current losses	R3590	
Downtime reduction	(R2872)	
Maintenance cost		R188
Current cost	R133	
Additional cost	R272 (0.2)	
Total cost for 1 year		R20264

To calculate the cost for the system over a longer period a correction had to be made for the effect of tax saved. An annual tax saving was obtained from the effect of depreciation. The amount saved on depreciation was the following:

Capital expenditure * Depreciation rate * tax rate

A tax rate of 40% and an annual depreciation of 20% was taken. The cost of the system for a five year period was therefore calculated as follows:

R6250 + ((R1108 + R12000 + R188 + R718) - 0.2*0.4*R6250)* present value factor = R51521

The present value factor was taken as an annuity type payment factor and was taken as 3.35 for five years and 5 for ten years.

The cost for the system over a ten year period was calculated as follows:

R6250 + ((R1108 + R12000 + R188 + R718) - 0.2*0.4*R6250) *3.35 (R1108 + R12000 + R188 + R718) * (5 - 3.35)

= R69038

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