

Using Fundamentals to Break the Breakdown Maintenance Cycle

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INTRODUCTION

During 1991 - 1993 the author interviewed approximately thirty senior managers of varying responsibilities in either the engineering, construction or operation of a heavy industrial facility. The purpose of the exercise was to determine the factors driving a deterioration of the working relationship between the engineering and the operating company following practical completion of a major project. From the research a number of conclusions have been drawn as to the root cause of the deteriorating relationship. For this paper we are drawing on this initial research and our ongoing experience of solving problems of this nature to present some fundamentals that can be used to break the breakdown maintenance cycle.

Our research showed that approximately eighty percent of all new heavy industrial plants and manufacturing facilities fall into a one to two year revenue generation slump shortly after practical completion. When hundreds of millions of dollars are invested in new heavy industrial plant or manufacturing facilities the principals rightfully expect a reasonable return on the investment once the operation has started production. The reasons for the slump in revenue generation are numerous and varied and this paper is aimed at addressing some of the factors that can be easily corrected with today's understanding of the forces involved.

The 1991 - 1993 research indicated that a lack of formalisation prior to practical completion was the main cause of a company falling into a revenue slump following practical completion of the new plant. On the operating company side of the equation this lack of formalisation is brought about due to ignorance of the importance formalisation has on revenue generation. With no understanding of the importance of formalisation to revenue generation there is a very strong tendency by the operating company not to spend any capital for formalisation during the pre practical completion investment stage of the project. This problem is so severe on the operating company's side that most of the companies when building a new plant do not even budget for formalisation at all. With all good intentions the operating company's management make incorrect decisions about the need for formalisation and/or the timing of the development of the required procedures to the detriment of the revenue generation of the project.

On the engineering side of the equation this lack of formalisation is brought about predominantly by the short term view of a design and construct mentality with little or no consideration of the long term operational requirements. In some cases the engineer is also ignorant of the importance formalisation has on revenue generation for the operating company and as such is not even aware of the effect of lack of formalisation. On the other end of the scale the engineer may know the importance, but chooses to exclude the work from the tender in order to be more competitive than their competition with the view that this portion of the project can be added as an extra at a later date.

On the positive side, the 1991 - 1993 research indicated that twenty percent of companies who have not experienced the post practical completion drop in revenue either stayed at the designated name plate data design rate or were able to operate at a production rate that was within the plant capabilities and at a value higher than name plate data thus generating a revenue higher than projected. In addition to the stable revenue, some of the companies evaluated experienced a lower than average number of early life failures following practical completion. The solution to staying out of breakdown maintenance following practical completion is to formalise the following areas before the plant start-up:

¹ Paradigm Shifting Pty Ltd

- Company Procedures
- Production Standard Operating Procedures
- Maintenance and Operator Training
- The Development of a Maintenance Program

During the 1991 - 1993 research, in addition to looking at “the factors driving the deterioration of the working relationship between the engineering and operating company” we also evaluated the factors contributing to the achievement of the optimum Maintenance/Production cost point. From our research of the problems on this level we have determined the following elements need to be addressed to achieve the optimum cost point for each plant.

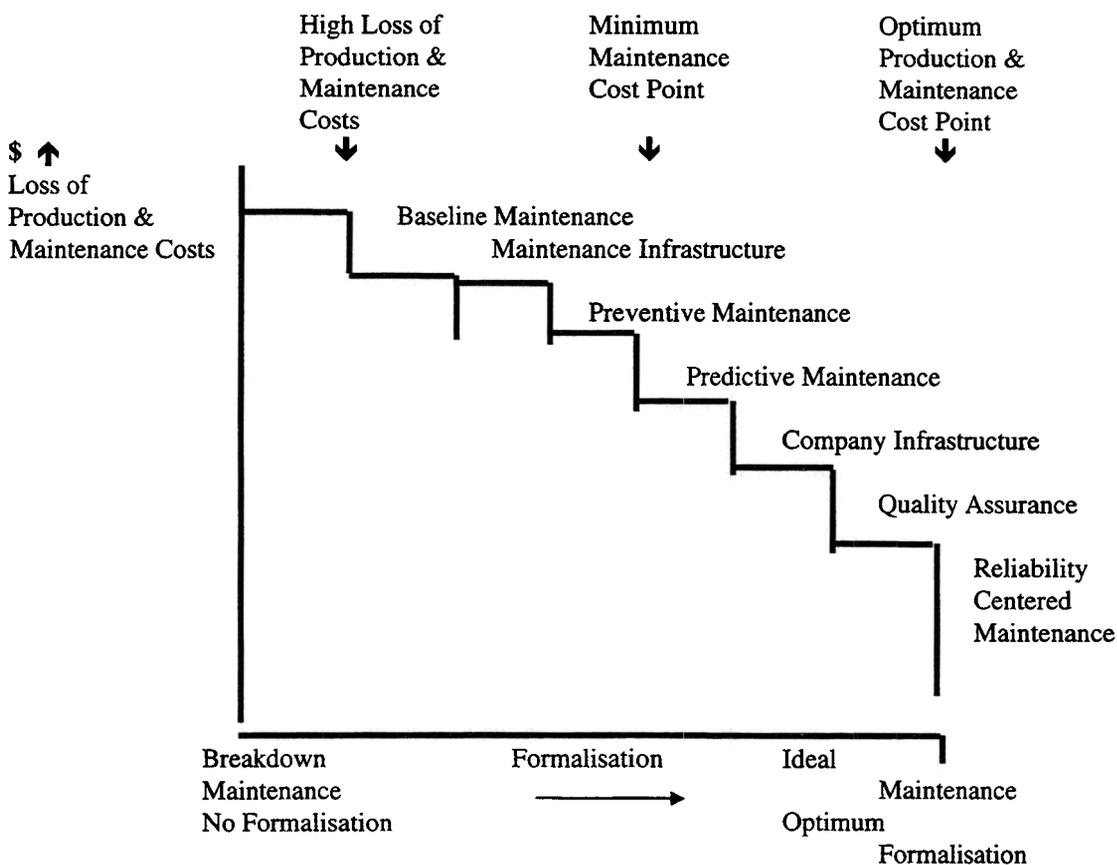


Fig. 1 - Maintenance / Production Cost Relationship

Most companies are addressing a number of the key elements to some degree or another. The solution is to evaluate and systematically apply all of the elements as appropriate for each plant. This systematic application will move a company from a severe degree of breakdown maintenance to the optimum cost point and in the process generate the desired results of reduction of costs and improved quality and productivity of product.

Attached as Appendix is a fault tree that can be used to assist the personnel in an operating company evaluate and determine their present position, determine what areas need to be improved and then using internal manpower or with outside assistance take actions that will generate the desired improvements.

MAINTENANCE PRODUCTION COST RELATIONSHIP

The profitability of a company, or the bottom line, is the core issue as to whether an organisation is allowed to continue to exist, the employees continue to work and the facility has a future. As such, the first topic that needs to be discussed, when breaking the breakdown maintenance cycle, is the relationship between maintenance and loss of production costs. Once the relationship is understood the operating company can determine the relevance of the material.

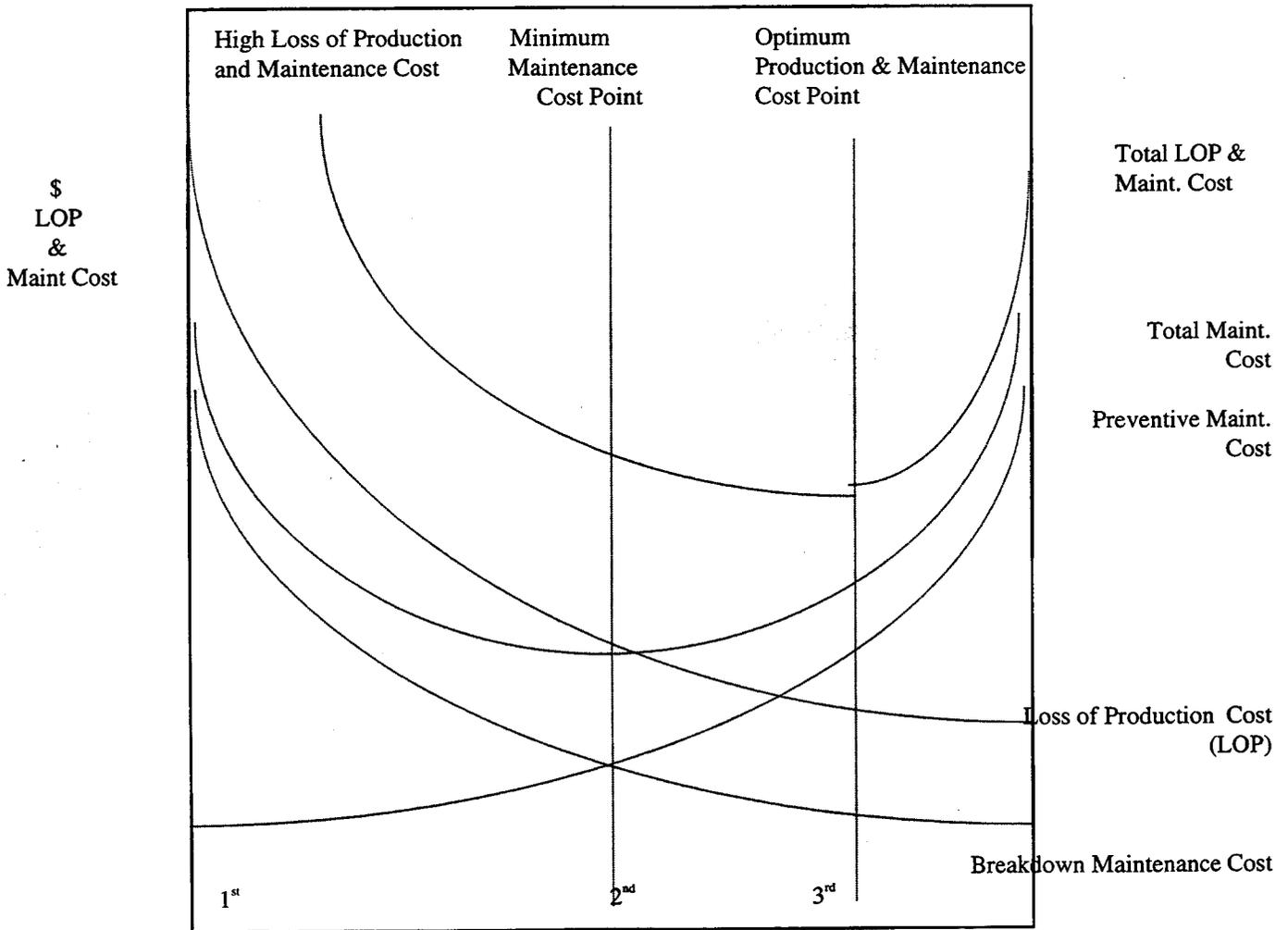


Fig. 2 - Maintenance Production Cost Graph

The above cost graph is a reflection of the relationship between the cost of preventive maintenance, breakdown maintenance and the loss of production over the 1st, 2nd and 3rd generation maintenance philosophies.

Minimum maintenance cost point

Starting with a 1st generation logic of zero preventive maintenance the result will be that 100% of all maintenance will be breakdown (ie. fix it when it breaks) resulting in a high loss of production. As preventive maintenance (2nd generation philosophy) is introduced and applied to the machinery, the cost of breakdown maintenance and the cost of loss of production decrease on parallel paths. These paths will be similar until the point of minimum maintenance cost is reached. At this point maintenance cost is minimised, but still results in a high degree of loss of production. This type of operation has a high degree of emphasis placed on reducing maintenance cost rather than looking at the bigger picture of maintenance cost per unit of production.

Optimum loss of production and maintenance

If additional preventive maintenance is applied beyond what is required to reach the minimum maintenance cost point the total cost of maintenance will start to increase, but the loss of production cost will continue to decrease. If this process is allowed to continue a point will be reached where the optimum cost of producing the product will be realised. This optimum cost point is the desirable point to be at - this is where the product is at the lowest cost /unit produced.

Exceeding the optimum cost point

In some industries such as space, nuclear and others dealing with explosive or dangerous materials it is prudent to continue to apply additional preventive maintenance beyond the optimum cost point. In this region of the graph the facility is no longer operating at the optimum cost point and in fact is expending additional resources to ensure that safety requirements and environmental constraints are met.

Determining the actual position in relation to optimum cost point

To determine where a facility is in relation to the optimum cost point it is necessary to observe the contribution of loss of production. If for example, loss of production is being caused by breakdowns the facility is being maintained to the left of the optimum cost point, in a 2nd and possibly, worst case, a 1st generation philosophy. On the other hand, if loss of production is being caused by over maintenance it is an indication the facility is being maintained to the right of the optimum cost point.

Obviously, the evaluation presupposes that the key point indicators of preventive maintenance (PM), breakdown maintenance (BM) and loss of production (LOP) are being tracked.

ENTERING THE WHIRLPOOL

The decisions made prior to practical completion for fixed plant and those made prior to site delivery for mobile plant are the ones that determine whether or not a company will realise the benefits of the capital investment or whether the plant or equipment will enter a breakdown maintenance mode. If the plant and equipment goes into breakdown maintenance the revenue generated from that plant and equipment will fall into a slump. In most cases this slump will last for one to two years. The purpose of this section is to show how a company gets swept into the whirlpool and to show what is required to ensure that the whirlpool is never entered.

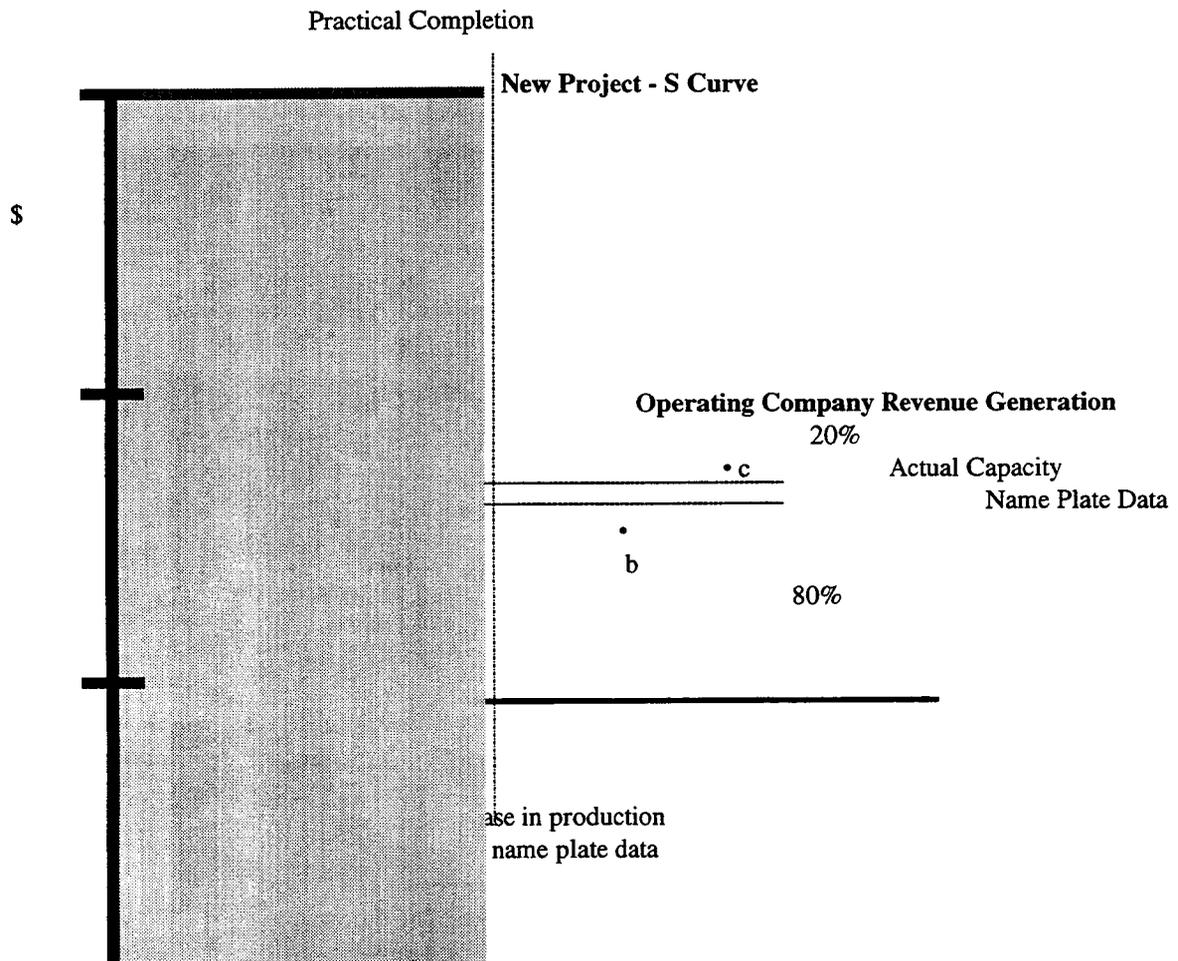


Fig. 3 - New Project Revenue Generation Relationship

1. Company Procedures
2. Standard Operating Procedures for Production
3. Training Program for both Maintenance and Production
4. Maintenance Program
 - 3 Stages Of Maintenance Program
 - a. Prior to Practical Completion
 - b. In Breakdown Maintenance
 - c. A Mature Program

Return on Investment

Investors spend large sums of money on building new facilities with the view that they will generate a reasonable return on their investment based on the production rate of the plant, ie Name Plate Data. Our investigations show that 80% of these new facilities do not generate the desired revenue and in fact fall into a revenue slump shortly after achieving practical completion. This slump can easily last 1 to 2 years and in some cases has been as long as seven or eight years. The impact of this lost revenue is the curtailment and/or delay of other future projects identified in the company's long term plans. The company's efforts instead need to be focused on the new plant that is now in breakdown maintenance.

Misconceptions Leading to High Loss of Revenue

The following points are generalisations of some of the factors that have lead to a facility dropping into a revenue slump following practical completion:

Initial Scope of Work

When an operating company goes out to tender to build a new plant, in most cases, the requirement to assist in the development of company procedures, standing operating procedures, training for maintenance and production and the development of a maintenance program are not included as part of the scope of work.

Recognising the Need for Formalisation

In a number of cases the operating companies have a negative view towards procedures and formalisation of any type and instead take the view that operators are hired because they know how to operate, and the maintenance department can develop the maintenance program after practical completion. The expenditure of any money for procedures prior to practical completion is unnecessary and is just extra money going out. These views are totally wrong and they are the major cause of companies falling into the revenue slump.

New Equipment Will Run Until the Program is Developed

The view exists that new equipment will run with no problems; the new maintenance department will be under utilised with lots of spare time; we can hire all the trades and operators at the last minute and we will have time after practical completion to develop all of the maintenance program requirements. The problem with this view is that after practical completion a plant has a number of major early life failures and poor design problems to sort out. Also if you do not perform preventive maintenance a piece of equipment will fall straight into breakdown maintenance. The period of time following practical completion is one of the busiest periods of time for maintenance over the design life of the plant. They most assuredly do not have time to develop a maintenance program during this phase of plant life.

Staying Out of the Whirlpool

From our research the 20% of companies that did not fall into breakdown maintenance had the following in place prior to practical completion:

- Company Procedures
- Standard Operating Procedures
- Training (Maintenance and Production)
- Maintenance Program

SWIMMING AGAINST THE FLOW OF THE WHIRLPOOL

This section of the paper deals with breaking the breakdown maintenance cycle. How do we get out of the whirlpool once we have been sucked into the vortex. What do we do that is different from what we have been doing and still stay cost effective. To break the breakdown maintenance cycle and to obtain the goal of "Optimum Cost Point" the following key elements need to be put in place. The order is not especially crucial and in most cases an organisation will have facets of each key element in place and may be working on all seven simultaneously.

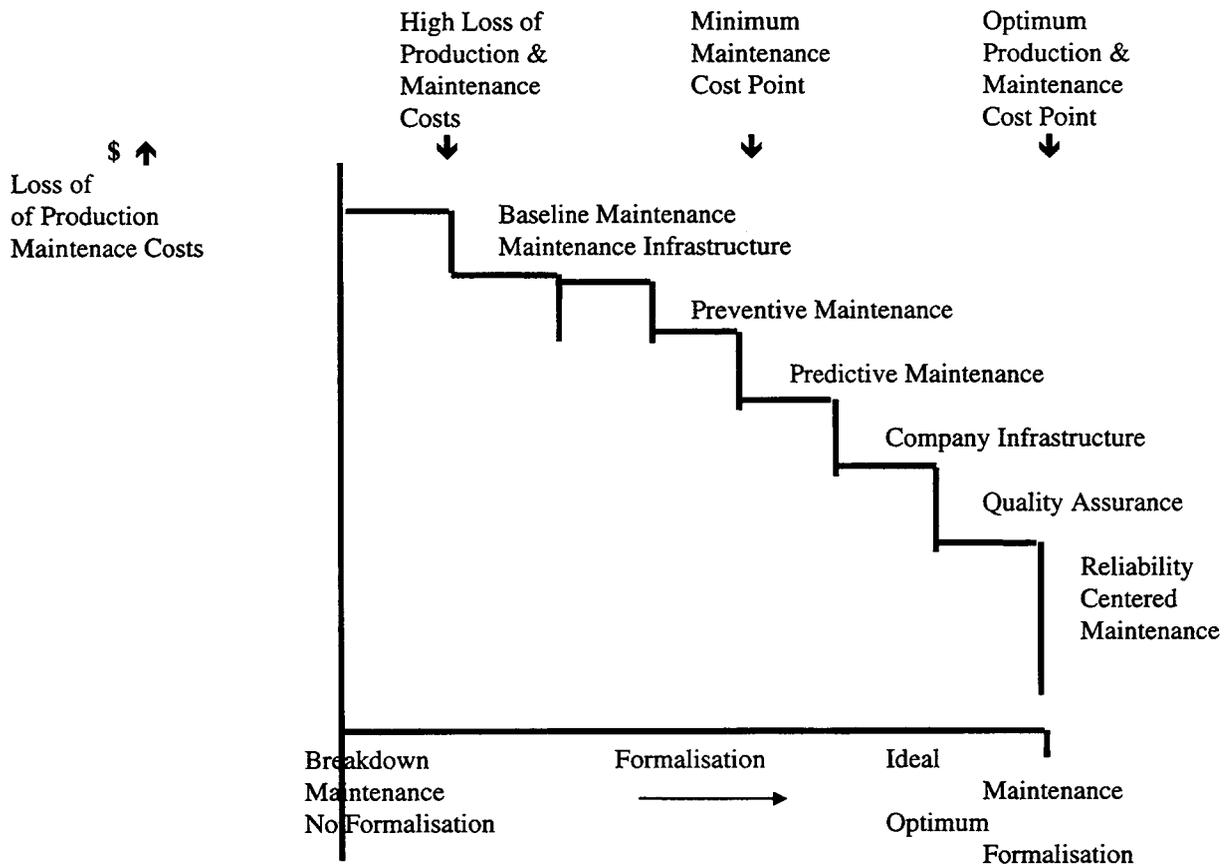


Fig. 4 - Maintenance / Production cost relationship

Loss of production, and maintenance costs, decrease as you approach an ideal maintenance program

Baseline maintenance

Baseline maintenance is the ground level and starting point of an effective maintenance program. This level of the maintenance program addresses documentation, skilled labour, parts and materials and special tools. Plant and equipment will fail and some of these failures will be unexpected. It is the development of baseline capabilities that determines how

effective the organisation is in dealing with these unexpected failures. Some of the consistent weak points observed during plant audits are as follows:

- Poor care and control of insurance spares;
- Poor identification, care and control of special tools;
- Purchase of alternate spares to save a few dollars;
- Access to parts and materials during back shifts; and
- Poor technical library and few “As Built” drawings;

Maintenance infrastructure

Maintenance infrastructure deals with the way maintenance is organised to carry out maintenance. This level of the maintenance program addresses organisational structure, the responsibility, authority, accountability and ownership factors and the work process system. Some of the consistent weak points observed during plant audits are as follows:

- Organisational structures are put in place, but are seldom an accurate reflection of the field practice;
- There is an imbalance between the assigned responsibility and authority, but the individuals are still held accountable for non-performance, generating negative feelings towards ownership and company loyalty;
- Work process systems are ad hoc or not in place at all;
- Companies are in a high degree of breakdown maintenance requiring the maintenance supervisor to perform supervision while still expecting them to carry out the planning functions;
- Breakdown crews are formed and empowered in such a manner that they become self fulfilling and continue the breakdown mentality; and
- Management decides to control costs by reduction of labour in the maintenance workforce making it difficult or impossible to increase preventive maintenance to realise the desired results.

Preventive maintenance

This key element is the most cost effective and most crucial in that it has a direct impact on the length of time that a piece of equipment operates. Lengthening the time of equipment operation results in higher production. This level of the maintenance program addresses the formalisation of evaluation, planning, organising, scheduling and executing those activities that will prevent failures of plant and equipment. Some of the consistent weak points observed during plant audits are as follows:

- Disregard of the basics of maintenance, clean, inspect, lubricate and carry out minor adjustments
- Ad hoc approach with no formalised maintenance procedures,
- Adverse attitude of management, supervision and trades towards formalised procedures,
- Management attitude that if you don't have a wrench in your hand you are not working,
- General lack of communication.

- The feedback loop not being closed, and
- At this point the flow and location of parts and materials is often still a problem.

Predictive maintenance

Predictive Maintenance is the second most cost effective activity in the maintenance program. Once the maximum lifespan of a piece of equipment can be achieved through the application of preventive maintenance activities, the organisation needs to know the possibility and timing of potential failures through the application of predictive maintenance techniques. This key element deals with the application of on-condition monitoring, the collection and analysis of the data and the prediction of the failures based on the data. Some of the consistent weak points observed during plant audits are as follows:

- Pieces of equipment are allowed to run to failure without operators communicating the potential failure to maintenance;
- Pre-start checklists are nonexistent or disregarded ;
- Poor shutdown planning with a large number of additional items added at the last minute ;
- Resistance to utilising contract labour; and
- A view that on-condition monitoring is high tech and very costly;

Company infrastructure

Company infrastructure addresses the way the company is organised to support the maintenance activities. This key element deals with the upper tier infrastructure factors and is typically not recognised as having an impact on maintenance. Some of the consistent weak points observed during plant audits are as follows:

- Poor recognition by management that the product of maintenance is “equipment availability” and therefore the foundation of high productivity;
- Promotion of the importance of production to the detriment of maintenance
- Accounts clearing the warehouse of all slow moving parts and materials without consulting maintenance for a proper evaluation of their requirements;
- Selection of a computerised maintenance system that is good for accounts but poor for maintenance;
- Shift competition and bonus schemes encourage one shift to run equipment to total failure to benefit the shift, but to the detriment of the company; and
- Engineering is an empire unto itself, allowed to design, procure and build without consultation with production and maintenance;

Quality assurance

Quality assurance addresses the formalisation of the entire organisation in its desire to carry out repeatable activities that can be improved in a systematic, step by step process to generate a high quality product at a reasonable cost. Some of the consistent weak points observed during plant audits are as follows:

- No quality assurance program exists at all;

- The company did not know the direct cost of poor quality prior to implementing quality assurance;
- The company tries to recover the cost of quality assurance application through the increase of the product selling price, rather than the reduction of direct cost of poor quality or the resultant increase in sales;
- The introduction of quality assurance was too far removed from the shop floor, ownership does not exist and the documents are now dust collectors; and
- Quality assurance was adopted to meet some outside requirement rather than seen as an internal mechanism that could generate systematic improvements;

Reliability centred maintenance

Reliability Centred Maintenance (RCM) is the most recent addition to the series of key elements that can be used to assist in the attainment of the optimum cost point. The RCM approach deals with a systematic analysis of plant and equipment to determine the corrective (breakdown), preventive and predictive maintenance required to ensure the reliability of the plant and equipment in the most cost effective manner. Some of the consistent weak points observed during plant audits are as follows:

- Most organisations must first improve the sophistication of their existing 1st and 2nd generation programs, before considering RCM;
- Companies have backed away or withdrawn from the RCM analysis techniques due to the perceived cost of implementation;
- Companies have fallen into breakdown maintenance because of the view held during implementing “that the overall outcome was a reduction in maintenance so lets stop performing preventive maintenance now and spend our extra time on RCM”;
- Most companies have not conducted any type of formalised analysis to determine the requirements to ensure reliability;
- Most companies do not capture root cause of failure data via the feedback loop; and
- Most companies do not track nor analyse the cause of early life failures.

SUMMARY

In summary this paper has been designed with the idea that operating companies can be improved by concentrating on the following areas:

- Making the correct decisions regarding the need for formalisation prior to practical completion;
- Realising that to achieve the optimum cost point management may be required to allocate additional funds to the maintenance department and trying to achieve minimum maintenance cost may be counter productive;
- Utilising the “self analysis check sheet” and applying to the following to areas:
 - Audits,
 - Training,

- Formalisation

New Greenfield site

When building a new plant the problem of only 20% of companies achieving the desired results where 80% of all new projects fall into a revenue slump within 3-6 months of practical completion and the fact that the slump will last for one to two years must be addressed. This is a mismanagement problem where the operating company - in most cases - does not understand the need for formalisation and training prior to practical completion. The engineering contractor further contributes to the problem by not addressing the negative impact that little or no input into design, from maintenance and operations will have on the revenue generation following practical completion. To solve these problems operating companies must provide additional funds at the start of a project to formalise maintenance and operations prior to practical completion. If this view is embraced, projects will become more profitable, the risk of building new projects will be lowered and the investors will be more inclined to further invest in additional new projects.

Success factors of the 20 %

The following four success factors were present in the companies that built new projects, and then, following practical completion, did not fall into a revenue slump. The development of the maintenance program was predominantly the most important of the four.

Company procedures

Sorting out the company procedures prior to practical completion had the effect of setting the infrastructure in place before it was required. During a relatively non-hectic time, individuals were able to develop and formalise a whole series of procedures addressing day to day requirements. This meant that when the frenzy of activities required to commission and reach practical completion was taking place, the company procedures were in place providing support to the process, rather than being developed at the same time under pressure during the commissioning program.

Standard operating procedures

Standard operating procedures specifies how you want the operators to run the plant. If the plant does not have a standard for operation, each operator will make decisions and adjustments to the process based on how they personally feel it should be operated. Invariably at the end of every shift the plant and process will be stable, producing a quality product but when the new shift starts the control set points are incorrect, from their point of view, and so they will change the process. In some cases this tendency has been so severe that the first six hours of each twelve hour shift produced out of spec product.

Other problems that can be present are incorrect operations, non transferable activities, different valve line ups from shift to shift and lack of consistent application of safety, environment and hazard considerations.

Training for maintenance and production

Specialised training must be provided for maintenance and production. The training should be skills based for the specific role each individual is to fulfil and should also include some upper level cross training between the two departments. This cross training will ensure that maintenance and production personnel have a greater appreciation of each others role and will then be able to consider the larger impact of the decisions they make on a day to day basis.

Maintenance program

The most important requirement is to put in place an effective maintenance program. If this is not done the plant will fall into breakdown maintenance.

This is a manhour intensive exercise. To develop a preventive maintenance program for 500 pieces of equipment will require about 1500 individual preventive maintenance activities and it will require approximately 3000 manhours of labour to complete the work. The two most cost effective things to put in place are the preventive maintenance basics (clean, inspect, lube and minor adjustments) and the on-condition monitoring activities that can generate the data that once analysed, can be used to predict potential failures.

Starting with a 1st generation logic of zero preventive maintenance the result will be that 100% of all maintenance will be breakdown (ie. fix it when it breaks) resulting in a high loss of production. As preventive maintenance (2nd generation philosophy) is introduced and applied to the machinery, the cost of breakdown maintenance and the cost of loss of production decrease on parallel paths. These paths will be similar until the point of minimum maintenance cost is reached. At this point maintenance cost is minimised, but still results in a high degree of loss of production. This type of operation has a high degree of emphasis placed on reducing maintenance cost rather than looking at the bigger picture of maintenance cost per unit of production.

If additional preventive maintenance is applied beyond what is required to reach the minimum maintenance cost point the total cost of maintenance will start to increase, but the loss of production cost will continue to decrease. If this process is allowed to continue a point will be reached where the optimum cost of producing the product will be realised. This optimum cost point is the desirable point to be at - this is where the product is at the lowest cost /unit produced.

MAINTENANCE CAPABILITY SELF-EVALUATION CHECKLIST

Maintenance evaluation at a glance

The Fault Tree gives you a brilliant snapshot of all the steps required to take any plant from Baseline Maintenance, through Maintenance Infrastructure, Preventive Maintenance, Predictive Maintenance, Company Infrastructure, Quality Assurance, and Reliability Centred Maintenance to an Ideal Maintenance Program.

The fault tree is both a diagnostic tool and a success roadmap

The Fault Tree allows you to set realistic maintenance improvement targets that are logical, manageable and achievable. Say you work through the fault tree and evaluate your plant as operating at the level of Preventive Maintenance. Then Predictive Maintenance would be your next goal. We have found that companies achieve significantly better results when they proceed methodically and logically, one step at a time.

How it works

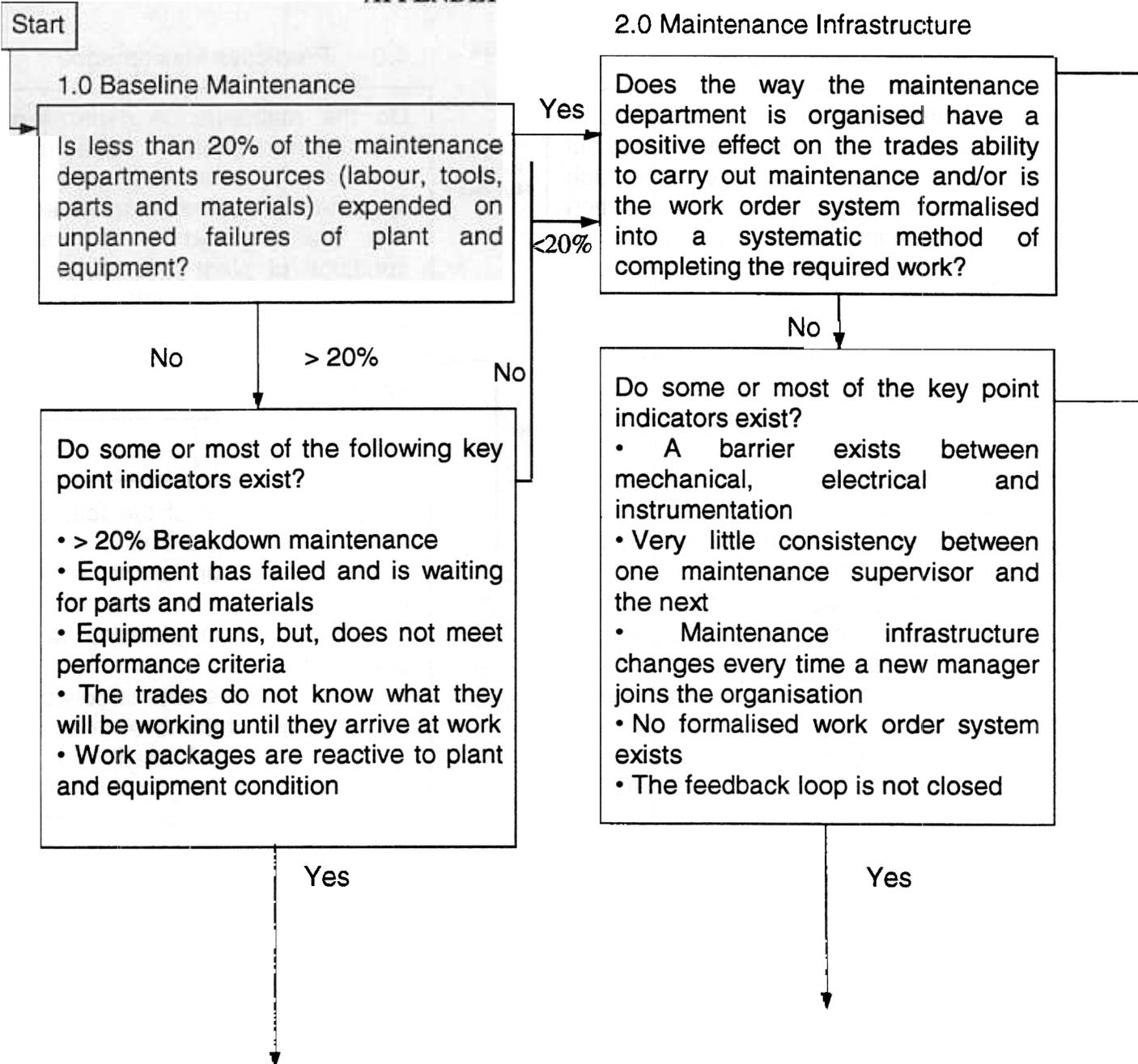
Start with Baseline Maintenance. Read the criteria and then answer YES or NO. If your maintenance costs are greater than 20% a year, you'll answer YES and go to the key point indicators box, immediately below.

If you answer YES to the Key Point Indicators, you'll go down to the Actions Required box which tells you what you need to do to remedy the problems identified above.

However if you answer NO to the question in the Baseline Maintenance, you'll move across to Baseline Infrastructure. When you answer YES, you're moving DOWN. When you answer NO, you're moving across to your right. Eventually you will arrive at your current level of maintenance capability and what needs to happen next to make the improvements needed.

APPENDIX

2.0 Maintenance Infrastructure



Consulting

- Conduct Maintenance Audit
- Develop and revise Vision & Goals
- Develop Maintenance Improvement project c/w a work order system
- Present Plan to Site Management

Paradigm Shifting Solutions

Yes

3.0 Preventive Maintenance

Does the maintenance department personnel systematically carry out the basic maintenance tasks such as cleaning, inspecting, lubrication and minor adjustment that are required to ensure that plant and equipment reaches its maximum expected lifespan?

No

Do some or most of the following key point indicators exist?

- Equipment fails due to dirt ingress, lack of lubrication and/or lack of minor adjustment
- Preventive maintenance takes a back seat to breakdown maintenance
- Production do not understand the importance of preventive maintenance
- Production do not assist in carrying out any maintenance

Yes

Yes

4.0 Predictive Maintenance

Do the maintenance department and production department personnel systematically carry out the on-condition monitoring tasks that are required to determine condition of plant and equipment while in operation and once the data has been collected do they use the data to predict condition and dates of potential failures.

No

Do some or most of the following key point indicators exist?

- Production run equipment to failure
- Little or no preplanning takes place
- A lot of process data is collected and filed away but, never analysed
- The data collected in the maintenance management system is a continuation of the old manual system data
- History is being collected, but the feedback loop is not closed by analysing the data.

No

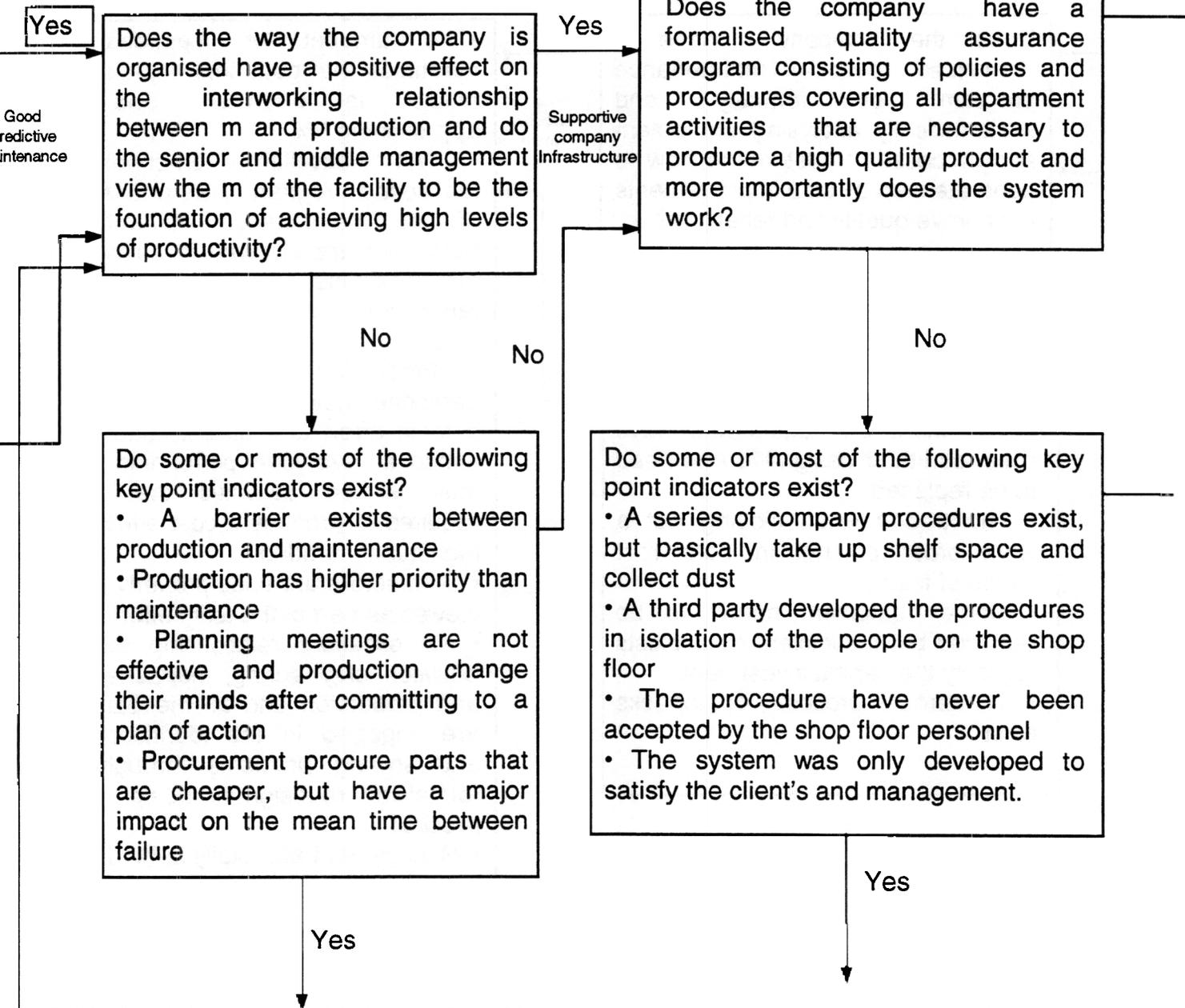
Yes

Technical Writing

- Provide technical writers and /or a site technical writing coordinator to assist in developing the required m procedures. Note: Some companies want their own trades to write the procedures so conduct One Day Procedure Writers Course.

5.0 Company Infrastructure

6.0 Quality Assurance



Consulting

- Conduct Audit
- Revise Vision & Goals
- Revise Maintenance Improvement Project
- Plan to Management

7.0 Reliability Maintenance

Ideal Maintenance Program

