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Mine Maintenance – The Cost of Operation

O Kreilis¹ and T Singleton²

ABSTRACT

Increasing world competition puts pressure on sales volumes and prices. This in turn reduces potential profit margins. This in turn increases the focus on costs.

Increasing demands on quality and service puts pressure on delivery performance - the right product at the right time. This in turn reduces the scope for errors and delays - and this in turn increases focus on equipment reliability. In the mining industry, both costs and equipment reliability have one significant thing in common - they are driven substantially by maintenance.

Maintenance, once the Cinderella of the boardroom, is a pivotal function and demands management attention and, if managed well, can be a source of competitive advantage. They made the decision to put maintenance high on their agendas because they realised that good maintenance is a vital factor in achieving excellence.

Maintenance, because of its impact on return on capital, is a key driver of performance. By reducing maintenance costs, companies can improve their performance. Top managers are increasingly recognising that maintenance is an area in which they must be involved. As Australian mining and metallurgical companies look to the year 2000 and beyond, maintenance will become an increasingly strategic function, capable of delivering sustainable competitive advantage to those companies that get it right.

INTRODUCTION

In the current economic climate, minimising costs assumes even greater importance, so that equipment reliability must be stepped up to reduce delays. Equipment reliability means effective maintenance. Maintenance costs in the mining industries are commonly between 30% - 50% of minesite total operating costs. BHP Minerals spends alone between \$1 and \$1.5 billion each year on maintenance (Ellis, 1994).

Maintenance in the mining and metallurgical industries can benefit from successful examples of maintenance practice in industry generally, and vice versa. Maintenance improvement involves a vision of future requirements, the changes necessary and to achieve those improvements, and understanding how to accomplish them. Maintenance suffers by poor planning, and management that is too occupied by crisis maintenance to institute preventive maintenance. In this stressful atmosphere, production losses are reduced by overlarge inventories of replacements and spares and consequently capital costs are inflated.

The solution to these inherited problems lies in a complete rethink of hitherto purely technical maintenance. Maintenance should be a component of production activities. All participants in the workplace should be involved in the broader thinking absent in former traditional maintenance by involvement of equipment/spares suppliers and by involvement of efficiency, motivational and business specialists. Thus a new production-oriented maintenance is incorporated as a business management tool.

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MAINTENANCE: A STRATEGIC FUNCTION

The ultimate objective of the maintenance function is to provide competitive advantage by increasing the efficiency of maintenance actions and increasing reliability and availability of equipment through effective strategies, planning and continuous improvement. High levels of equipment reliability and availability improve product quality and delivery performance, reduce asset intensity, and also reduce direct operational and maintenance costs.

To achieve excellence in maintenance requires the following:

1. Maintenance goals and objectives set to suit the business
2. A strategy to achieve those goals and objectives
3. A system to measure and manage the maintenance function
4. The right resources

Goals and Objectives

Application Design

Firstly it is critical that the business objectives of a mining operation are set out correctly so the operating system criteria can be determined to match the business needs of the future. Given the economic climate, equipment supplied today has very little performance to spare in excess of the contracted requirements.

Particular attention should be made of the key performance criteria which result in production performance. For example, for a longwall mining system;

- Tonnes per annum = Average tonnes/ week * Number of production weeks
- Average tonnes per week = Average TPH * Operating hours/week
- Average TPH = % of Process TPH
- Process design TPH = Dependant on longwall nameplate TPH and cutting cycle factors
- Operating hours/week = Process availability * Planned longwall operating time
- Planned longwall operating time = Total manned time/week - Planned maintenance time/week
- Process availability = Function of mechanical, electrical and operational downtime for equipment, systems and resources affecting longwall production time. (Operating time / Planned operating time)

Assuming a nameplate 3000 TPH longwall with a process design TPH of 2,000 TPH, average TPH of 1,500 TPH (75% of process TPH) and a process availability of say 55% for 45 weeks per year, 15 * 8 hr manned shifts and 3 * 8 hr planned maintenance shifts per week, 3.56 million tonnes per annum would be achieved.

However if process availability was improved to 65%, then 4.21 million tonnes per Annum would be achieved, with a probable increase in revenue of say \$18 Million dollars, whilst similarly if the average TPH was increased to 1,770 TPH, or planned production time increased to 14 shifts per week whilst process availability was maintained, the same result would occur.

Clearly maintenance strategy takes it's place along side of equipment design, productivity potential and operations management (see Fig. 1).

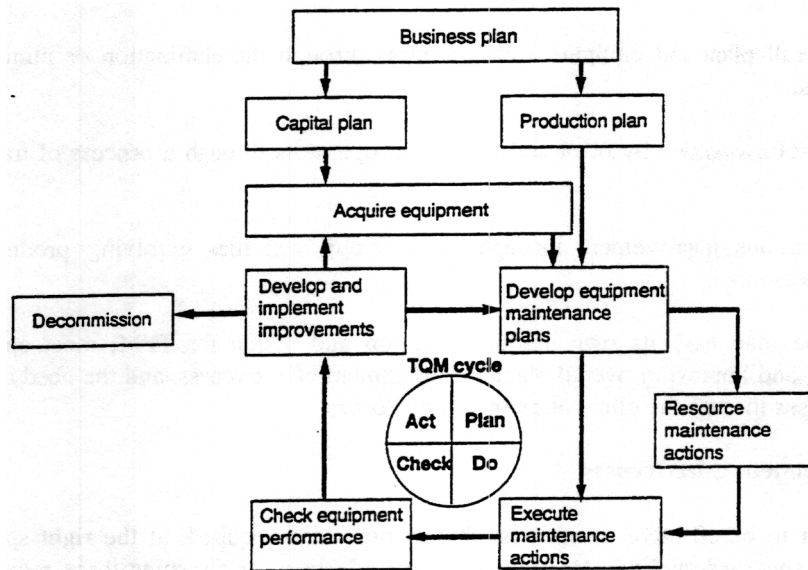


Fig. 1 - TQM Cycle (Has the works business plan in a box on top and “Decommission” in the LH box”)

By careful evaluation of the production system, a suitable strategy for optimising production and maintenance is achievable.

Determine The Preferred State - Goals and Objectives

The best performing companies have a vision, and have a coordinated maintenance strategy in place to implement that vision. The strategy is fully supported by corporate, plant and departmental management across the company. Maintenance that is treated as a strategic function has a substantial influence over and impact on profitability, and therefore deserves top management attention and adequate resources. On the other hand, companies where management treats maintenance as a cost to be contained rather than as a activity that creates value, will not perform well.

The basis of a winning maintenance strategy is planned preventative maintenance with a focus on continuous improvement. Maintenance to prevent in-service failures must, by its nature, be planned. The maintenance plan must identify the equipment components to be maintained to ensure that the maintenance is effective. It must detail how the component will be maintained to ensure execution is efficient and safe. It must define when it will be maintained - on failure, on usage or on condition. It must define who will execute the activities required to implement the plan. It must list the special tools and spares required. Finally, it must define success - the expected performance of the equipment and the resulting costs.

To win in the future, top management must understand the strategic nature of maintenance, and have a sufficient understanding of maintenance to participate in the management of maintenance.

Maintenance Strategies

A number of key maintenance strategies and elements shall be discussed as follows:-

Total Productive Maintenance

The prime objectives of TPM are to:

- Maximise overall plant and equipment effectiveness through the elimination or minimisation of the six big machine losses;
- create a sense of *ownership* by plant and equipment operators through a process of training and involvement; and
- promote continuous improvement through small group activities involving production, engineering and maintenance personnel.

Although each enterprise may have its own unique definition and vision for TPM, most approaches recognise the importance of measuring and improving overall plant and equipment effectiveness, and the need to address the root cause of failures and output losses through the elimination of chronic losses.

Overall Plant and Equipment Effectiveness

For plant and equipment to be effective, it must be able to run when required, at the right speed, and be capable of producing output to the specified quality. *Overall equipment effectiveness* measures these requirements by combining three key performance indicators *availability*, *performance rate*, and *quality rate* (see Fig. 2).

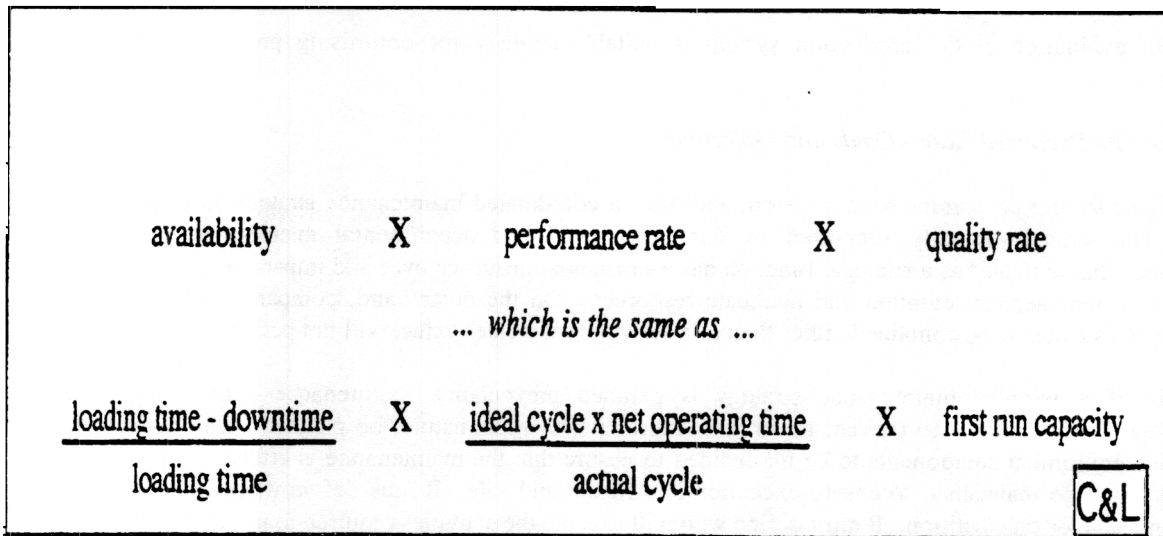


Fig. 2 – Overall equipment

These three measures can be subdivided into breakdowns and set-up adjustments relating to availability, idling/minor stoppages and equipment speed relating to performance rate, and process defects and start-up losses relating to quality rate. These six measures are referred to as the six big losses (see Fig. 3).

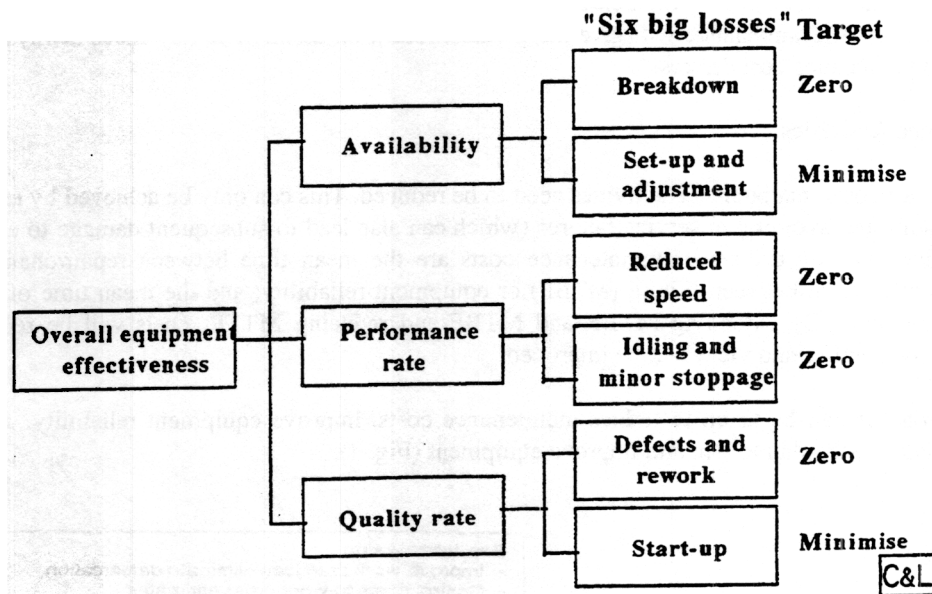


Fig. 3 - The 'six big losses'

The six big losses need to be investigated holistically. Attention to only one or two of these losses will produce a sub-optimal result. For example, if availability is the only measure that is stressed, plant and equipment will often be run at a slower speed to make the measure look good, whilst the effectiveness of the plant and equipment is downgraded. Conversely, plant and equipment may be running at the right speed and be available but because of excessive wear is producing output that is out of specification.

When many organisations first measure overall equipment effectiveness, they find they are achieving in the order of 40 per cent to 60 per cent. International best practice is recognised to be 85 per cent.

Sporadic and Chronic Losses

The driving objective of TPM is to eliminate or minimise, the six big losses not just reduce them. To achieve this TPM is an ongoing journey to excellence which challenges the paradigms. One such important challenge is the traditional mindset that focuses on sporadic or breakdown losses and largely ignores the chronic losses which are the root cause of output defects and breakdowns.

Sporadic or catastrophic losses are the infrequent or unusual events that cause a sudden breakdown or loss of quality. They are obvious and the traditional solution is to create systems to react to them quickly and attempt to reduce them.

Chronic losses are subtle and not obvious. They are much more difficult to identify and correct because they are traditionally accepted as the norm. Chronic losses are caused by hidden defects in machinery, equipment and methods. They resist traditional remedies because their roots are hidden in the structure of the plant and equipment and the methods used to operate and maintain it.

Capital versus Repair and Maintenance Expenditure

The total life costs for a piece of equipment need to be analysed as the Repair and Maintenance portion can be significant as a ratio of the initial purchase price. Financial elements such as Depreciation, Investment and a value on Obsolescence are added to Maintenance and Operational costs to determine the Total Economic life. Cost drivers for maintenance need to be identified with the major impact costs being those that are focused on, and from these options for possible lowering of cost can be assessed. Outsourcing of rebuilds, changing the whole site strategy on maintenance from a repair on failure to 'On Condition', or determination of the operational influencers will help in the formulation of a work plan for

improvement. All of this must be done with a clear link between costs and the productivity of the unit. Higher utilisation with the same base costs of maintenance will give the greatest return on asset. The key focus always must be the close management of all maintenance cost drivers.

Reduce Maintenance Activities

To reduce maintenance costs, maintenance activities need to be reduced. This can only be achieved by extending the life of equipment components and avoiding in service failures (which can also lead to subsequent damage to equipment). From a total cost perspective, the key drivers of maintenance costs are the mean time between repair/changeout (MTBR) or equipment life; the mean time between failure (MTBF) or equipment reliability; and the mean time of repair (MTTR) or equipment maintainability. By extending MTBR and MTBF and reducing MTTR, costs will be reduced and product quality, production availability and yield will be improved.

Three generic approaches can be taken to reduce maintenance costs, improve equipment reliability, and hence increase profitability; eliminate waste, plan to win and improve equipment (Fig. 4).

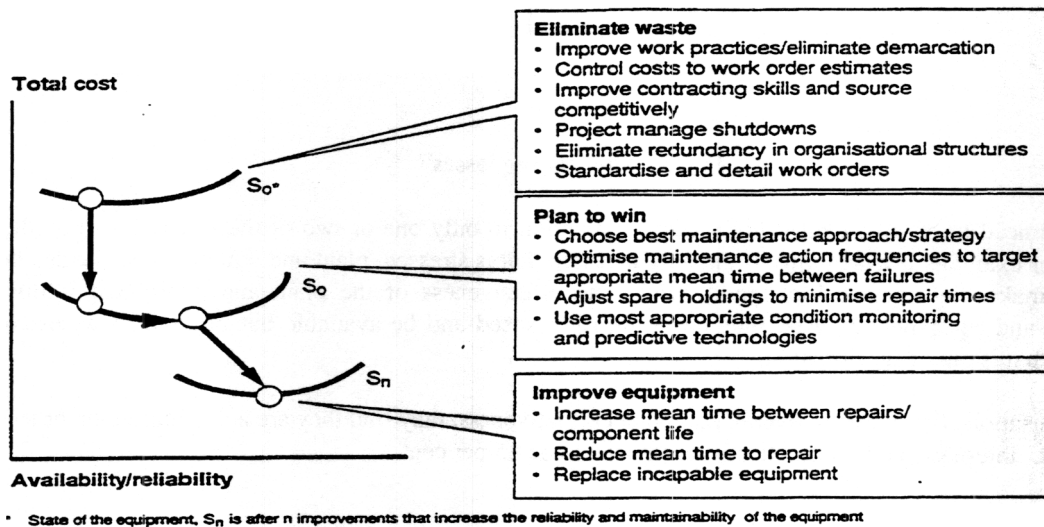


Fig. 4 – Total cost versus Availability/ reliability

Eliminate Waste

This approach increases the efficiency of the resources used to perform maintenance activities - although without improving equipment availability and reliability. It includes project managing major maintenance activities (such as shutdowns), reducing shift crews, making the right contracting and sourcing decisions, eliminating restrictive work practices and standardising work requirements.

In many plants in Europe, the United States and Australia, McKinsey has found that shift crews have been larger than could be reasonably justified on economic grounds. McKinsey has also noted that substantial savings could be achieved by moving some tasks to day shift, allowing shift crews to be reduced. In many instances, shift crews have simply been too big - usually because operations managers are risk averse and have allowed maintenance departments to staff the shift crews so that they can cope with the worst case scenario, which rarely eventuates. In addition, shift crews are often not reduced when the breakdown rates has been decreased through a process of continuous improvement.

The trade-off with reducing shift crews is that when a major failure does occur, more time will be taken to carry out a repair because there are fewer mechanics and electricians in attendance. However, this occurs more rarely than expected, because operations and maintenance staff respond to small shift crews by improving their diagnostic systems, using operators on breakdown work, and instituting appropriate call-out arrangements for maintenance personnel.

Another major opportunity is to improve approaches to the sourcing of maintenance services. As maintenance becomes more effective, the urgency of work requirements is reduced and work is better defined. This opens up opportunities to improve the way products and services that support maintenance activities are procured. In McKinsey's experience, the costs of resourcing maintenance activities comes down by two to four-fold as maintenance breakdown work is eliminated.

In many companies, the biggest opportunity to capture these savings has been to improve contracting approaches. In metallurgical and mining companies the contracting and purchasing approaches have been inadequate, and have resulted in higher costs. Closer cooperation between maintenance, supply and contracting functions, and the use of more rigorous contracting approaches are often necessary prerequisites to capture the full benefits of controlled equipment performance that results from improved maintenance management.

Poor work practices and demarcation between trades, and even between work groups, also reduces the efficiency of executing maintenance activities. Over the last decade most demarcation problems have been eliminated, and those which remain are being negotiated away through enterprise bargaining, or through retraining and multi-skilling the work force.

Another major avenue to improve maintenance costs is to standardise and document work requirements and manage the work done in accordance with defined expectations. This need is not apparent when equipment fails regularly because maintenance personnel are experienced. They know the job and they know the equipment. Documentation would be superfluous. This is not, however a winning strategy. If the aim is to reduce the number of breakdowns to an insignificant level, companies cannot continue to rely on their experienced trades force over the longer term. By documenting and standardising work orders and managing the work so that it is completed in accordance with the work orders, companies develop a vehicle for learning how to do tasks in the best way, which enables them to control their costs, not just report them.

McKinsey has worked with many companies emerging from breakdown maintenance eras that have failed to document the tasks that they perform. They quickly encounter a skills barrier as the breakdown work reduces and the tradesmen's familiarity with the tasks declines. A key factor for success is documentation of task requirements; what to do, how to do it, with what spares and tools, by what labour group and the expected duration.

Improve The Equipment

This strategy invokes the philosophy of maintenance prevention, focussing on improving the equipment to make it more reliable and easier to maintain. The most cost-effective means of minimising the maintenance requirement is to build or purchase equipment that requires minimal maintenance, that is, equipment that is very reliable and available. For existing equipment this is clearly not always possible but, in the long term, management should ensure that all new equipment acquisitions are evaluated on a total cost of ownership approach. Maintenance personnel should be an integral part of the equipment acquisition team that is responsible for the specification and evaluation of new equipment.

In most mining and metallurgical situations, the equipment used is relatively unique, either because there are few replicas of the equipment in other installations and/or because the mine conditions, feedstock or process are unique. As a consequence, mining and metallurgical equipment should be viewed as being prototype equipment with ample opportunity to be improved. In addition, as the life of most capital equipment is in excess of 10 to 20 years, there is an opportunity to design out problems and introduce equipment improvements.

Manage Technology

The future will be more technologically complex due to demands of capacity increases driven by cost minimisation and availability of technological improvements to provide such. This complexity, whether it be equipment and system technological complexity or the management structure and systems of the business has to be satisfactorily managed.

In the case of equipment and systems, the matrix shown in Fig. 5 applies

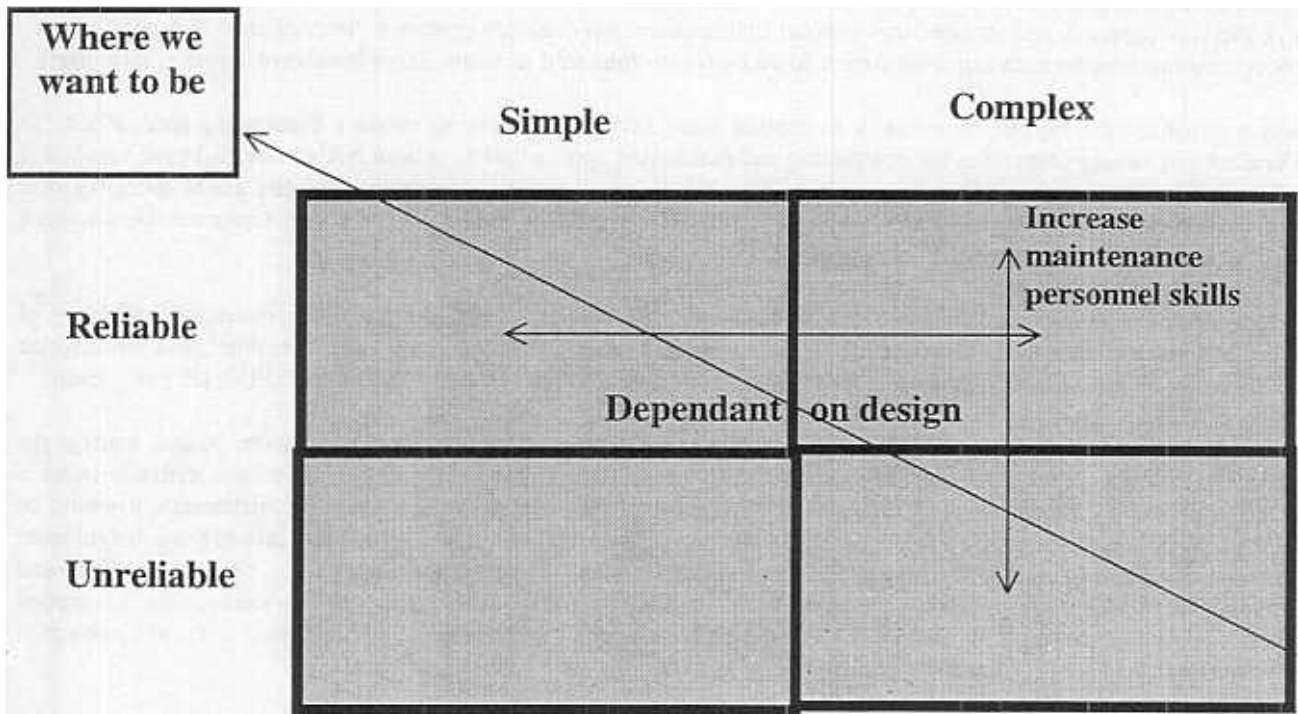


Fig. 5 – Managing Technology

Maintenance Resources - People

The Learning Environment

Learning is, for most, hard work. It takes concentration to succeed. But first, there must be a *desire to learn*, and a willingness to make the effort. In order to want to learn, most individuals need to understand what is expected of them, and why they ought to learn. Answers to these questions serve to place issues in *context*, and assist in determining whether to make a commitment to a learning activity, or not.

A noted British author on organisational communication, Francis (1987) notes that:-

“People need to feel part of an overall strategy and feel they have some responsibility and involvement in decisions which affect them. No amount of table-thumping in the boardroom will achieve optimum performance from senior executives, middle managers or the shop floor if they do not understand the reasoning and accept some responsibility.”

It is not enough to be told what to do and then be expected to learn how to do it. There is need to understand ‘what is expected of us’, how this links in with ‘what is expected of others’, and how associated activities interact. There is a need to know ‘what the real issues are’, ‘why things need doing’, ‘what the consequences might be if they were not done’, ‘how our work impacts on the business’, ‘what standards need to be and why’, and so on. For most people, answers to these questions are needed before commitment can be positively made to a learning process/programme and the demands it will make.

A leading author and contributor to the field of management thinking Send (1992), makes the point that:

“From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden, enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of

connection to a larger whole. When we try to “see the big picture”, we try to reassemble the fragments in our minds, to list and organise all the pieces. But as physicist David Bohm says, the task is futile - similar to trying to reassemble the fragments of a broken mirror to see a true reflection. Thus, after a little while we give up trying to see the whole picture altogether.”

It is difficult to imagine putting a jigsaw puzzle together without having an overall picture to work from. The confusion, frustration and disinterest that must result is obvious. Yet the tendency is to expect others to undertake activities without ensuring that they appreciate how these activities fit into the larger picture. What the larger issues are is not often explained. Is it any wonder that there is so often difficulty engendering enthusiasm and commitment?

As discussed above, it is not sufficient to focus simply on the proficiency with which one performs a task, no matter how critically important that task may be. People also need to appreciate the task’s wider implications and how their performance plays a part in a larger picture.

The National Training Board (NTB) (1992) highlights the importance of having - and assessing - ‘underpinning knowledge and understanding’, but the knowledge and understanding referred to is solely associated with performance of action-based tasks. It states:-

“...it is not consistent ... with a competency based approach to have a unit or element defined solely by knowledge, without the context of what the knowledge is required for in its application to a work situation.....”, and

“...Only that knowledge which is related to the required actual workplace performance outcomes of the particular unit or element should be included in (the standard)....”

This is a serious issue. A concert pianist’s skills can never be developed by concentrating on the ‘training up’ of each hand separately and ensuring proficiency of the hands independently. Integration and appreciation of the larger musical picture is essential. A champion boxer, likewise, can never be developed by training up each arm and leg in isolation. Lack of systems and procedures for ensuring full appreciation of *context* may well be the ‘Achilles Heel’ of the NTB’s competency based education and training (CBET) movement. Unless in possession of an adequate *contextual framework*, it is difficult to make commitment, take responsibility, communicate effectively, anticipate consequences and persuasively convince others that one is unlikely ever - as far as it is in one’s control - to carry out one’s responsibilities in an unsafe, incompetent or irresponsible manner. Yet these are the very assurances that are increasingly sought, and must increasingly be provided.

Our ability to succeed in business can only be based on the ability and commitment of our human resources. As leaders of our industry we must strive to develop the skills of our people. And we must strive to develop an environment in which they can perform.

Organisations, like organisms, must be able to respond and adapt to changes in their environment. Those that can’t respond fast enough will not survive. If we are standing still, we are effectively going backwards as someone else is moving forward.

With the continuing development of new technology and the interdependencies of global markets, the only thing that organisations can be sure of is that change will continue, and that it will continue at an increasing pace?

One of the critical factors in adapting to change is the ability to learn. This is as true for organisations as it is for organisms. For an organisation to survive in an environment that is constantly changing, it must be constantly learning. Individuals within the organisation must be able to *detect* what it is that they need to learn and meet these needs quickly. Most organisations have recognised that in order to adapt to change, people need to acquire and use new skills and knowledge. The reaction to this need has been to provide more training. Each time a new requirement is uncovered, more training is provided. This is equivalent to feeding hungry people fish. One must always keep feeding them or they starve.

A better and more sustainable strategy is to *teach them how to fish*. That is, provide a learning strategy where people *learn how to learn* and become responsible for acquiring and passing on learning.

Sharing The Wisdom

The same problem occurred three times in the last year. No-one bothered to pass on what caused the problem and how to fix it. We haven't learnt a thing! (Issie Frustrated, Engineering Manager).

Joe knows how to maintain the valves and Fred knows how to maintain the pumps. Why can't they learn from each other? (I.M. Keen, Maintenance Manager).

Both of these comments are symptoms of an organisation where individuals are not sharing their wisdom. This is not an uncommon situation. Too often, the knowledge and skills possessed by an individual remain the property of the individual. Individuals may in fact feel motivated to protect their wisdom as this makes them more valuable to the organisation. If they know something that no-one else does, this increases their job security.

An effective learning strategy motivates individuals to share their wisdom and helps the organisation to learn from past problems. In this way, the whole organisation continues to learn and is therefore better able to adapt to change.

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