

Reducing the Variability in Dragline Operator Performance

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ABSTRACT

Australian coal mines have spent considerable capital on dragline improvements over the last two years. This has included ~\$30 M on UDD conversions, >\$20 M on new buckets, boom upgrades, electrical upgrades, etc. This is a natural part of the response of mining companies to technology and replacement programs. Capital expenditure is a normal part of the ongoing success of most companies. There is however, a tendency for some people to rely on the capital alone to provide the ongoing improvements in equipment productivity. Implementing new technology through capital expenditure is only part of the equation in continuous improvement. For 80 - 90 per cent of the year, the operator controls the productivity achieved by the dragline.

Variation between operators is huge. The average standard deviation in productivity is 12 per cent and maintenance impact is over 40 per cent. Robbins 2003, states:

Contrary to what we were taught in grade school, we weren't all created equal. Most of us are to the left of the median on some normally distributed ability curve.

Further, he states:

The issue is knowing how people differ in abilities and using that knowledge to increase the likelihood that an employee will perform his or her job well.

There are two options for reducing variability between operators; improving operator ability and getting the machine to take over what the operator is doing (automation). Dragline automation will be discussed, however, this paper will focus more on the 'human factor' and how to establish a dragline with minimum variability between operators.

INTRODUCTION

Minor variations in dragline productivity can be leveraged into large variations in coal production and mine profitability, (Hettinger and Lumley, 1999). Given that a one per cent increase in dragline productivity is valued at between \$50 000 and \$2 300 000 per annum, (GBI Consulting Pty Ltd, 2004), it is not surprising that significant interest has been shown in dragline productivity over the last 20 years. But why do some draglines continue to out-perform others? Why has so much of the research money spent on improving dragline productivity not been reflected in improved productivity? Why, over the last few years, has there been an emphasis on capital improvements rather than the cheaper option of process improvements? Why have we, as an industry, largely left the operators without sufficient support? Peterson, Latourrette and Bartis, 2001, state:

...despite the prospect of automation and other technology enhancements, people are becoming more critical to the success of a mining operation, not less.

This industry can't afford to be satisfied in the gains achieved over the last ten years. In 2003/2004, the average Australian dragline underperformed best practice by 25 per cent. The average Australian dragline was 46 per cent below 'best feasible'. Some of this average 46 per cent difference may only be achieved through capital expenditure, eg stronger booms, better motors, high productivity buckets, etc and some of it will never be achieved, eg higher payloads cause slower swinging, faster swinging causes more downtime, etc. However, it is this author's belief, supported by other industries' experience, that at

least half the difference between current performance and best feasible may be achieved through process improvements. Those process improvements are heavily reliant on human factors.

Peterson, Latourrette and Bartis, 2001, recount a mining executive's response to the greatest constraint to his organisation improving productivity as 'Getting people to think!'. Mine site productivity starts at the top and the attitudes and actions responsible for this productivity permeate through the whole workforce. Good attitudes lead to good productivity while poor attitudes lead to poor productivity.

Some sites get caught on the three 'P's'; personalities, power and politics. People get in the way of objectivity. More than ever, the need for objectivity in evaluating dragline performance is essential. 19th century American humorist, Artemus Ward, put it very cleverly when he said, 'It ain't the things we don't know that gets us into trouble. It's the things we know that ain't so' (Zikmund, 2003).

WHAT IS DRAGLINE BEST PRACTICE?

Defining 'best practice' is not a simple matter. In this paper, best practice is referred to as the average of the top ten per cent of dragline years in the GBI dragline productivity database.

The GBI database contains data from draglines all over the world and, as of April 2005, contains more than 150 million cycles spanning nearly 500 dragline years from Queensland, NSW, USA, South Africa and Canada.

Table 1 summarises the results of an analysis of the productivity of the best performing ten per cent of draglines in the database. It shows the average figures achieved by the top ten per cent of draglines ('best practice') against the average of all the draglines in the data with the difference noted in terms of impact on productivity. An average *in situ* SG of 2.20 t/m³ is assumed.

TABLE 1
GBI database results (normalised for BE1370w/M8050 dragline size).

Key performance indicator	Average	Best practice	Impact
Daily swings (#)	861	957	+13.0%
Payload	88	103.1	+17.2%
Fill time (secs)	15.8	14.9	+1.6%
Swing time (secs)	25.3	25.7	-0.5%
Ret time (secs)	21	20.1	+1.6%
Spot time (secs)	4.7	3.5	+2.2%
Cycle time (secs)	66.8	64.2	+4.8%
Dig time (%)	66.6	72.4	+8.2%
Productivity (BCM/day)	34 440	44 850	+30.2
Productivity (BCM/yr)	12.6 M	16.4 M	

The difference between the average of the top ten per cent and the average of the whole database is illustrated in the waterfall chart depicted in Figure 1. The blue bars represent activities where performance is better whilst red bars show areas where the performance is worse.

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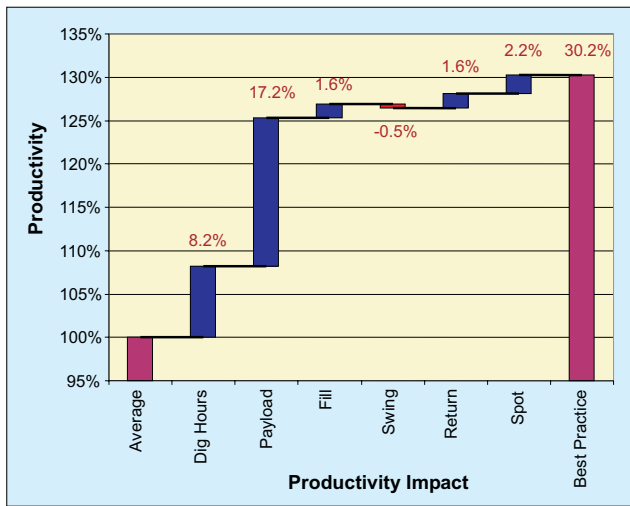


FIG 1 - Difference between 'best practice' and average productivity.

Of further interest is the trend in dragline performance. Figure 2 shows average dragline productivity from 1997 to 2003. Average dragline productivity has increased by 17 per cent since 1997 while best practice productivity has increased by 10.5 per cent. In both cases the key component is payload which is up by 7.1 per cent on average and 6.9 per cent in best practice draglines. The potential to increase further is also demonstrated on this plot. The most productive dragline, (normalised to this class), is also shown on this plot along with the best feasible performance which is a combination of the best key performance indicators (KPI's). The average dragline in 2003 needs to improve by 26 per cent to achieve average best practice and 48 per cent to achieve feasible best.

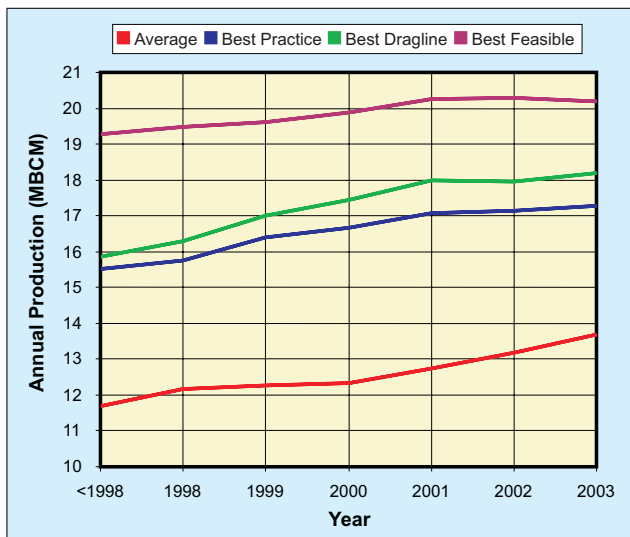


FIG 2 - Change in dragline productivity 1997 - 2003.

Figures 1 and 2 show that most draglines have huge potential to improve productivity.

In 2003/2004, the average Australian dragline underperformed best practice by 25 per cent. The average Australian dragline was 46 per cent below 'best feasible'. Some of this average 46 per cent difference can only be achieved through capital, eg stronger booms, better motors, high productivity buckets, etc and some of it will never be achieved, eg higher payloads cause slower swinging, faster swinging causes more downtime, etc.

It is this author's belief that the average Australian dragline has >20 per cent improvement available through process improvements, largely through improving the 'human factor'. Even those Australian draglines achieving current 'best practice' (>17MBCM for a BE1370W/M8050) have >10 per cent improvement available. This corresponds closely to the one standard deviation (12 per cent for draglines) achieved by other industries when the 'human factor' is controlled (Newman, 2004).

WHAT KPI'S ARE CRITICAL IN IMPROVING DRAGLINE PRODUCTIVITY?

Figure 1 demonstrates that the best practice draglines achieve higher payloads and higher dig hours than the average – thus a concentration on payload and related issues has the greatest potential to increase productivity.

To demonstrate the importance of certain KPI's, the strength of the relationship between the key performance indicators (ie payload, fill time, swing angle, etc) and the productivity, is calculated. The strength of the relationship of each KPI is quantified by the correlation coefficient and is described as the r² value.

r² is the *relative predictive power of a model* (in this case, the formula of the linear relationship) and is a value between zero and one. *The closer it is to one, the stronger the relationship* where 'stronger' implies a greater ability to predict. This is extremely helpful because it shows which KPI's have the strongest relationship to productivity. The r² values for the KPI's relative to productivity for nearly 500 years of dragline data are:

Payload	- 0.92
Dig time	- 0.40
Cycle time	- 0.08
Fill time	- 0.00
Swing time	- 0.01
Swing angle	- 0.02
Return time	- 0.01
Spot time	- 0.30

It is clear that there is a strong correlation between productivity and payload whilst fill time has a negligible relationship with productivity. This confirms that the most productive draglines achieve high payloads – even at the expense of fill time and other components of the cycle time.

WHAT OPTIONS ARE AVAILABLE TO REDUCE DRAGLINE OPERATOR VARIABILITY?

Dragline automation

To determine the desirability of automating parts of the dragline process, individual components of the cycle are separated and the efficiency of those parts of the operation determined.

Fill efficiency

The fill time and fill distance can be used to determine how efficiently the operators have filled the bucket. A plot of fill time versus fill distance cycle by cycle is created. It is normal for this plot to show a vast spread of results above a fairly well defined lower boundary. A sample plot is shown in Figure 3.

Where the bucket was 'perfectly' easy to fill the average would fall on the peak performance line. This peak performance line represents those cycles where the operator did everything right and is representative of the peak motor output.

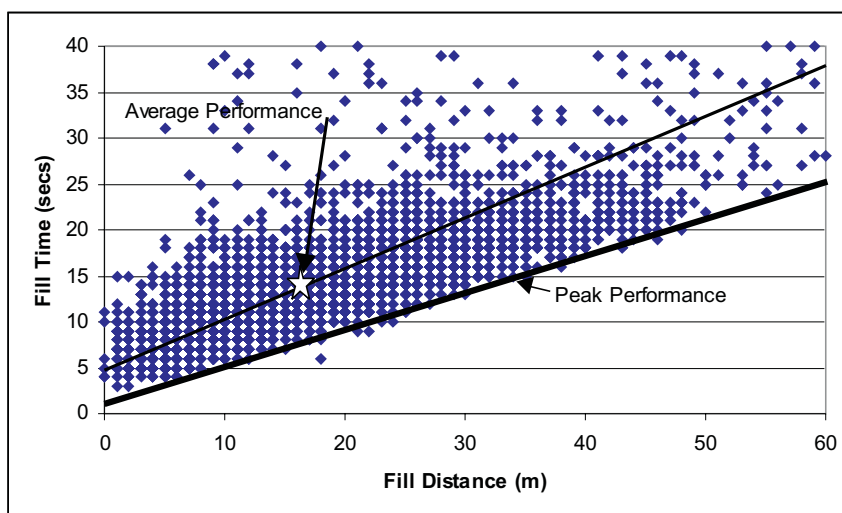


FIG 3 - Fill time versus fill distance.

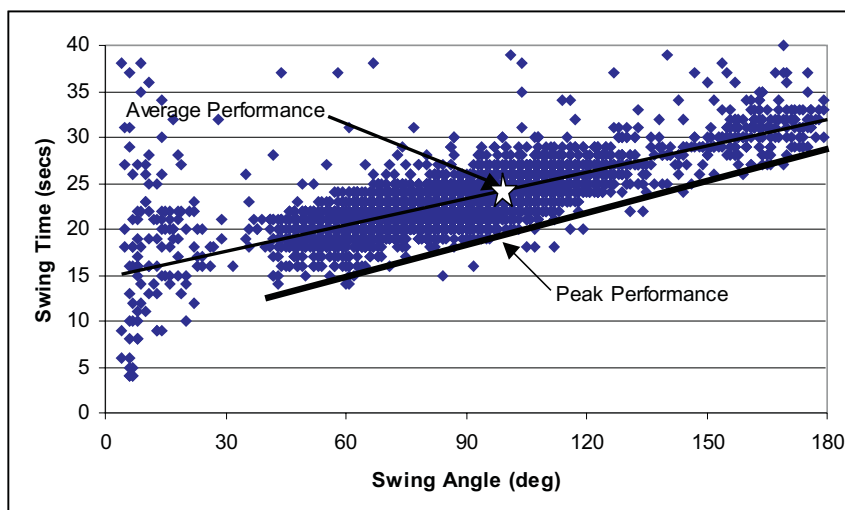


FIG 4 - Sample swing time versus swing angle.

Taking this one step further, it is proposed that as the average moves away from the peak performance line, the more difficulty the operator is having in keeping the bucket travelling at the speed the motors will allow. The filling efficiency is defined as the fill time on the peak performance line for the fill distance achieved divided by the average fill time.

The trend in fill efficiency over time is useful in determining operator filling performance. The factors which may impact on the filling are:

- geology,
- blasting,
- drag motor performance,
- engage location,
- operator ability and performance, and
- bucket behaviour.

Swing, hoist and return efficiency

The extended analysis of swing performance versus swing angle produces a swing efficiency factor, which is calculated in the same way the filling efficiency factor was determined. The same

can be done for swing time (for hoist dependent cycles) versus hoisting time and return time versus swing angle as shown in Figure 4.

Figure 4 can be created for each time period and the peak performance at the average swing angle divided into the average swing time to give swing efficiency. The factors that may impact on swing time are:

- mine plan,
- swing motors,
- operator ability and performance,
- drag payout, and
- payload.

The standard deviation of fill rate, swing rate and return rate on a cycle by cycle basis are typically 40 per cent, 30 per cent and 40 per cent respectively of the average. A significant part of this variability can be attributed to the operators and more specifically, differences between operators.

The major attempt, which the Australian coal industry has made in this area, has been work at the CSIRO over the last 12 years on automating the swing, dump and return parts of the cycle. The latest step was a trial of the system on the BE1350W

dragline at Boundary Hill (CSIRO, 2003). The system is able to match or exceed operator performance in some, but not all, cycles. This system proved the following points:

1. return time was significantly better than swing time;
2. skills such as bucket disengage, dumping and recovery are performed consistently well;
3. the system was highly reliable; and
4. the system's interface was intuitive and readily accepted by the operators.

The report explains that the computer's skills are not perfect but the trial demonstrated that they may be improved with further work. The lack of terrain data caused the system to require larger margins of safety in bucket trajectory than what the operator may use. Consequently, the two key areas of future work required are the integration of a form of machine vision (which CSIRO is working on) and the refinement of the swing and return algorithms.

Right now, the CSIRO – Dragline Swing Assist system is not ready for commercial release and the timing for it becoming available is not possible to predict.

Operator impact

During the 1980s and 1990s an industry-wide culture of industrial deadlock and regulatory institutions that quarantined Australian coal operations from global competitive pressures, made workplace reform very difficult, (Goldberg, 2003). The wealth generated from coal operations provided relatively little for the shareholders. While the rest of the Australian mining industry responded to the opportunities and threats of globalisation, the nation's coal sector didn't. In terms of safety, productivity and profitability, coal operations were increasingly out of step.

The possibility that the industry would lose considerable market share to competitors in Indonesia, South Africa or Central America appeared very real as little as seven or eight years ago. The performance of coal in Australia, especially in NSW, was 'abysmal'. However, some new ventures were doing things differently and securing better outcomes, (Davies, 2001). During one six week strike the staff ran the operation. The performance – admittedly under abnormal circumstances – demonstrated the efficiencies that a more flexible operation could achieve.

Thanks to the changes that have taken place in the workplace, there has been a significant improvement in productivity and an accompanying reduction in costs. Figure 5 shows the improvement in productivity through the late 1990s.

Many of the structural changes and improved work practices sought in 1997 have been achieved (Goldberg, 2003). Australian coal mines in general have become more efficient and more profitable. A major part of this is the ability of the mines to choose the employees they want to hire based on merit rather than seniority. Davies (2001) states that one of the major improvements was the ability to make changes without having to first ask permission from the union. Retention of the 'best workers' at a mine in late 1998 was the first time a merit based selection process had been implemented for retrenchment in the NSW Coal Industry.

There has been little documented on the variations between dragline operators apart from private work undertaken by this author and his company GBI Consulting Pty Ltd. The average difference between best and worst operators is 35 per cent in productivity and 140 per cent in damage impact (Lumley, 2004). Standard deviations are 12 per cent and 40 per cent respectively. An example of this is Figure 6 which shows a month of dragline data reporting each operator on a plot of productivity versus damage.

The plot shows a month of data where the most productive operator (5) was 33 per cent more productive than the least productive (14). The most damaging operator (13) caused 150 per

cent more damage than the least damaging (3). This is a dragline that consistently achieves productivity in the top ten per cent of draglines worldwide and would be considered above average in terms of ability of its operator teams. All of GBI's private work would suggest that this large variance is the norm (or better than the norm) rather than the exception (Lumley, 2004).

Unfortunately, as a general statement, this industry has not supported the operators well. This is demonstrated clearly by the variation in performance. Consider the following Australian statistics:

- the variation in productivity between operators is significant;
 - 35 per cent average difference between most and least productive; and
 - 12 per cent standard deviation;
- the variation in maintenance impact between dragline operators is extremely high;
 - 140 per cent average difference between least and most 'damaging'; and
 - 41 per cent standard deviation.

For draglines which have operated over 20 years with very low turnover of operators, why does this scenario of large variations between operators occur?

The large variation is a function of several inter-related factors:

- Poor management practices/attitudes.
- The historical system of equipment operators being chosen based on seniority; that is, the longest serving employee, who wanted the available job, got it.
- A shortage of trained operators stemming from the following:
 - Training for operators has traditionally been done 'on the job'. Hence, a trainee learns by doing, with the resultant exposure for the mine to reduced safety, increased damage and reduced productivity. On hugely expensive equipment training was a large cost and risk factor. The logical consequence was that training was done on an 'as needed' basis and generally, only the minimum number of people were trained.
 - The industry is expanding. New mines are opening, eg Coppabella, Hail Creek and Rolleston. Other mines are expanding, eg Newlands, Blackwater, Goonyella/Riverside, etc.
 - Mine workforces are ageing; particularly in some of the areas of low turnover, ie dragline and shovel operators. The natural consequence has been an acceleration of trained and experienced people retiring and leaving the workforce.

The logical consequences of these factors are:

- many current operators doing jobs they are not naturally suited to;
- no pool of trained operators to replace the under-performing operators; and
- very large variations in operating performance on very expensive pieces of equipment.

For 80 - 90 per cent of the year, the operator is in control of the productivity achieved by the dragline. Therefore, the greatest potential for gains to be achieved by the dragline is by providing support to the operator.

Support for the operator may be in the form of:

- management approach,
- ensuring they are naturally suited to the job before they start,
- training, and
- setting targets and performance feedback.

These points are addressed in turn.

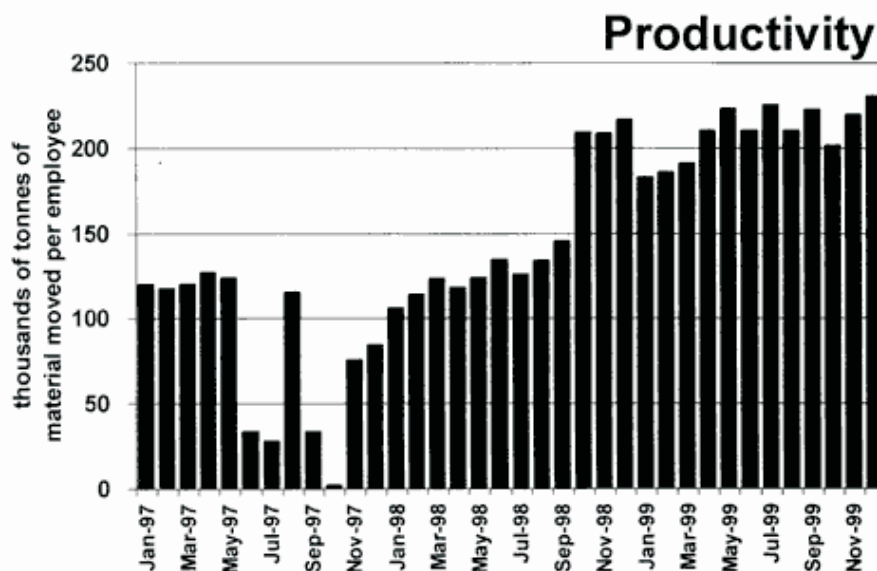


FIG 5 - Productivity changes in NSW coal mines (after Davies, 2001).

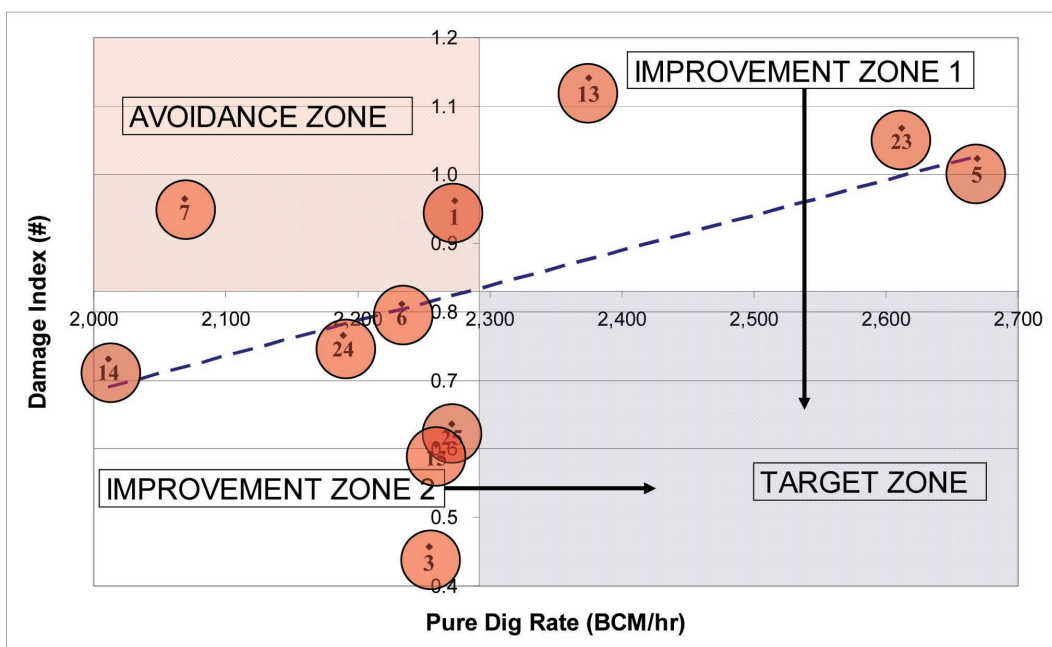


FIG 6 - Damage versus productivity for dragline operators (taken from private work).

Management approach

Productivity is about attitude. Much can be learnt about the theory behind operating draglines and improving productivity but if the mine does not have a ‘culture of productivity’ then achieving best practice is virtually impossible. The productivity attitude must be established and supported from the highest level on the mine site. The experience at Robe River mine in 1986 (Copeman, 1987), provides an excellent account of the way companies may act if they are not happy with mine site attitude. It is important to note who were the first people dismissed at Robe River.

Profitability is usually highly leveraged against the productivity of the dragline and thus significant management effort and enthusiasm should be focussed on getting the most out of the dragline. Exactly what this entails is not always well

understood and often other activities are given preference sometimes to the detriment of dragline productivity. The actions of mine planning, blasting, scheduling, maintenance and man management all play a significant role in production but need to have a common productivity focus or else they can negatively impact the dragline performance as shown in Figure 7.

In Figure 8 the productive dragline shows a different flow of ‘impacts’. The dragline productivity is made central to the mine’s performance. People and personalities become less important and the dragline productivity becomes of primary importance.

The dragline productivity now ‘drives’ other aspects of the mine operation. It is no longer acceptable for other people to impact productivity negatively; they know what is expected of the dragline and they should do their job in such a way as to help the dragline achieve it. This is the way which all mines achieving best practice operate.

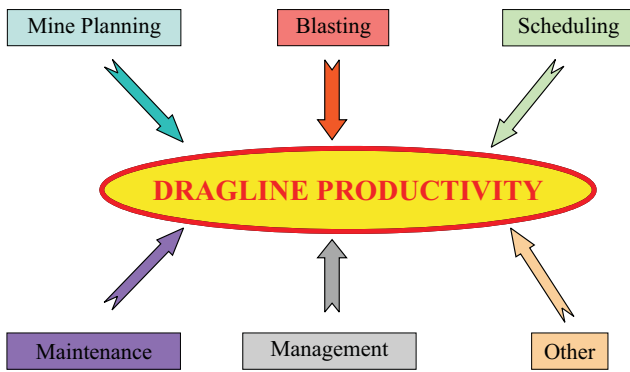


FIG 7 - Impacts on dragline productivity.

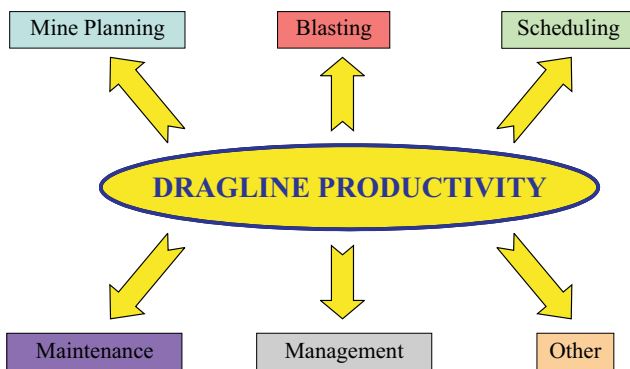


FIG 8 - Dragline productivity impacting on the mine.

Dragline management, as well as bringing the right attitude to the job, must seek to understand the people working for them and the job they do. This is why some of the best managers come from the 'school of hard knocks' rather than the 'mining schools'. Individuals behave in a given manner based on their perception of their external environment, not necessarily the way it actually is (Robbins, 2003). An interesting and challenging work place; management effort; pay; performance appraisals; working conditions; may all be irrelevant if the operators don't see these issues. In order to influence productivity, the manager must assess how workers actually perceive their jobs.

Operator suitability

Once the concept of seniority is overcome, mines can start thinking about who they will hire. Information in making hiring decisions is generally regarded to come from three sources (Angus 1996):

- employment history and resume,
- standardised tests, and
- interviewer impressions.

Of these three sources, interview has traditionally been the measure most relied on in making hiring decisions. Research suggests that this is entirely the wrong approach – interviews have an extremely poor track record as selection tools (Gilmore, Ferris and Kacmar, 1990; Gilliland, 1993; Campion, Palmer and Campion, 1997, etc). Performance history is the best indicator (Childs and Klimoski, 1986), that is, past behaviour is the best predictor of future behaviour. Targeted ability testing is also highly effective in predicting job performance, especially where the abilities that underpin performance in the job are well understood and are measurable.

Tests of maximum performance using test tasks analogous to the duties of the job are used to identify the abilities of a prospective employee. However, such ability tests typically do not measure important personal style characteristics such as honesty, reliability, leadership style, job involvement, customer service orientation, team spirit, etc. Further they do a less than perfect job of measuring the elusive variable known as common sense which is important in the workplace (Bersoff, 1988). The best estimates suggest that ability test results by themselves probably account for about 25 per cent of the variance in job performance (Angus, 1996).

Numerous studies have shown that modern psychological testing is one of the most valid predictors of future job performance. With increasing frequency, employers are now turning to testing to aid in selection decisions as well as evaluation of personnel.

Comparisons of human attributes and differences have a very long history (Fröschl, 2001):

- Hippocrates – (400 BC) attempted to theoretically define four basic temperament types: sanguine (optimistic), melancholic (depressed), choleric (irritable) and phlegmatic (listless and sluggish).
- Galton – (19th century) measured human individual differences in terms of ability to discriminate between stimuli.
- Binet – devised tests to measure differences in specific human abilities. Now numerous tests measure specific abilities, strengths and competencies.
- 1917 – Psycho-Technical Test Office opened in Germany.
- Army Alpha and Beta tests (WW1 and WW2) – developed out of an urgent need to select personnel with specific aptitudes for training in specialist and strategic roles.
- 1990s – Computer-aided test procedures developed.
- 2000s – Linkage to statistical packages such as SPSS.

The reasons for using testing have not changed over time. They are rooted in the necessity to place the right person in the right job. Significant studies have been conducted on using psychomotor testing in several industries including aviation, train operation and driving. Previous work also demonstrated that the computer based ability testing was a predictor of student naval aviator and naval flight officer performance (Delaney, 1992; Street, Chapman and Helton, 1993). Portman-Tiller, Biggerstaff and Blower (undated), report on testing conducted by the Naval Aerospace Medical Research Laboratory. They found that the historic paper-based system and a computer based system have some commonalities but the computer based system offers significant advantages in aviation selection. Specific tests in tracking and dichotic listening tasks are similar to the real world environment and provide predictive validity using a flight performance criterion.

Schuhfried, in Traffic Psychology Psychomotor Testing Research Report (undated), reports that psychometric testing and psychological performance is an excellent predictor of future driving performance. Strong correlation is found between driving performance and tests for concentration, visual perception, reaction speed and intelligence.

History and results from the Psycho-Technical Test Office of the Deutsche Reichsbahn, (German Railways) indicate that the system is able to provide significant information as to the suitability of applicants for a range of jobs (Fröschl, 2001).

Various mines have used psychomotor testing to select equipment operators, including Coppabella, Beltana, Hartley, Ekati, New Mexico, Syferfontein and Kwagga. The results from these mines have not been published.

A strong correlation was found between computer based test results and a qualitative assessment of 28 BHP dragline operators (Moore, 1998).

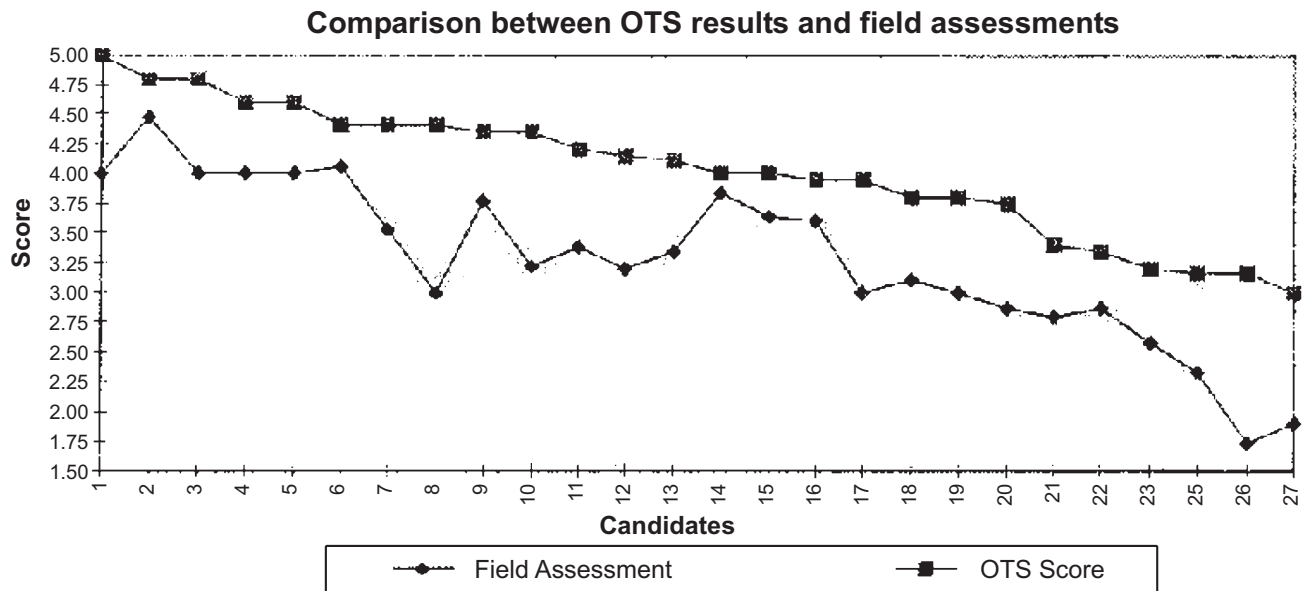


FIG 9 - Comparison between computer based test results and field assessments (after Moore, 1998).

As can be seen from Figure 9, the results were predictive of operator performance (statistical regression results $r^2 = 0.78$), suggesting that it is likely to be effective as a selection device. However, the reliability of the results is limited by the size of the sample and the qualitative approach used for field assessment. From a research perspective, the sample is of doubtful value because it is unclear how the sample was selected (ie potential sampling bias). A sample of 28 in an industry population of about 780 provides a confidence interval of 18.9 per cent (ie potential statistical power issue). This means the industry result extrapolated from this data could be plus or minus 18.9 per cent. This doesn't change the trend identified in the data, but it makes it virtually impossible to place an accurate cut-off between acceptable and not acceptable performance.

It has been demonstrated in several industries that people have different cognitive abilities. Put simply, everyone is different. Different people are suited to different activities. The coal industry endured significant pain through the mid to late 1990s and early 2000s as companies sought reforms to work and management practices. One key issue to come from this 'pain' is that most mines' selection processes are no longer constrained by considerations of seniority. Most mines are now able to select the people they want.

This is a tremendous opportunity for the coal industry.

Some mines have put processes in place for selection of suitable people and the aim of this paper is not to undermine any of that work. The position of dragline operating is seen as being a different consideration to other pieces of equipment. It is the largest piece of equipment; it is the most expensive; there is extensive data from monitors; and it has one unique feature – the bucket is not constrained by the machine. This provides a unique challenge for operators and their selection.

A tool has been developed by an Austrian company, Schuhfried, called the Vienna Test System (VTS), which is a computer based testing program consisting of six tests. These tests assess the co-ordination abilities required for safe and productive performance of machinery and vehicle operators.

ACARP is funding a comprehensive program which aims to confirm what combination of VTS output and demographic/environmental/psychological factors assessment is most appropriate for predicting dragline operator performance.

Table 2 shows the factors which the VTS can quantify.

TABLE 2
Factors quantified by the VTS.

Test	Abilities assessed
Cognitron	Concentration <ul style="list-style-type: none"> • variability of attention • impulsive responses • visual information processing style
Two Hand Coordination Test	Hand-eye coordination <ul style="list-style-type: none"> • coordinating visual perception and hand movement • fine motor movement • learning physical responses from mistakes
Time Movement Anticipation	Visual tracking and movement anticipation <ul style="list-style-type: none"> • estimating speed of moving objects • estimating direction of movement
Vienna Determination Test	Multi-limb coordination <ul style="list-style-type: none"> • visual and auditory responses • eye and limb coordination • perseverance after failure
Signal Detection	Visual pattern recognition <ul style="list-style-type: none"> • selective visual differentiation • recognition of weak signals • attention in low stimulus environments
Tachiscopic Traffic Test	Situational comprehension <ul style="list-style-type: none"> • speed of perception • visual short term memory • response choice

The selection of suitable operators is an area of great potential cost-benefit in the dragline operation. The cost in production by training on the full size machine is between 100 000 and 150 000 BCMs over the first six months. If the trainee is cut after two months the cost is probably about 50 000 BCM, which is worth between \$20 000 and \$40 000 per trainee. If the VTS (and other factors) works it will cost less than \$500 to come to the same conclusion.

Operator training

The cost of training can be substantial. Figure 10 shows the performance of a 'green' operator over a period of six months on the dragline. In six months, 120 000 BCM productivity was lost.

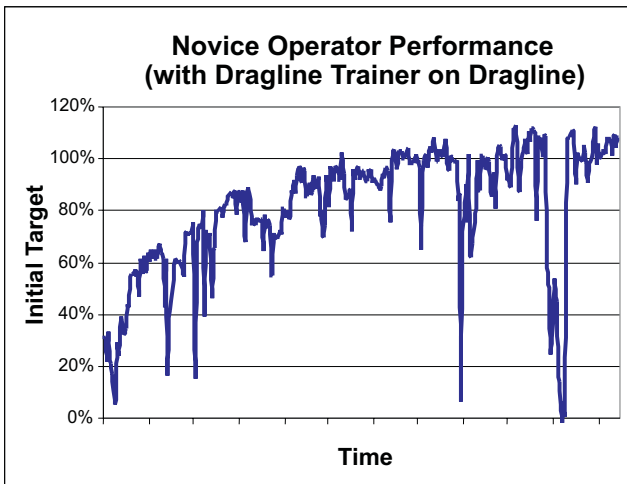


FIG 10 - Novice operator performance over six months (after Lumley, 2004).

The challenge for initial training is how to reduce this cost. The challenge for experienced operators is assisting the process of continuous improvement.

Operator training can take several forms:

1. use of a physical or computer simulator,
2. external operator trainer works on the dragline with the operator,
3. internal trainers, and
4. self training.

Each of these has an important part to play in the optimisation of dragline productivity.

By far the most important is self training. This comes from the management attitude and the selection of the 'right' people. Self training goes on as long as the person is operating the dragline. The best aspect to self-training is that it costs very little.

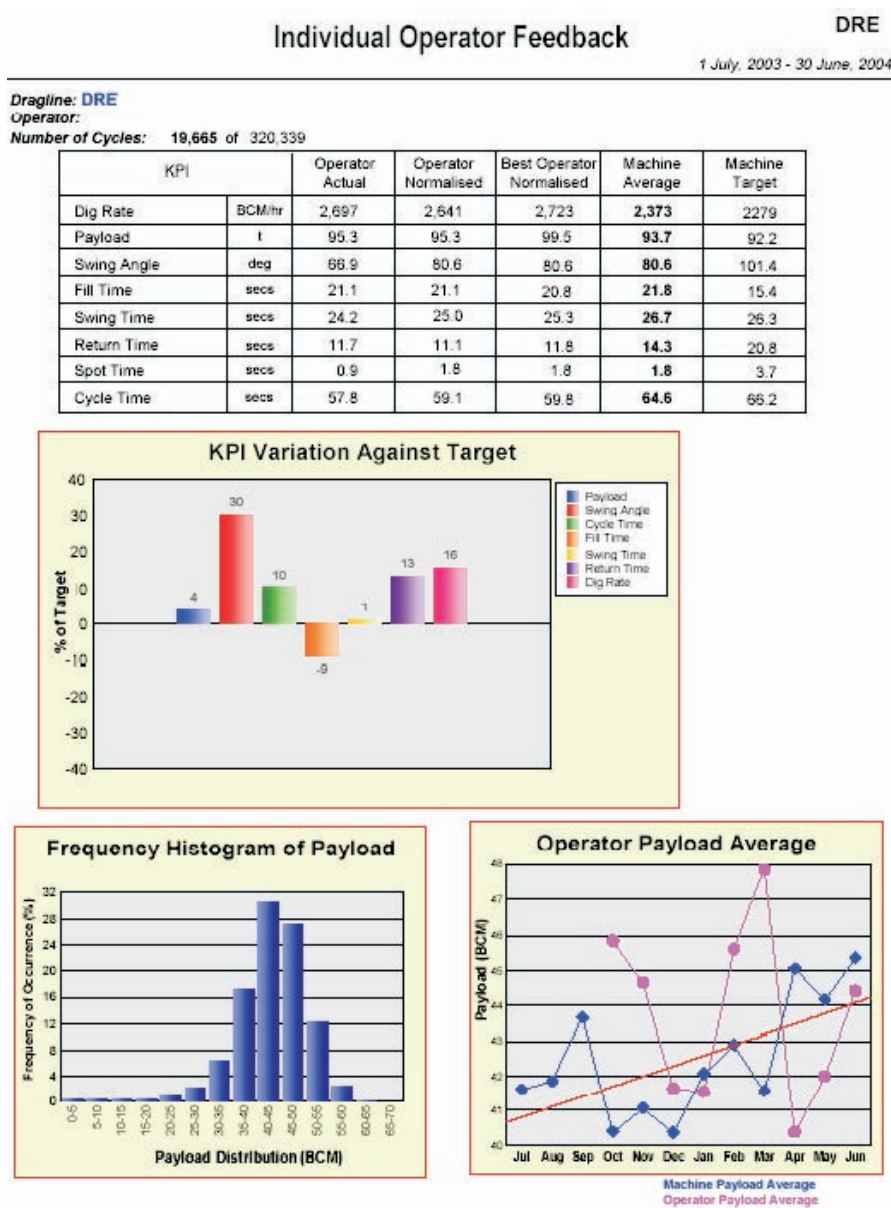


FIG 11 - Sample individual operator feedback.

Setting targets and performance feedback

The author's work has shown that at least 95 per cent of dragline operators are interested in doing a good job. The easiest way to support this is to provide ongoing feedback to the operators. Some mines haven't progressed to the point where the operators feel comfortable with individual reports. In that case, provide feedback for the dragline as a whole. When starting out, any reporting is better than nothing. Figure 11 shows a simple operator report. The key to operator feedback, regardless of the level of detail, is that it must be discussed with the operator to ensure they understand what the report means. This links closely with the concept of self training. Operators must be encouraged to do better and use the information contained in reports to improve their own performance. Unfortunately, most reporting to operators is wasted because mines do not make the investment in time required to discuss the results with the operator.

CONCLUSIONS

This paper provides guidance on where this author believes the most cost-beneficial improvements in the dragline operation may be obtained. The following are the main points.

- The potential for dragline automation is large but the technology is still being worked on. The CSIRO – DSA system is the first effort to automate part of the dragline operation. It has demonstrated that computer control of a dragline is possible and that it can perform better than a human average in some situations. Enhancements are currently being worked on to overcome the suboptimal performance in certain situations.
- It is this author's belief that the average Australian dragline has >20 per cent improvement available through process improvements, largely through improving the 'human factor'. Even those Australian draglines achieving current 'best practice' (>17 MBCM for a BE1370W/M8050) have >10 per cent improvement available. This corresponds closely to the one standard deviation (12 per cent for draglines) achieved by other industries when the 'human factor' is controlled (Newman, 2004).
- Attitude is important when approaching productivity. If current results are viewed negatively and mines make excuses for why results came out the way they did then nothing will change and productivity won't change.
- Establish selection processes which target employees who are naturally suited to dragline operating.
- Support training, both external and internal.
- Provide reporting structures for operators.

This author does not advocate the need to spend significant capital to achieve best practice. Whether a mine spends capital on their dragline is irrelevant to the message of this paper. All draglines currently have the potential to improve their processes. The majority of the gains are available through changes in the 'human factor'. Improving processes; including management, operational issues, maintenance, etc are issues that don't need large sums of money spent on them.

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