Whitepaper
TruckShovel Calculator

Optimization of Trucking Levels for Truck Shovel Fleets.

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1. Introduction

Maximizing the material moved is the principal point of focus for most miners, in particular contract miners. Given that the income is directly related to the amount of material moved, this is understandable. However too much focus on moving material (income) and utilization of machines leads to a misplacement of resources. This can lead to choices which result in costs building up without realizing that the profitability of the operation is being affected.

In truck shovel operations, the most direct way or misplacing resources and losing profit is by overtrucking or undertrucking a working truck-shovel fleet.

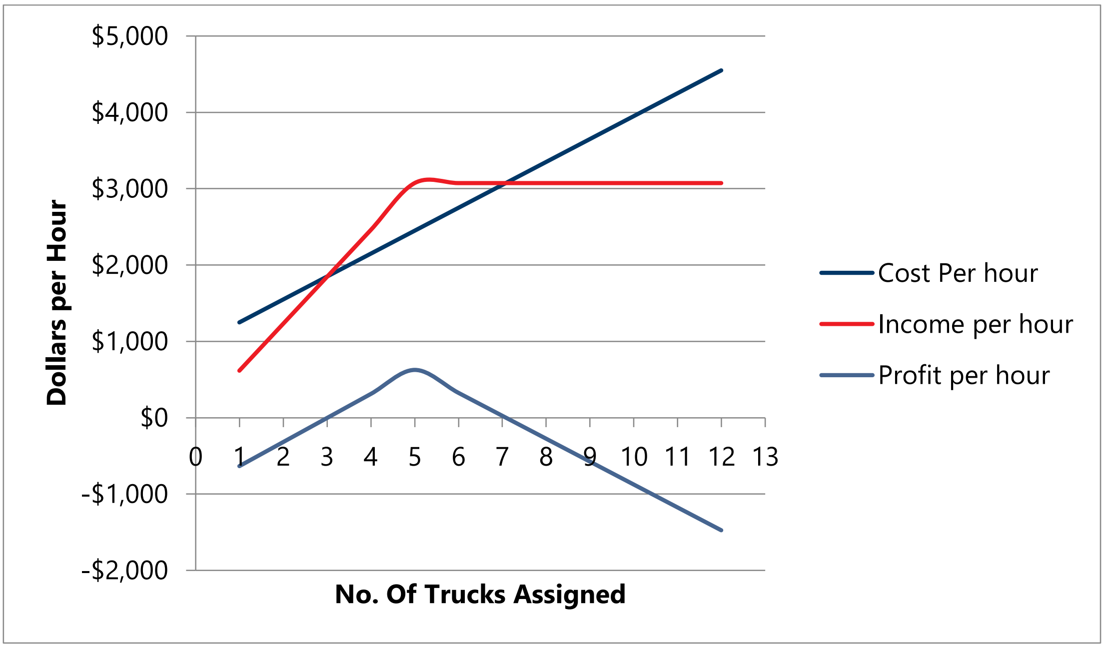
2. Truck fleet resourcing and profitability example

In this paper we will use a simple example of a single truck/shovel contract operation:

- The dig and dump location are fixed during the shift
- A truck takes four minutes to be loaded by the digger
- A truck costs $200 per hour to run in variable costs
- A shovel costs $700 per hour to run in variable costs
- The ancillary equipment required to keep the strip operating (dozers, grader etc.) costs $250 per hour in variable costs
- Filling a truck takes four minutes
- A full circuit takes 24 minutes
- A full truck earns $205 in income per truckload (fixed mine costs deducted)
- 10 hour shift working time

From these figures, it can be calculated that each truck needs to take 15 loads over 10 hours (1 load per 40 minutes) for its income to break even with its costs.

The income, costs and profit versus the number of trucks assigned is shown in the following graph.



This sort of graph is probably familiar to most people in charge of mining operations, but it is often forgotten or not fully apparent to people in direct control of truck-shovel operations (e.g. supervisors and dispatchers).

Some of the points to note in this example are:

- After five trucks, the system is "saturated" with trucks, and there is no increase in income.
- One truck too many or too few results in a halving of the profit of the operation.
- Two trucks too many or two trucks too few results in the operation no longer being profitable.
- This example is specific to a particular point in time. The loading rates can vary dramatically due to a number of factors, the circuit time can change with different dump locations and the income rate can change with haul distances.

An operation like this example cannot afford to be complacent in trucking levels. It is clear that there will be a "sweet spot" for profitability, and too many or too few trucks will impact on profitability. Calculating this "optimum trucking level" is done before the shift starts, and depends on route timings such as haul times, shovel loading rates, dump times and spot times.

In practice, the calculation of the optimum trucking level often over-relies on assumptions about truck and shovel cycle times. The optimum trucking level can also change during the shift, particularly if the shovel loading rates change or there is a change of dump location. Maintaining the optimum trucking level during the shift often falls prey to a combination of a lack of information, mixed messages in priorities and faulty reasoning.

3. Organisational reasons for over or under trucking

There are a number of reasons why overtrucking or undertrucking occurs. Some are technical, others less so.

3.1 Inability to calculate/estimate cycle timings:

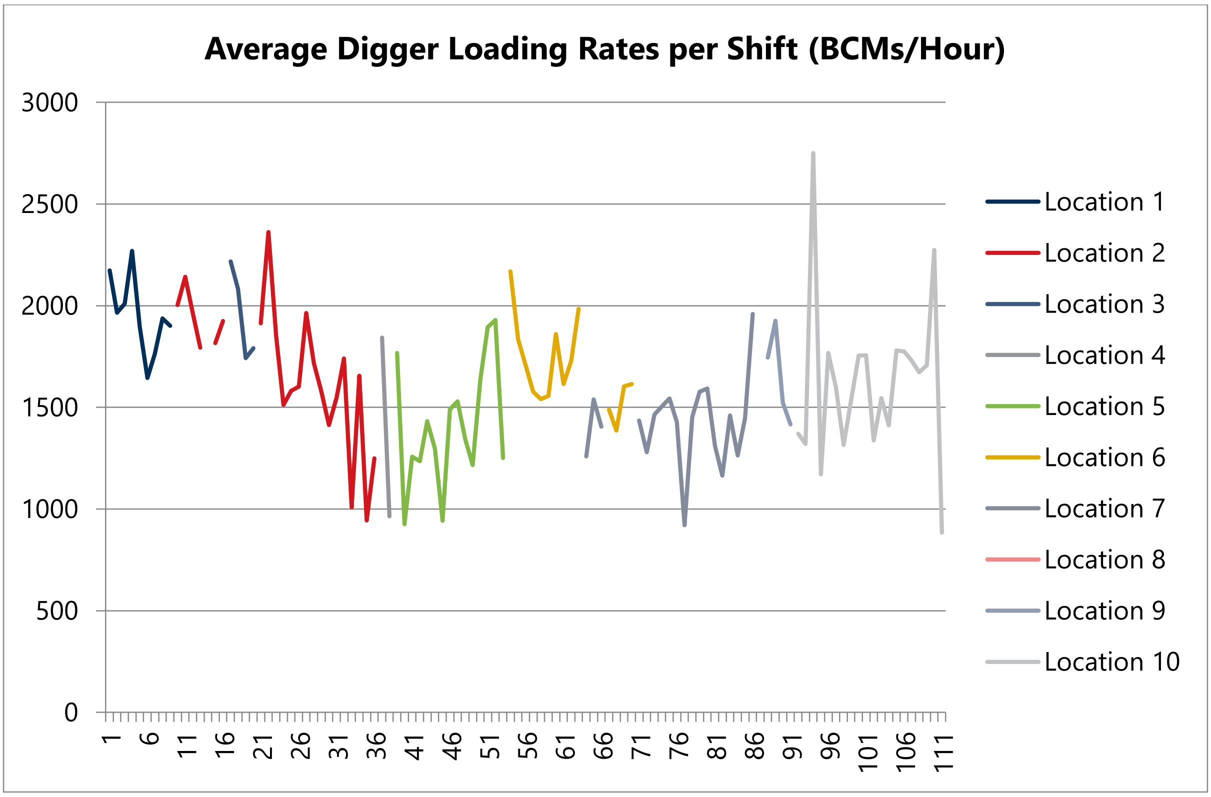
Calculation of the optimum trucking level requires estimation of cycle timings (e.g. fill, haul, dump, return and spot times). For the person assigning trucks at the beginning of the shift, there are complications to finding the optimum trucking level. Some of these complications are:

- Cleanup at the dig is occasionally required. This can result in occasional truck waiting time.
- Holdups on any part of the circuit, e.g. dump stoppages
- Spot times change due to conditions the dig location

- Dump times change due to conditions within the dump location (e.g. waiting for dozers to clear dumped material)
- Shovel digging and loading rates change due to a number of factors, including combinations of:
    - Operator skill and training levels
    - Changing dig conditions
    - Machine health (e.g. engine power)

These are hard to accurately quantify. In particular, the combination of operator skill and dig conditions can change markedly and have effects which can last for hours or days.

The diagram below shows the actual loading rates over a period of 111 shifts for a single shovel on a mine site. Note that this is the "pure" loading rate, and has all delays removed.



Actual example of the average loading rates per shift over a period of 111 shifts

Differences between operator skill levels are responsible for the shorter term trends. These shorter terms changes are highly volatile, and can change loading rates by over 100%. Dig conditions and machine health are responsible for much of the longer term trends, and lead to changes up to 40%.

Most sites do not measure or take into account these issues, instead preferring to use an "average" loading rate value which is rarely questioned or measured. Yet changes to this fill rate can make a big difference to profitability.

3.2 Prioritisation:

In a mine with multiple truck shovel strips operating, some shovels may have a higher priority to move material within a given time. Supervisors often tend to overtruck the strips with a higher priority and undertruck other strips.

In the worst cases this could lead to the profitability of all strips being degraded because some are essentially overtrucked and some are undertrucked. It could also lead to the lesser priority shovels being less productive due to undertrucking. Meanwhile at the at the higher priority shovels there is no extra production due to the extra trucks because they have reached truck saturation.

3.3 Running too many strips:

On a site with multiple shovels, there can be occasions when there are not enough trucks available. This can be due to maintenance issues, faster shovel loading rates or longer haul routes.

In this situation, there can be a decision to keep all shovels working, which then leads to undertrucking of all strips. This is particularly the case if one shovel cannot be prioritised over another.

Alternatively, all shovel are kept working but with the higher priority shovels given more trucks and the other shovels are given less trucks. As mentioned above, this can lead to a degrading of profitability where there are shovels which have too many trucks as well as those with too few. Undertrucked shovels may be tempted to do excessive and expensive "make work" such as cleanup and scavenging rather than switching the engines off and saving costs.

3.4 Over-reliance on "Utilisation" as a KPI (Key Performance Indicator)

In some cases "utilisation" is used as a KPI for productivity. Often however "utilisation" KPIs include the following cases:

- A truck spends time waiting for a shovel.
- A shovel spends time waiting for a truck.

Utilisation KPIs still counts this as "productive" time. Variable costs are still accrued during these periods, but no income is produced. This makes utilisation a risky and inaccurate measure of performance.

Focusing on utilisation without weighing up costs and income will lead to situations where all machines are working for the sake of it, even if the systems are clearly unbalanced.

As an example, consider a situation where a contractor is experiencing a period where all of the shovels are in difficult digging. This slows down their loading rates, and hence they need fewer trucks. The supervisor makes the correct call in reducing the number of trucks to the optimum level and parks them during the slower period. This achieves the maximum possible *profit* as well as the maximum possible *income*. However, the truck utilisation figures will decrease. This decrease in utilisation (or the sight of parked trucks) will leave the supervisor's decision open to attack by someone who does not understand that utilisation does not equal profit.

A second example is one where the haul routes are longer than usual or there are less trucks available. A focus on utilisation might prompt the use of too many shovels, leading to either all strips being undertrucked; or alternatively shovel prioritization leads to some shovels being better resourced than others. In either case, profits may be being lost in the drive to have all machines working. Parking up a shovel and its ancillary equipment may be the right call, but it does not help the utilisation KPIs.

Hence the need for all management levels to understand that the two paramount objectives are profit and contracted volumes. Utilisation is a KPI used to justify purchase or lease decisions, and is not the correct tool for assessing profitability, volumes or production efficiency.

4. The risks and rewards of assigning an extra truck

When deciding the right amount of trucks for a strip, there is a tendency for the person in charge of assigning trucks to overtruck the system. However too many trucks only add cost. Yet it is always tempting to put on another truck "just in case". This is usually for a number of reasons:

- If the digger has time to fill a truck (or appears to have time) and it is not doing so, then that is seen as lost income. Volume has become the primary concern instead of profit.
- Many sites focus very strongly on machine utilisation, without thought of running costs.

There are six main scenarios to consider in terms of having one extra truck "just in case". Each will be examined in detail for the case of the example shown in section 1.

Case1: Unexpected Stoppage of the Dig Unit

In this particular situation, there is no gain whatever to having an extra truck. The trucks merely bank up at the loading point. There is a net loss of $3,000 for the shift.

Case 2: Stoppage of any other part of the dump area or haul route

If there is a stoppage on the route or dump area, the shovel will continue to fill trucks until there are no more to fill. The extra truck will mean a single extra truckload will be carried through once the stoppage ends. However this is not a justification for assigning an extra truck.

Consider if there is only one major stoppage during the shift. The truck will cost $3,000 for the shift, yet will only earn $205 for the shift by covering during the stoppage. The net result of overtrucking is a $2795 loss for the shift.

Case 3: Loss of the truck from the system

If a truck is lost from the system, then the extra truck can immediately take its place. However it is an expensive way to cover for such an event. A truck assigned for an entire shift of 10 hours must carry 15 full loads to break even.

If the extra truck is assigned for the purpose of covering for the loss of a truck, the supervisor is essentially gambling on a truck being lost for at least 5 hours (i.e. 15 full loads).

A cheaper solution in this case would be to have the truck on standby off strip with its engine off. It can then fill in where required.

Case 4: The digger decreases its loading rate

This particular case sees the worst case scenario: an extra truck has been assigned, which costs $3000 per shift, and the strip gains more excess trucking by the fact that the shovel has slowed its loading rate.

Decreasing production rates is quite common during a shift. The main reasons are:

- a change of operator
- a change of dig conditions
- a change in the shovel health (e.g. low engine power issues)

Case 5: The digger increases its loading rate

In this scenario, the extra truck can take the extra loading capacity of the shovel. However, for the assigned extra truck to break even, the loading rate must increase by an average of 10% for the entire shift. If the loading rates increase for a shorter time, then the rate must increase further still to cover the cost of an extra truck for ten hours. The table below shows this relationship:

Loading Rate Improvement required to break even for one extra truck assigned for ten hours:

10%	in	10 hours
22%	in	9 hours
38%	in	8 hour s
57%	in	7 hours
83%	in	6 hours
120%	in	5 hours
175%	in	4 hours
267%	in	3 hours
450%	in	2 hours
1000%	in	1 hour

Note that this is an exponential relationship. Before committing to an extra truck for the longer term, the supervisor should be assured that a 10% minimum change in dig rates are likely to continue for the rest of the shift.

Increases in the shovel loading rate during the shift are rarer than decreases. They will occur for two main reasons:

- a change of operator
- a change of dig conditions

Case 6: The haul route is changed

This particular scenario demands a recalculation of the optimal trucking numbers rather than relying on an extra truck "just in case" of this scenario.

Conclusions: The effect of assigning an extra truck

Assigning an extra truck has a far greater chance of increasing costs which cannot be recovered under most changes to situations. In the few cases where an extra truck would be an advantage, a better method would be to have a truck on standby with its engine off to cover for these instances. The best possible implementation would be to have a truck on standby with operator (but engine off) at the dig location, to fill in only when there is a gap long enough to fill the truck.

5. Optimum trucking via profit analysis

The ideal situation to optimising profits would be to estimate the trucks required before each shift taking into account the following:

- The predicted loading rates of the machines based on dig conditions, operator and machine health
- Haul, return and dump and spot times based on recent performance for the haul routes and dig/dump locations

After this, the strip should be monitored for a period (e.g. one hour) after the initial queue of trucks has been filled and is on its way. This performance monitoring needs to take into account of the costs, income and amount of waiting time of either the trucks or the shovels. The assessment should be able to tell the following:

- Is the strip currently profitable?
- Can it be made profitable under current conditions?
- Under the current digging conditions, what number of trucks will yield the maximum profit?

This assessment should be done periodically to take into account changes in conditions.

In practical terms, such an assessment method involves solving the following problems:

- What is the minimum amount of easily accessible information required?
- Can this analysis be one without expensive recording systems? (e.g. a dispatch system)
- Can the analysis be done while protecting sensitive commercial information?

In theory, this assessment could be done by a dispatch system. In practice however dispatch systems try to balance a strip, but rarely do they take into account the profitability of the strip. A strip can still become unprofitable even with perfect balancing, particularly if the dig rate slows down too far. Furthermore, a dispatcher can also ignore or override the dispatch systems' efforts to optimise the strip. Therefore a simple profitability procedure would still benefit a mine with a full dispatch system.

On a large site (about five shovels) with a working dispatch system, the balancing of the truck/shovel resourcing has been measured as follows:

Resource Match	Occurrence	Waiting Time
Undertrucked	25% of all shifts	Average 50min per digger per shift
Overtrucked	50% of all shifts	Average 66 mins per truck per shift
Properly Matched	25 % of all shifts	-

As this example shows, even a working dispatch system is no guarantee of an optimised operation.

For smaller mining operations without dispatch systems, a simple profitability analysis procedure would be invaluable.

If a profitability analysis is used, then all levels of production management must be educated in the main aim being profits, not utilisation. Making decisions to add or remove trucks from a fleet to maximise profits must be supported.

Extensions of this profitability analysis could eventually see better calculations of loadings rates for operators and dig conditions leading to better estimations of the optimum trucking points before the start of shifts.

6. Conclusions

Maximum profit in a truck-shovel system occurs at an optimum trucking level. The method to calculate this number is straightforward, but in practice this number is often only an estimate. On some sites the profitability margins are very thin and can easily be degraded by having one or two trucks too many or too few on the strip. Even on a site with a working dispatch system, the optimum trucking levels were only reached 25% of the time.

Having a site maintain the optimum trucking level is also very difficult. There are changes to conditions which can change the number of trucks required. Equally, balancing misconceptions about what is the actual priority for the site and how to address it via truck levels is often poorly understood. This leads to trucking levels which are not optimal.

The particular problems leading to suboptimal profits are:

- Ignoring the high variability in loading rates when calculating the trucking level
- An overemphasis on utilisation, leading to overtrucking or running too many shovels at once (and hence overall undertrucking).

Assigning of extra trucks in an effort to boost strip performance or cover unforseen situations, which instead often only leads to increased costs.

Having a simple yet effective procedure to measure actual strip profitability and optimum trucking rates during the shift would be an invaluable tool to correctly optimise operations. However all levels of management must be aware of profitability being the driving motive for optimisation, so that resourcing decisions can be properly supported.