Truck Shop Simulation

Chris Vernon

Melinda Hodkiewicz
School of Mechanical and Chemical Engineering,

Steve Richardson
School of Engineering, Edith Cowan University

Richard Durham
School of Civil and Resource Engineering

Abstract

Many of the mine production models used in industry today do not simulate maintenance operations that take place in the "Truck Shop". These maintenance operations are relatively expensive, time consuming and important to the long term health of the equipment. There is therefore great opportunity to improve mine performance by identifying and evaluating important maintenance and reliability operations. Insights backed by data on the relative importance of truck shop operations will act to improve the effectiveness of current operations. Greater understandings of the operations that are undertaken in a truck shop will ensure future work can build towards answering more advanced questions.

1. Introduction

Mining is a large-scale capital intensive business operation; there is a high necessity to eliminate bottlenecks and inefficiencies to meet market commitments. Due to the continuous nature of mining it is particularly important to have a reliable well-maintained fleet to maximise the time trucks are available for operation. However a balance needs to be found to ensure they are not over maintained as this can lead to unnecessary downtime and increased costs associated with performing maintenance tasks.

Using Arena simulation software a mine site model was built in order to provide quantitative insight into operations that take place in the "Truck Shop". It is based upon previous work from 2008 during a 6-month collaborative research project between the UWA School of Mechanical Engineering (Dr. Steve Richardson and A/Prof Melinda Hodkiewicz) and the asset management group in Rio Tinto Iron Ore. A major component of this previous project came in the development of the Truck Shop model where maintenance operations occur. However, the model never provided any useful output due primarily to an excessively rapid escalation of model complexity which has been attributed to a lack of clear boundaries for the model. As a result a new mine site truck shop model was developed to enable simple questions to be answered before expanding to higher levels of complexity. The resulting model enables exploration of which Truck Shop operations are important to overall mine performance.

1.1 Mine Site Operation

Haul trucks travel between shovel locations and crusher locations to collect and dump ore. The Truck Shop is the place where heavy mobile equipment e.g. haul trucks and shovels, go for maintenance and repair operations. These operations are categorized as either preventative maintenance (planned) or corrective maintenance (unplanned failures). The Truck Shop as a limited number of resources to be allocated to these operations, which when fully utilised will result in equipment queues. As described in Figure 2on the following page, Truck Shop resources, queue priority and scheduling are variables in the Arena model enabling evaluation of their relative importance to overall mine performance. The reliability strategy employed in a Truck Shop can affect performance of the mine directly through availability of equipment and indirectly through costs of maintenance.

1.2 Project Objectives

The key objectives of this project are:

- Build a working model of a Truck Shop
- Ensure that the Truck Shop model design allows it to be combined with a more advanced mine model currently being developed by another student.
- Evaluate Truck Shop resource allocation effects on overall mine performance.
- Evaluate the effect of varying Truck Shop queue priorities on overall mine performance (e.g. shovel requiring repair should jump the queue).
- Provide a greater understanding of Truck Shop mechanisms so that future work can build towards answering more advanced questions.

2. Process

Figure 1 below shows Banks' (2005) 'steps in simulation study' process. These steps are explained below in detail in the context of this project.

2.1 Model Conceptualisation

Figure 2 below conceptualises the model. Truck Shop operations to be assessed are individually varied as inputs to the Arena model. Resources are represented by bays in the truck shop, Queue Priority is varied between 'shovel first' and 'first in first out' (FIFO) and Scheduling varies the frequency of planned maintenance intervals. Further clarification of these tested inputs can be found in Section 3. The outputs from the simulation enable the effects on performance to be measured based on production, truck availability and shovel availability.

Rockwell's Arena is a discrete event simulation software package which enables the user to build an experimental model by defining modules that represent processes or logic. These modules direct the flow of entities travelling around the model. The software is non trivial as its functionality needs to be sufficient for different users to build their models. Models of substantial complexity require an advanced understanding from the user. The model built in this project was designed and built from scratch.

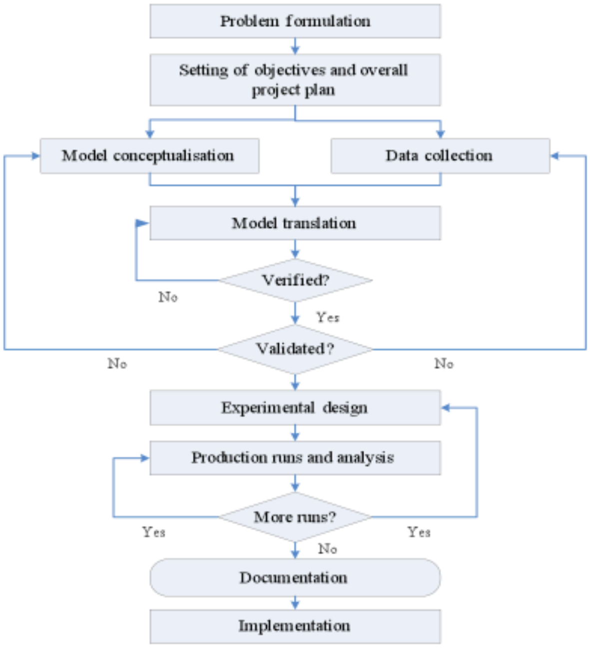

Figure 1 **Steps in simulation study (Banks et al, 2005)**

Figure 2 **Model Conceptualisation**

2.3 Model Translation

Designing and building the model to sufficiently simulate the mine site operations (described in Section 1.1) was nontrivial and required a high level of Arena familiarity. A screenshot of the mine part of the model can be seen in Figure 3 below.

2.4 Experimental Design

Trucks travel back and forth between the crusher and shovel locations transferring ore until maintenance operations require them to visit the Truck Shop. Shovels operate at fixed locations and load trucks from an unlimited pile of ore. Queuing is necessary since the shovel and crusher can only deal with one truck at a time. Aside from preventative and corrective maintenance operations it is assumed that trucks and shovels operate continuously, so shift changes and crib breaks are ignored.

Travel times between shovel, crusher and Truck Shop are treated as constant. Trucks proceed to the shortest queue when approaching the shovels. The loading times, dumping times, repair times and the time it takes to travel to the Truck Shop after failure are all modelled as log normal random variables. In the Truck Shop shovels have priority over trucks.

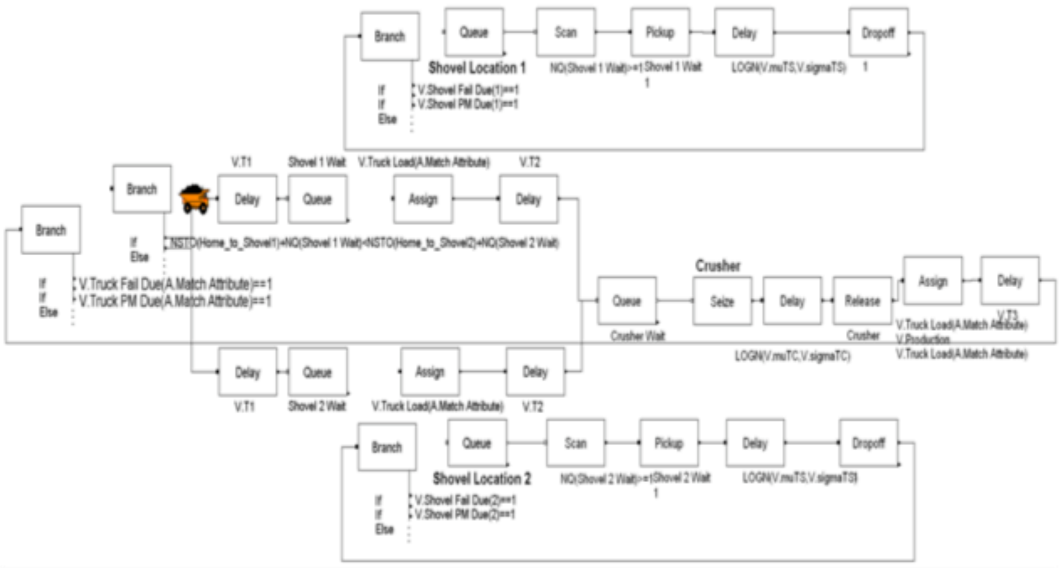

Figure 3 Screen shot of arena simulation model

Failure distributions to determine when trucks or shovels fail are modelled using Wiebull distributions with respect to operating hours, the parameters for which are taken from Louit and Knights (2001) and are of "wear out" type. That is, the longer they operate without maintenance the more likely they are to fail. It is assumed that repairs return the truck or shovel to "as good as new" condition. Preventative maintenance tasks are scheduled periodically and require the asset to complete its current task before presenting at the Truck Shop. Corrective maintenance operations experience longer travel times to the Truck Shop, longer repair times and immediate task interruption. The Truck Shop has finite resources (e.g. bays) to be seized during each maintenance operation.

3. Results and Discussion

3.1 Validation

A 5 truck, 1 shovel, and 2 repair resource model was expanded by increasing the number of trucks in increments of 5 (3.1.1) followed by increasing the number of shovels (3.1.2). Each simulation runs 100 times for 100 days.

3.1.1 Increasing Trucks

3.1.2 Increasing Shovels

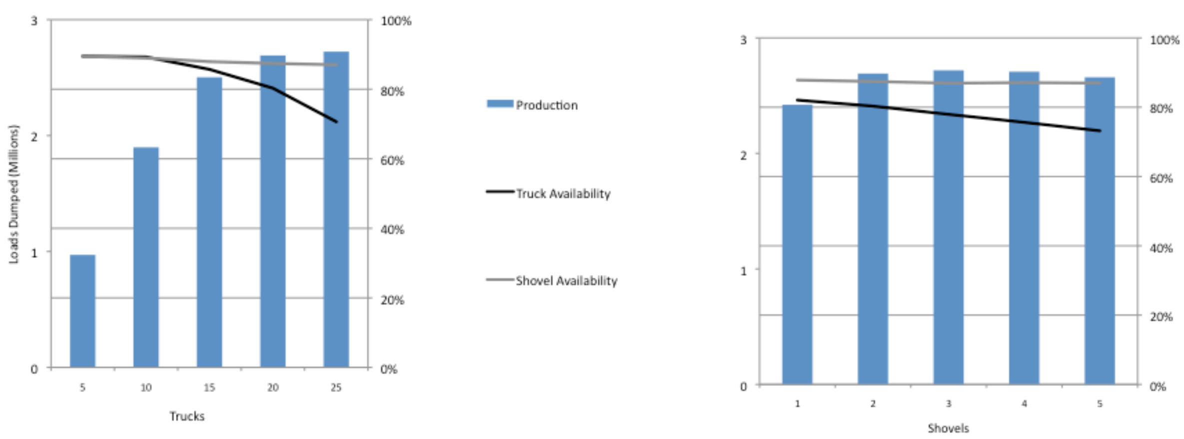

Figure 4 Validation exercise results

As can be seen in Figure 4 an increase in truck entities leads to an increase in production and a decrease in availability. This makes sense as more trucks should be able to dump more loads, while their availability decreases as the Truck Shop begins to get congested and their downtime is lengthened as they wait in queues. At 20 trucks the level of production levels off and availability decreases, illustrating the reducing marginal utility from increased truck numbers. The number of trucks was fixed at 20 when increasing the number of shovels in the second graph. It can be seen that production returns to similar levels after a second shovel is introduced, suggesting that for 20 trucks 2 shovels makes a good combination. As described in Section 2.4 the shovels have favourable priority when queuing so it follows that for more shovels there is no change in shovel availability, while truck availability decreases slightly as the Truck Shop experiences an increased load. These results verify that the model is performing properly as they reflect what is logically expected.

3.2 Resources

To test and observe how resource levels in the Truck Shop affect performance the number of bays in the Truck Shop was increased from 1 to 7. The number of trucks and shovels was fixed at 15 and 3 respectively. This combination was chosen to leave margin for expansion or contraction in either truck or shovel entity population without having to expand the model, i.e. half way between the minimum and maximum entity size used thus far.

3.2.1 Increasing Bays

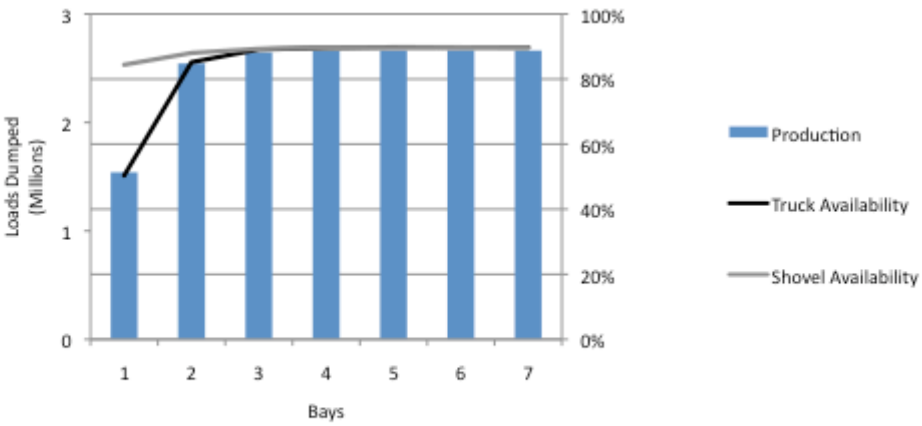

Figure 5 Resource level effects

Figure 5 shows that increasing the number of bays acts to increase the availability of both trucks and shovels. Again this makes sense since more resources in the truck shop enables faster turn around and less queuing. For this combination of trucks and shovels an increase in Truck Shop resource levels beyond 3 makes little difference to the performance of the mine.

3.3 Priority

Thus far queues in the truck shop have given priority to shovels above trucks. Figure 6 shows the difference in production and availability if the queue priority was FIFO. It can be seen that FIFO priority is inferior to shovel priority for low truck shop resource levels; the difference disappears when there are enough bays to services all of the equipment without queues.

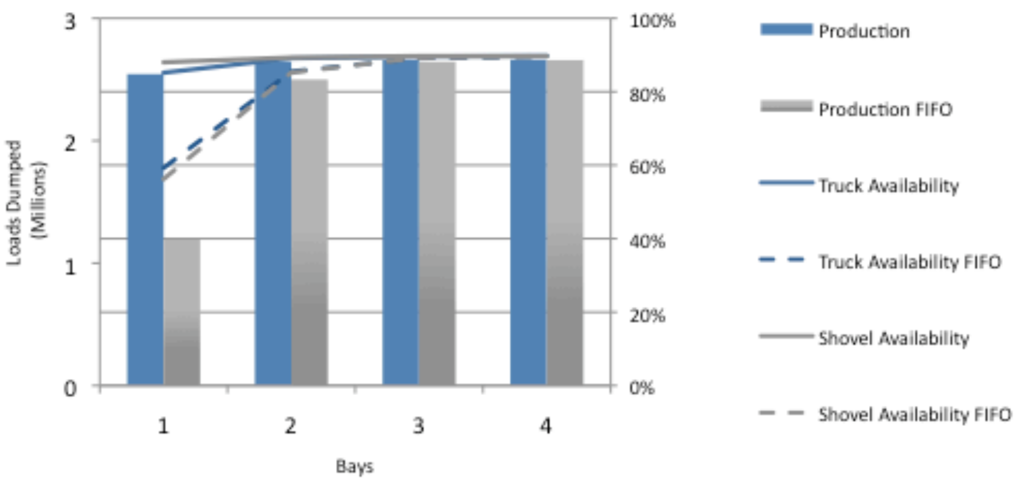

Figure 6 Priority effects

3.4 Scheduling

To determine the importance of scheduling operations in the Truck Shop the time between planned maintenance events was varied between extremes from 50 to 1000 hours. Similar to Section 3.3, the number of trucks and shovels was fixed at 15 and 3 respectively.

3.4.1 Planned Maintenance Service Frequency

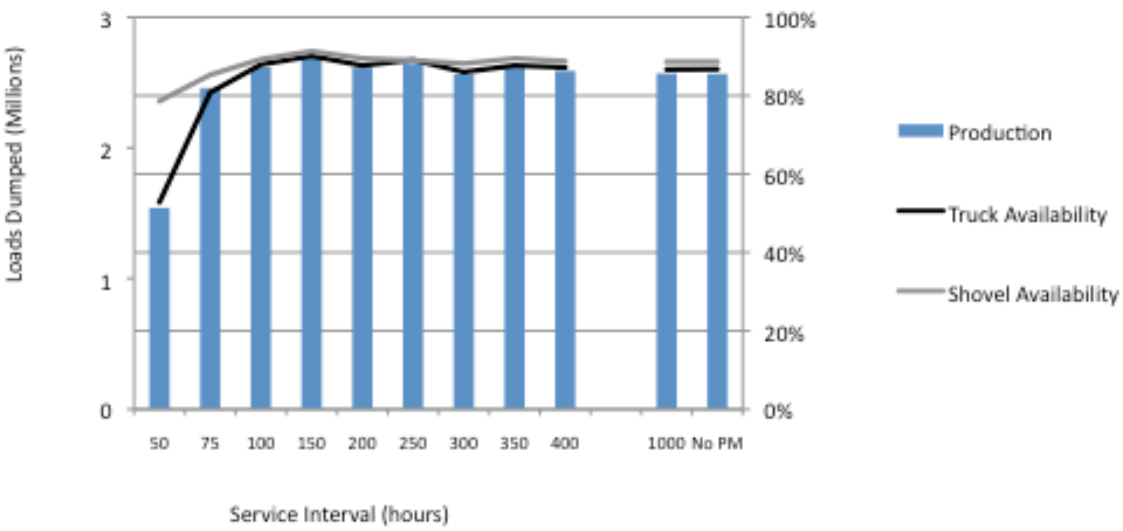

Figure 7 Scheduling effects

Figure 7 shows high levels of planned maintenance limits production and availability. This can be attributed to the interruption of mining operations for scheduled maintenance. If given the choice between similar levels of performance a planner would schedule as little maintenance work as possible to reduce total costs associated with maintenance. These results will become more meaningful when the model is developed to include the positive effect high levels of planned maintenance have on failure frequency in the long term.

5. Conclusions and Future Work

The model has been developed to a level of detail sufficient to begin inferring which Truck Shop operations are most important to overall mine performance. An increase in Truck Shop resources was found to have a positive effect on performance until saturation was reached. Queuing priority given to shovels lends to greater mine performance than FIFO. Testing levels of preventative maintenance had insignificant effects on model mine performance except for very high frequency service levels. The model has been built to allow for multiple expansions including multiple repair resources and multiple job types. As with this project each expansion requires verification to ensure the model is performing properly.

The point of saturation found in the results section can be valuable to mine planners in determining when marginal utility of increasing resources is unwarranted by comparison to the increased cost of providing these resources. If the cost data and parameter inputs were available a more accurate representation of real mine site performance could be developed. Retrieval of this cost data requires “cleaning” before it becomes meaningful for this model. Future work has already been commenced by another student seeking to validate the repair “as good as new” assumption in the model and thus allowing consideration of asset deterioration. The difficulty in simulating such complex processes can explain why simulation work of this type has not been done before.

6. References

Banks, J., 1998, Handbook of Simulation: Principals, Methodology, Advances, Applications and Practice, Wiley IEEE 1998.

Hodkiewicz, M., Richardson, S., and Durham, R., 2010, Challenges and opportunitites for Simulation Modelling Integrating Mine Haulage and Truck Shop Operations, CRC Mining Conference, School of Mechanical Engineering, UWA, pg 163-172.