Underground Ore Handling Systems

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ABSTRACT

Computer simulation modelling (discrete event) has been used at Olympic Dam (OD) to model the handling of ore from the point of extraction at the stope drawpoint through to the ore stockpile on the surface. Computer simulation is a well accepted tool for modelling the behaviour of such large and complex operating systems. It is a particularly useful technique in complex operations where there are multiple interactions between the inputs and outputs of various unit operations. In this instance it can be utilised during the early stages of a project, for example, as part of the business case definition phase or the early engineering phase. A well constructed and tested simulation model provides a sound base upon which informed business decisions can be made. Furthermore, the behaviour of the model with varying inputs can help build a solid understanding of how the asset behaves when varying inputs and constraints are imposed upon it and, as a result, the major points of leverage that designers and operations personnel have to affect the real world behaviour of those assets. Better decisions can be made when the right facts can be examined, various options explored and conclusions tested. Simulation modelling is one of the tools available to make this process work.

INTRODUCTION

Olympic Dam (OD) is the largest underground mining operation in Australia, hoisting over nine million tonnes per annum (Mtpa) of copper bearing ore. In the pursuit for increased production, OD is constantly striving for ways to improve the operation at minimum cost and lowest risk to shareholders. A part of this process has been to use modern techniques, such as simulation modelling, to test the operation in a manner that does not impact on production, before implementing any changes.

These simulation modelling techniques were originally derived from the manufacturing industry. In the last 20 years these techniques have proven to be highly successful in a number of mining operations. Several Australian mining operations, such as OD, have been at the leading edge of this technology.

During 1997 Fluor Daniel Simulation Services were commissioned by the OD Expansion Project to undertake a simulation study of the Underground Materials Handling System which was being proposed for the expansion project. The battery limits for the simulation were from the production stopes through to the mill stockpile. The aim was to quantify the maximum amount of ore that could be realistically hoisted, whilst taking into account planned and unplanned downtime. The results of the study showed that the Clark Shaft hoisting system would be constrained at between 7.8 and 8.8 Mtpa, dependent upon what external conditions existed. Clark Shaft has now been in operation for six years and the performance to date suggests that
the annual capacity exceeds 8.2 Mtpa.

This paper examines how OD and Fluor Simulation worked together successfully in 2004 using these modelling techniques to test and improve their understanding of the operation prior to implementing changes. It explores why the technique is invaluable in evaluating complex operations and how it can be used to dispel common myths as to why systems may not be performing as intended.

SIMULATION

What is computer simulation?

Simulation modelling is the process of representing a real life situation in a controlled environment. Computer simulation is a well-accepted tool for modelling the behaviour of large and typically complex operating systems, particularly where there are multiple interactions between the inputs and outputs of various\ unit operations. Less common is the use of simulation as a design aid, which can be applied at the early stages of a project, for example, as part of the business case definition phase or the early engineering design phase to assist with optimisation and risk management in a wide variety of mining, mineral processing and logistics applications. OD and the Fluor Simulation group have now been involved in several modelling studies focused on the underground materials handling systems.

Simulation modelling software

Most simulation studies are undertaken with commercial software packages. Fluor Simulation uses a simulation package called Arena®. Typically these packages are specialised tools using graphical interfaces to assist developmont of the models. Whilst these programs are becoming more user friendly, programming skills are required to tackle complex problems and a sound understanding of the way in which a system works is essential in order to correctly model it.

Arena is designed to provide the power required for successful simulation within an easy-to-use modelling environment. An animated Arena simulation model can be used to:

- Design a new facility or make changes to an existing one and ‘test drive’ it before beginning to pour the concrete, ie OD in 1997.
- Compare operational strategies so that the best outcome can be selected with confidence and that it can be implemented with the knowledge of how it will perform, ie OD in 2004.
- Assist communication to all concerned with the knowledge of how the project will function and what implications specific variations might have. This includes the management team who sign off on the decision, through to the operational personnel who will ‘drive’ it.

Arena has proven reliable when developing complex modules and Fluor Simulation has a library of support tools, which speed up the development of both the model and the infrastructure required to organise and set up different scenarios and process outputs.

Intellectual property

As with most software packages these days, which come out of the box with impressive capabilities, it is inevitable that they only do 95 per cent of what the client wants with their standard features. This is the same with Arena and as Fluor Simulation have been using Arena and its predecessors for over 15 years, they have developed a substantial library of intellectual property, all aimed at improving the efficiency and accuracy of the modelling process.

Examples of these tools include pre-processing Excel spreadsheets, which are used for the rapid entry of input data in a simple and consistent format, as well as enabling multiple scenarios to be set up and formulated in extremely short time frames. Post-processing spreadsheets enable rapid analysis of multiple scenario runs, which in turn aids in the focusing of analysis by removing the time-intensive and error-prone activities. These spreadsheets also enable the results to be presented in a standard format, which is driven by the client's needs. Having a consistent format means that results can be presented quickly, outliers or runs of little interest 'discarded', and then time and more detailed analysis can be directed to where it is of most value.

HISTORY OF THE PROJECT

There have been numerous papers written summarising the history of OD and the reader is referred to any of these, such as Webb 1998, for further information on the finding and early start up of this massive orebody. By the end of 1998, OD was producing at a rate of 3.4 Mtpa, all hoisted through the original Whenan Shaft. The capital works for the underground expansion were nearing completion, with the new Clark Shaft hoisting facilities just commencing commissioning. This facility would assist in enabling production to be almost tripled to a production rate of 9 Mtpa. Production would continue to be obtained through a combination of development ore and sublevel long hole open stoping, but with increased stope sizes now varying in size from 100 000 to a million tonnes.

In 1997, as part of the design process for the expanded underground operation at OD, Fluor Simulation was commissioned to undertake simulation modelling of the new Clark Shaft Material Handing System. The results of the modelling had shown that the Clark Shaft hoisting system would be constrained at between 7.8 and 8.8 Mtpa, dependent upon what actual mine operating conditions existed at the time. In the period following the expansion, this was shown to be the case with the rates attained on a monthly basis constrained within this range. Unforeseeable events meant that these rates were not produced on an annual basis. Table 1 summarises the production ore hoist over the years following the expansion.

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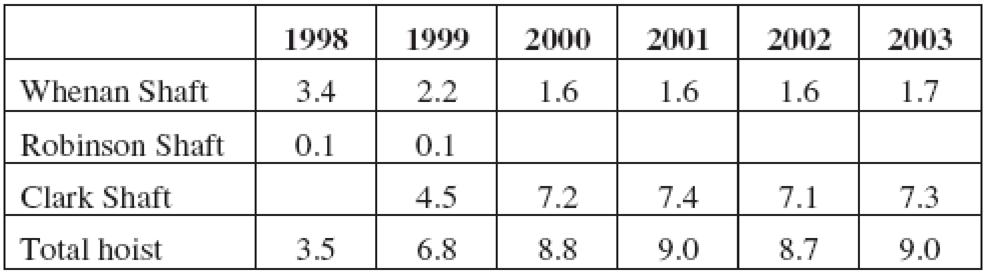
During October 2003, the performance data suggested that the annual capacity was constrained at 8.8 Mtpa, thus verifying the original Fluor modelling result. So seven years later the original modelling exercise was revisited. Once again, the modeling battery limits would consider the process from stope blasting through to ore stockpiling on the surface.

TABLE 1

Olympic Dam production ore hoist (Mtpa).



	1998	1999	2000	2001	2002	2003
Whenan Shaft	3.4	2.2	1.6	1.6	1.6	1.7
Robinson Shaft	0.1	0.1				
Clark Shaft		4.5	7.2	7.4	7.1	7.3
Total hoist	3.5	6.8	8.8	9.0	8.7	9.0

ABOUT THE OLYMPIC DAM MINING OPERATION

In order to understand how the modelling process was used at OD it is first necessary to familiarise the reader with the underground operation. A schematic view of the underground mine in shown in Figure 1.

Ventilation

OD is unique in that ventilation is a prime consideration in all aspects of the underground operation, more so than in other underground mines. The uranium in the orebody adds the complexity of needing to actively manage airborne radon daughter radiation on a shift by shift basis. On a mine global scale the ventilation system has been designed around creating ventilation districts, which are regionalised around specific intake and exhaust rises. Each ventilation district can support between one and three actively producing stopes and a fixed number of other mining activities. This effectively creates numerous ventilation districts within the one mine, which then becomes one of the major factors taken into consideration when building the annual mine production plan, as well in the scheduling of the daily mining activities.

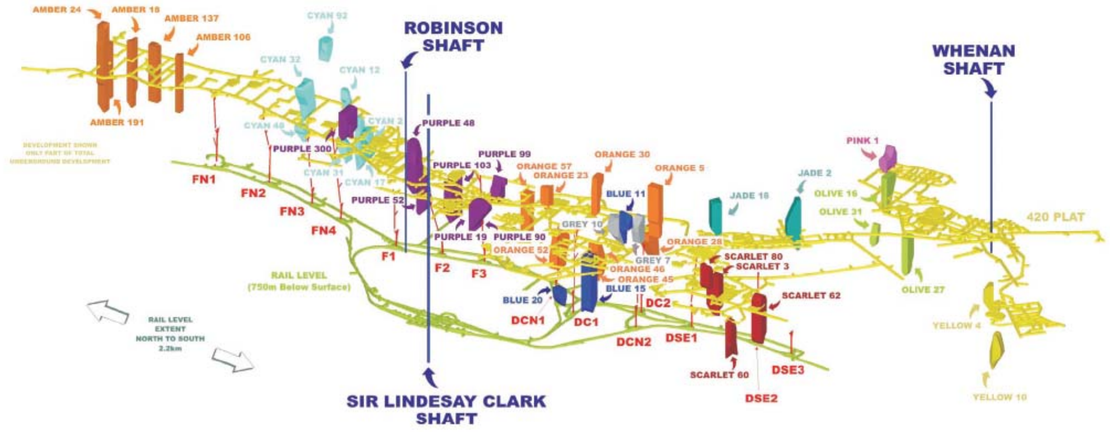


FIG 1 - Schematic of the Olympic Dam underground mine.

Sublevel long hole open stoping

To deliver a consistent feed to the process plant there can be up to 25 actively producing stopes in production over a monthly period, with both copper and uranium grades as well as the copper-sulfur ratio as the key drivers. The stopes vary from 60 to 310 m in height and can have from one through to six sublevels. Raisebores are used to create the first initial void prior to commencing a stope firing. During stope blasting the overlying strategy has been to employ vertical slicing over the height of the stope and to minimise the number of firings required for a stope.

Blasts range in size from about 500 tonnes when opening the initial undercut slot, to a maximum of 500 000 tonnes for a large multilevel ring firing. Dependent on the blasting requirements there can be from one to three stope charging crews in operation per shift.

Stope production

Ore from the stopes is mucked using either Caterpillar R2920 Supras or Elphinstone R2900 load haul dump (LHD) machines, as shown in Figure 2. The loaders either tram direct to an orepass or load into diesel trucks. Approximately 6.5 Mtpa is tipped directly into orepasses with one-way tramming distances of between 50 and 350 m.

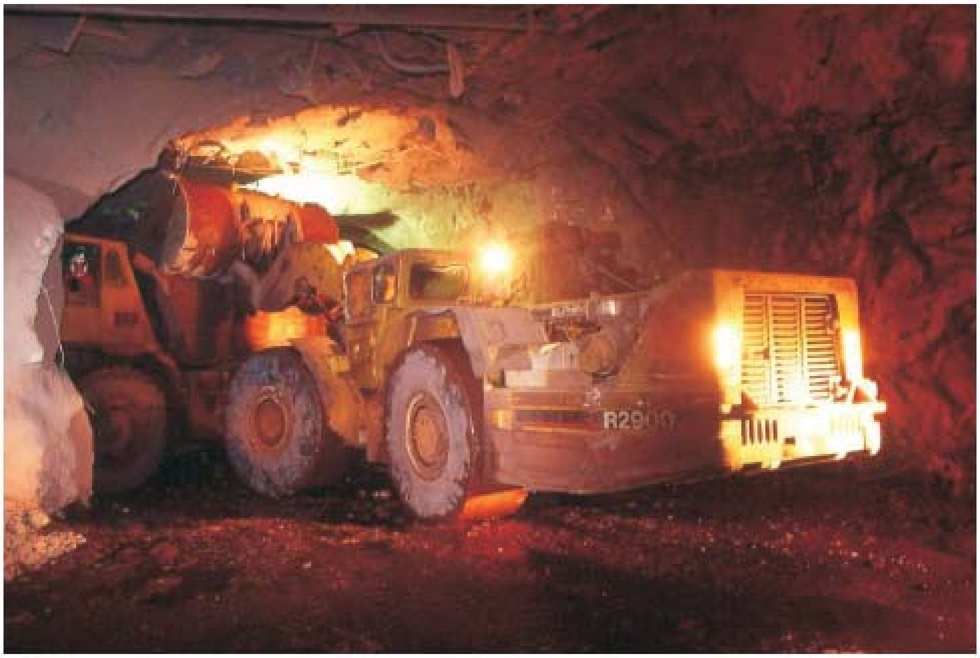


FIG 2 - An Elphinstone R2900 LHD loading a diesel truck.

A further 0.8 Mtpa is trucked to orepasses where one way trucking distances are in excess of 350 m. The remaining 1.7 Mtpa is trucked to the Whenan grizzlies, which feed the Whenan Shaft hoisting system. Both stope ore trucking and development trucking is undertaken by a mixed fleet of Caterpillar AD55s and Elphinstone AD40s.

Any secondary breakage is undertaken at either the stope drawpoints or at the orepass grizzlies by use of mobile rock breakers or popping jumbos.

Clark shaft hoisting system

There are a total of 14 orepass systems feeding an automated rail level, which comprises five rail spurs. Each orepass system consists of a 3.0 m diameter raise, with multiple grizzly tip points and either a 4.0 or 4.5 m diameter surge bin.

At the base of each orepass is a surface-controlled inline rail loading chute. The actual loading of the trains is undertaken by a surface control room operator with the aid of cameras that report the status of the chutes. Train route selection can be done manually or automatically. After a train has tipped its load, the movement of the ore to the surface is automated, based on PLC control using the Citect control system.

On the rail level two trains operate with typically one in the northern spurs and one in the southern spurs. Each train comprises 22 tonne front and rear locomotives, 15 bottom dump ore cars and will nominally deliver 320 tonnes per rake. The trains transport the ore from the orepasses back to a centralised dump station. The rail system has a maximum instantaneous rate of 1600 t/h. The dump station contains a 600 tonne ROM surge bin which feeds a 54 inch × 74 inch gyratory crusher (see Figure 3).

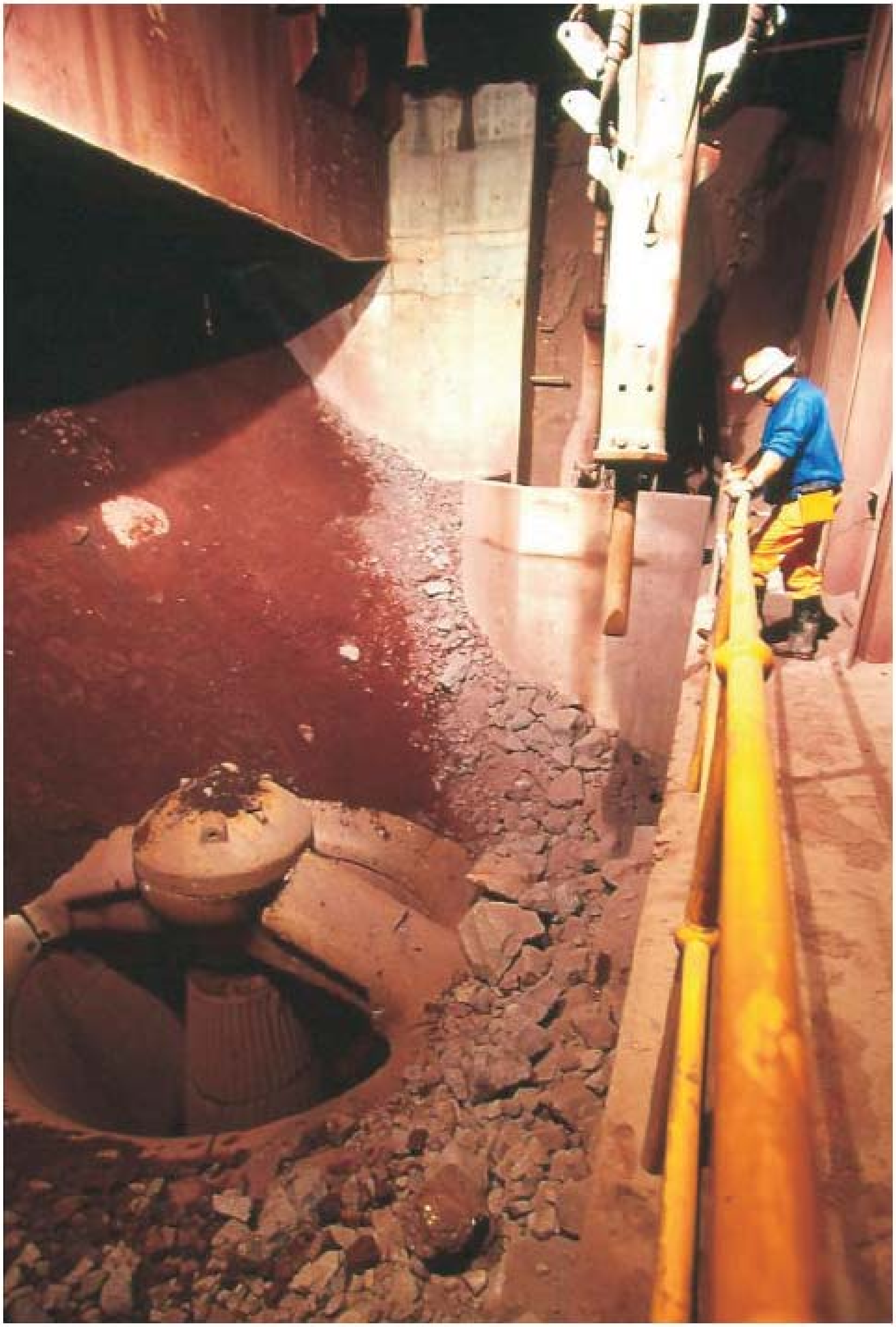


FIG 3 - Rail dump station ROM pocket and gyratory crusher.

The crushed ore is dropped into a crushed ore pocket, also of 600 tonne capacity, before being transferred horizontally by a plate feeder to one of two

3800 tonne fine ore bins at the transfer level. The loading station is at the base of the fine ore bins where the feeders direct the ore to a loading station conveyor that tips into a weigh flask, which discharges into 36.5 tonne skips before being hoisted to the surface. Clark Shaft is 7 m in diameter and was sunk to a depth of 860 m. The Koepe Winder is a 5 m diameter Siemag Winder with integrated motor, operating at 6.5 MW and is set to hoist the skips at a maximum velocity of 16.5 m/s. The Clark Shaft ore handling system is shown in Figure 4 (Clark Shaft or the Sir Lindsay Clark Shaft is also referred to as No 3 Shaft).

Once the ore is hoisted to the surface it is tipped into the headframe ore bin before being conveyed across the surface to the 1000 tonne bin and ultimately onto the surface stacker. The stacker can feed one of two stockpiles, which then feed to one of two autogenous mills. The stacker and stockpile add flexibility for underground grade control by allowing improved blending of ore on the surface, which ultimately results in more efficient utilisation of equipment and greater productivity from the underground mobile fleet.

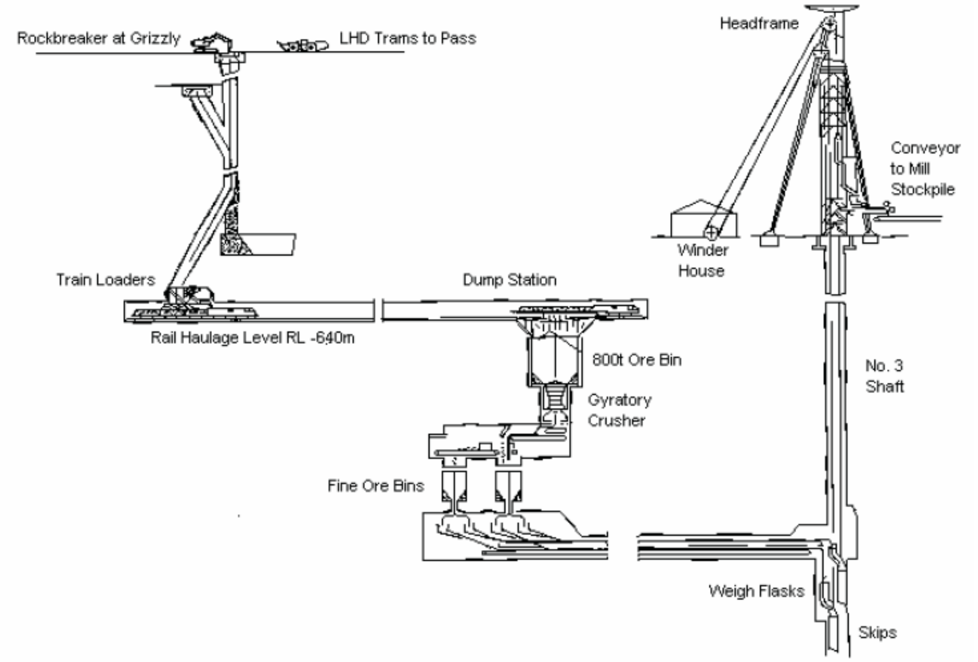


FIG 4 - Clark Shaft ore handling system.

METHODOLOGY

To maximise the value and minimise both cost and time of the study, a structured methodology consisting of project definition, data and logic collection, verification, validation, usage, analysis and reporting is utilised by Fluor Simulation. The following are some of the key steps in the approach used to efficiently carry out the study.

Objective

The objective for a simulation study is the most important step. It forms the cornerstone for any study and focuses the study team on what needs to be achieved. Hence the objective must be specific in its nature. In this case the objective was to:

> *Determine if the material handling system, for the Clark Shaft, can achieve and exceed a capacity of 10 Mtpa by using variations of the current materials handling configuration.*

Vague or ambiguous objectives only help to create confusion and can create extra work that may not add to value to the study.

Model boundaries and modules

Once the objective is defined and the operation is understood, the boundary limits can be defined. This process then allows the model to be divided into discrete areas. The model boundaries were defined as starting from the individual stope blasts and finishing at the surface ore stacker prior to the mill stockpiles.

Once the model boundaries are in place, the model can be broken into subareas or modules. A good rule of thumb is to define a module as being the area between two key storage points. For example the ‘haulage module’ represents the movement of ore from the individual orepasses to the crusher dumper station by the two trains. Table 2 identifies the individual modules and their boundaries.

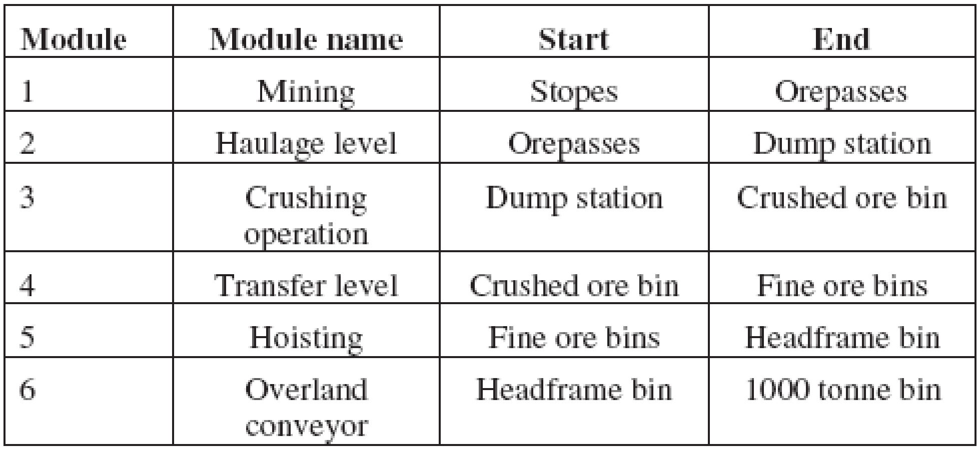
Data collection and analysis

Data collection and analysis is an important step in developing creditability of the simulation model and validating it against actual plant operations. In general, the time taken to collect the data takes far more work and effort than first imagined.

The old saying ‘rubbish in equals rubbish out’ applies and it takes time to collect, sort and prepare data to be used in any simulation model. The operation of the Clark Shaft ore handling system is managed using Citect software. An add-on feature of this software is the downtime recording module, which allows accurate downtime data to be collected and readily presented back to the operational personnel in a Pareto format. A typical Pareto is shown in Figure 5. A key to the success of the project was the allocation of a Maintenance Reliability Engineer who could assist with the collection of data and review of the final analysis.

TABLE 2

Simulation modules with boundary limits.



Module	Module name	Start	End
1	Mining	Stopes	Orepasses
2	Haulage level	Orepasses	Dump station
3	Crushing operation	Dump station	Crushed ore bin
4	Transfer level	Crushed ore bin	Fine ore bins
5	Hoisting	Fine ore bins	Headframe bin
6	Overland conveyor	Headframe bin	1000 tonne bin

Operating logic

The simulation model use rules or logic to determine how the plant will operate under specific conditions. A set of written rules is compiled for each area of the operation. A good example of this is the operating rules for the underground trains. During the 1997 study a set of operating rules were developed by the design team. To verify whether these rules still applied, the Maintenance Reliability Engineer was asked to review and update them with the relevant changes. A final verification of the rules was carried out by video recording the actual Citect screen of the haulage level operation for a 24-hour period using a movie software package. The movie file generated was played back at high speed and allowed the train operating rules to be checked against the actual operation. Figure 6 shows a Citect screen dump of the Haulage Level.

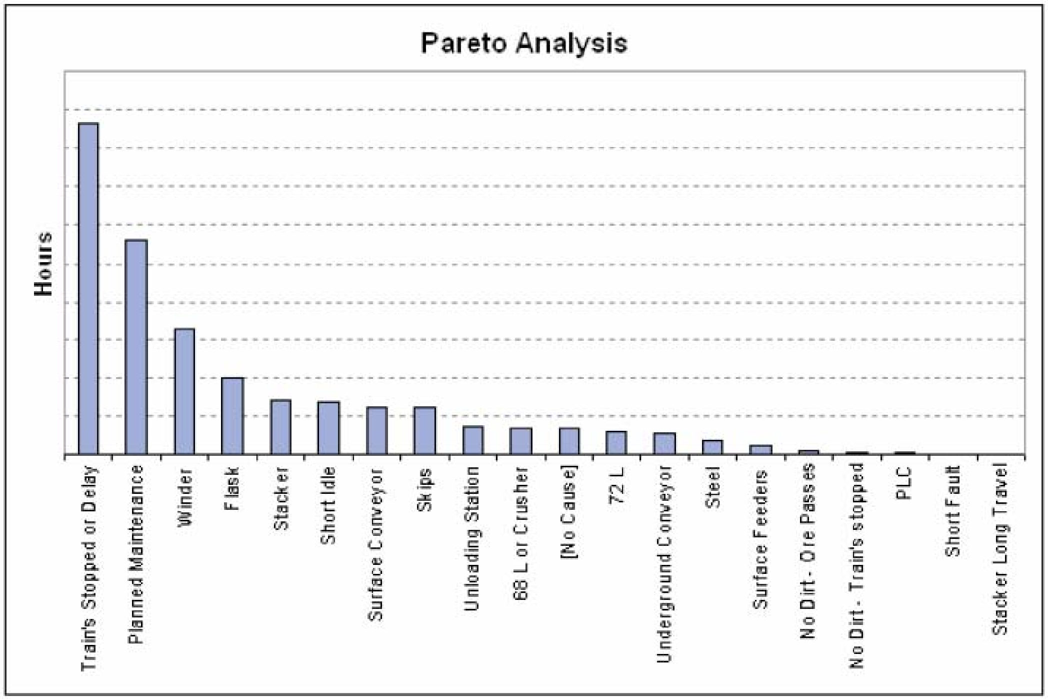


FIG 5 - Typical Pareto analysis chart from Citect.

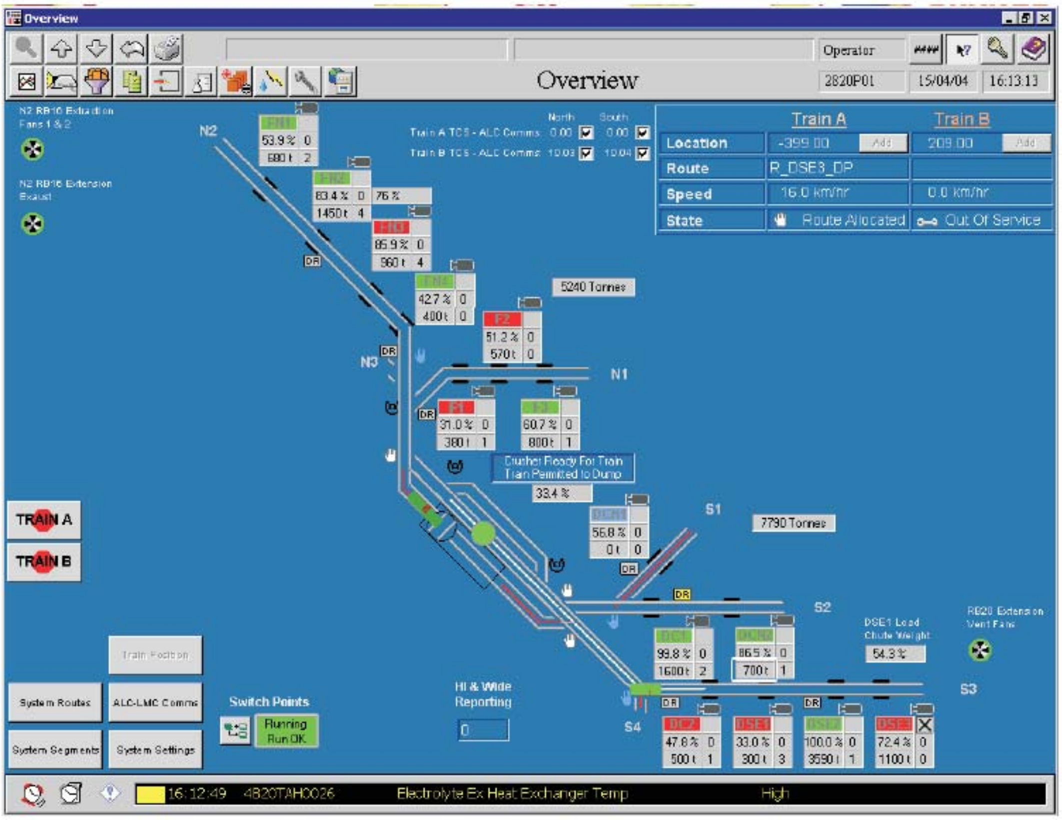


FIG 6 - Overview of the Citect screen for the haulage level.

This information along with data from the data collection and analysis phase is compiled into a single document known as the Simulation Model Design Criteria.

Verification

Verification is concerned with building the model correctly. The process compares the conceptual model, ie the Simulation Model Design Criteria to the computer representation of the model, ie the Arena model. The process asks the questions: Has the model been built correctly in the computer? Are the input parameters and structure of the model correctly represented? The verification procedure involved reviewing the Arena model against the Simulation Model Design Criteria document.

Validation

Validation is concerned with building the right model and it is utilised to determine that a model is an accurate representation of he real system. Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behaviour and using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is judged to be acceptable, at which point ‘the base case’ is established. Figure 7 shows the validation diagram of Module 6 Overland Conveyor.

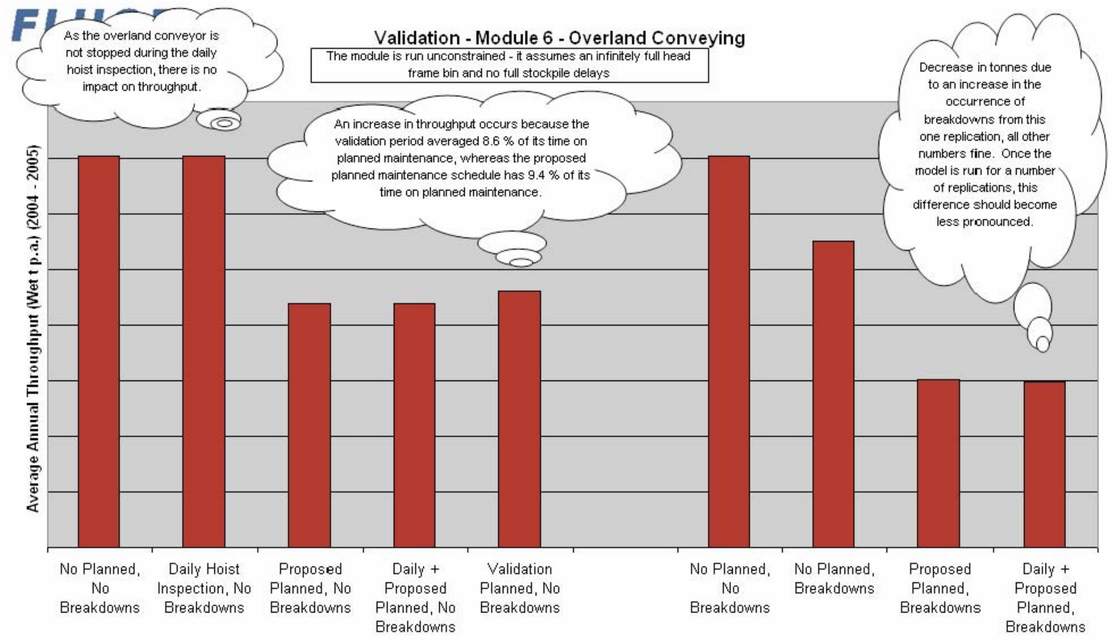


FIG 7 - Validation diagram for the Overland conveyor.

Usage and analysis

During the initial scoping of the study a series of case runs commonly known as ‘what if’ scenarios were developed to be tested by the model. Just prior to running the simulation model a meeting was held to review the original ‘what if’ scenarios, the model objectives and importantly, to review the insights gained during the data analysis and validation phases. A number of important findings were discovered in the lead up to running the model. This information allowed the team to critically analyse and revise what specific scenarios needed to be run. This approach saves time and effort by targeting the cases that are most likely to answer the key objectives.

Once the usage phase begins, the model results were fed back and discussed in meetings with OD on a regular basis. The frequency of the meeting varied between daily and twice weekly depending on the type of usage and analysis. Regular discussion of the output results during the usage phase was an important step in gaining understanding of the model, the model results and the impact that these results were likely to have on the actual operation.

Reporting

Several techniques have been used to take the raw text from each simulation run and turn it into meaningful results that can be interpreted by anybody. The trick is to present the results in a graphical format or as a schematic view of the operation where possible. Examples of this approach have been used later in the paper in Figures 9 to 12.

FINDINGS

Apart from the technical or engineering findings produced as part of the project, there were several wide-reaching findings, which hold true for the majority of simulation projects that Fluor Simulation gets involved with.

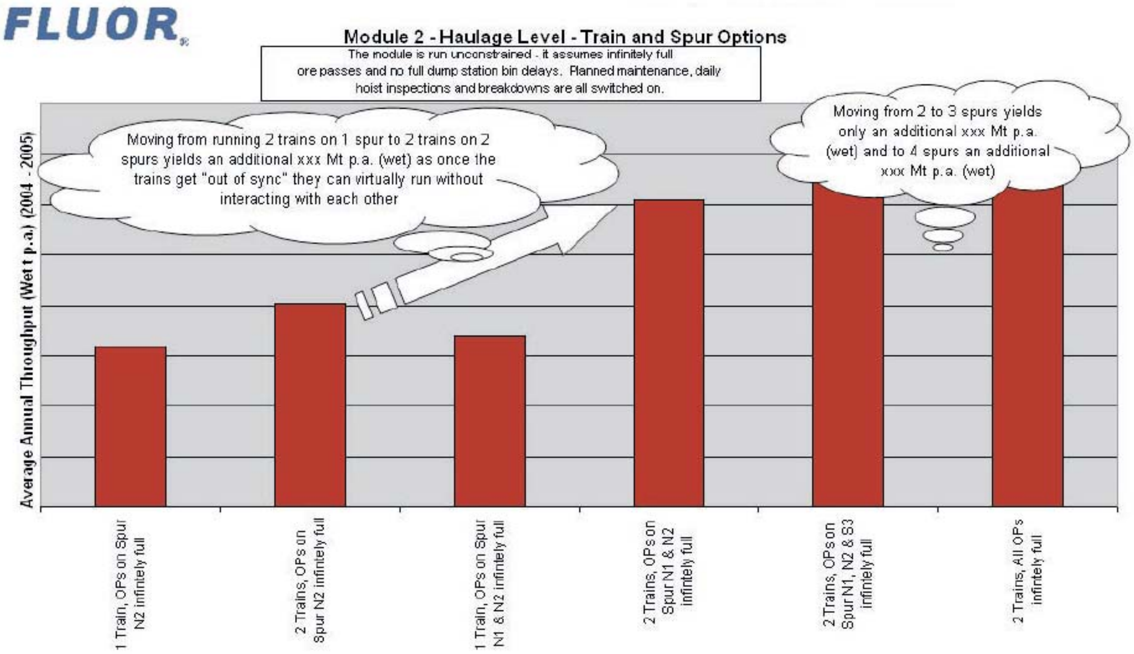
Quantification of improvements – not gut feel

The simulation modelling confirmed what was already known from years of operating this complex underground mine, but now this knowledge was supported with real numbers – independently run and open to scrutiny from all.

Part of the modelling process is a statistical analysis of the model outputs to provide a measure of the accuracy of the outputs and their possible spread. To determine how many replications are required of each case run, ie how random the materials handling system is, 50 replications of the Base Case runs were conducted and analysis of means and standard deviations completed. Based on these findings, the results for all of the case runs were plotted using 'whisker' plots (see Appendix). Whisker plots are helpful in interpreting the distribution of data and in these results the whiskers represent the possible range of values covered by ± x standard deviations from the mean.

Myth busters

An often talked about strength of simulation modelling is its ability to 'bust' or dispel myths about where bottlenecks or problems lie. These myths can often develop over time from one-off events, a simple misrepresented story, or out of inappropriate data analysis. In this instance it was widely believed throughout the operation that the underground rail haulage system was a major bottleneck to the movement of ore to the surface. As part of this process, each module of the simulation model is run unconstrained at its boundaries. By doing this we are able to determine the unconstrained capacity of an individual module. This was done for the underground rail system starting with running just one train on one spur, two trains on the same spur, one train on two spurs and so on, as shown in Figure 8.



Module 2 - Haulage - Train and Spur Options.xls

FIG 8 - Modelling output to test haulage level capacity.

By doing this the project team was able to demonstrate that the underground rail system had excess capacity, even running restricted to two spurs out of a possible five, ie rail is not the bottleneck – no matter which way it is operated. Given that all of the relevant data and logic had been signed off by the people who looked after the rail system, a commonly believed myth had been busted.

Whilst this might seem to be a minor benefit to the project and operation, the most significant benefit is that scarce capital and resources have not been wasted now or in the foreseeable future on investigating or upgrading this part of the operation's infrastructure. This allows personnel and available capital to be spent where it is most needed and where it will deliver the biggest return on investment.

Gaining insight

The technique provided OD with a means of testing their operation 'off-line'. Using the model in this manner is a powerful way of gaining insight on how the operation behaves and provides a means of quantifying the potential gains of individual improvements. The following are just some of the items tested using this approach:

- Where is the bottleneck in the material handling system?
- Why do some shifts perform better than others?
- Is there a need to increase rail car capacity? Is there a need to evenly balance he tonnes between the North and South rail spurs?

Graphical results – different ways of looking at things Data is a key part of simulation modelling as both an input and an output of the modelling. Considering just the output side of the equation, the simulation model was set up to write out a myriad of measures and statistics throughput from the simulation model runs. Fluor Simulation has developed some sophisticated post-processing tools, which facilitate rapid analysis of the outputs of these model runs. These tools culminate in summary sheets, which look in detail at the statistics written out for various areas of the operation, with the results summarised in a similar format so as to enable rapid comparison of the case runs. These sheets report the key performance indicators (KPIs) used in site meetings and reports, thus helping an individual gain an understanding of the results. The KPIs enable rapid analysis of individual areas as well as summarising the overall performance of the operation. At a glance the project team and key personnel can see if the proposed configuration delivers the required mine production plan.

Another method used to present results are the graphs shown in Figures 9 and 10. These show a summary of several case run plotted against one of the KPIs, annual tonnes hoisted. Figure 9 looks at the summary KPI and enables quick conclusions to be drawn as to the results for each scenario.

Figure 10 looks in more detail at the various states of the haulage system. The percentage of operating time for more than 20 different activities was recorded, and by using a plot like this, the impact of changes on the various activities can be quickly determined.

What if analysis

One of the reasons OD was attracted to simulation modeling was its ability to facilitate a rapid evaluation or ‘what if’ process. Once the model was built and validated, a series of scenarios or materials handling configurations were developed and run.

In one set of case runs, the following items were *varied in combination*:

- Transfer level plate feeder rate: 1200, 1400, 1600, 1800, 2000 tph
- Skip payload: 36.5 and 40 tonnes
- Hoist cycle time: 188 and 182 seconds
- Overland conveying rate: 1600, 1680, 1760, 1840 tph
- Number of ore cars per train (two trains): 15 and 18 ore cars

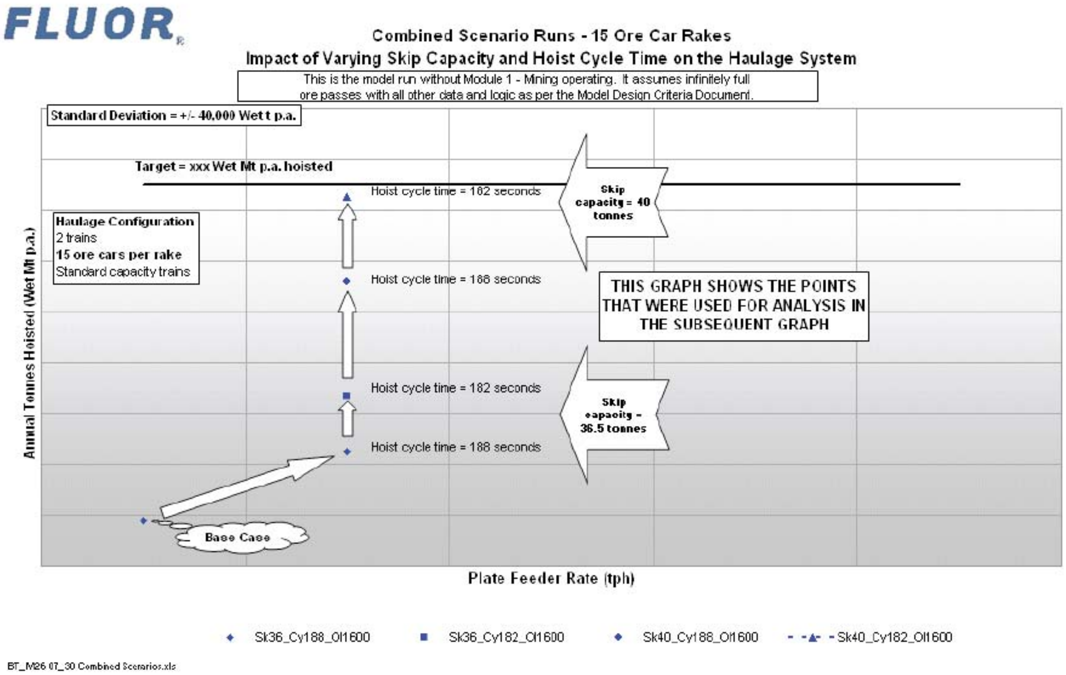


FIG 9 - Impact of varying skip capacity and hoist cycle time on the haulage system.

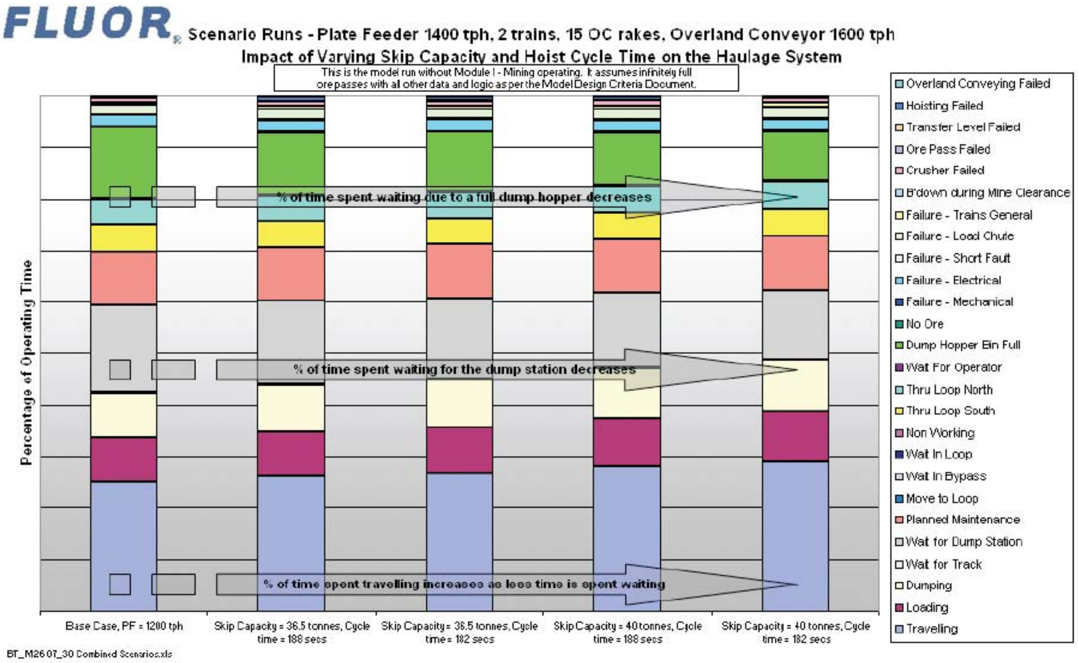


FIG 10 - Output plot showing per cent operating time of activities.

Combining these possible parameters yielded a total of *128 different materials handling configurations* that could be tested and compared back to the Base Case. These cases were split into two logical groups; one for trains running 15 ore cars and one for trains running 18 ore cars, and the results summarised at a high level into two graphs, the first of which is shown in Figure 11.

The chart is read in the following way:

- the X axis shows increasing plate feeder rates;
- the four sets of coloured lines represent the different overland conveyor rates:
    - blue = 1600 tph = Base Case,
    - purple = 1680 tph,
    - green = 1760 tph,
    - red = 1840 tph,

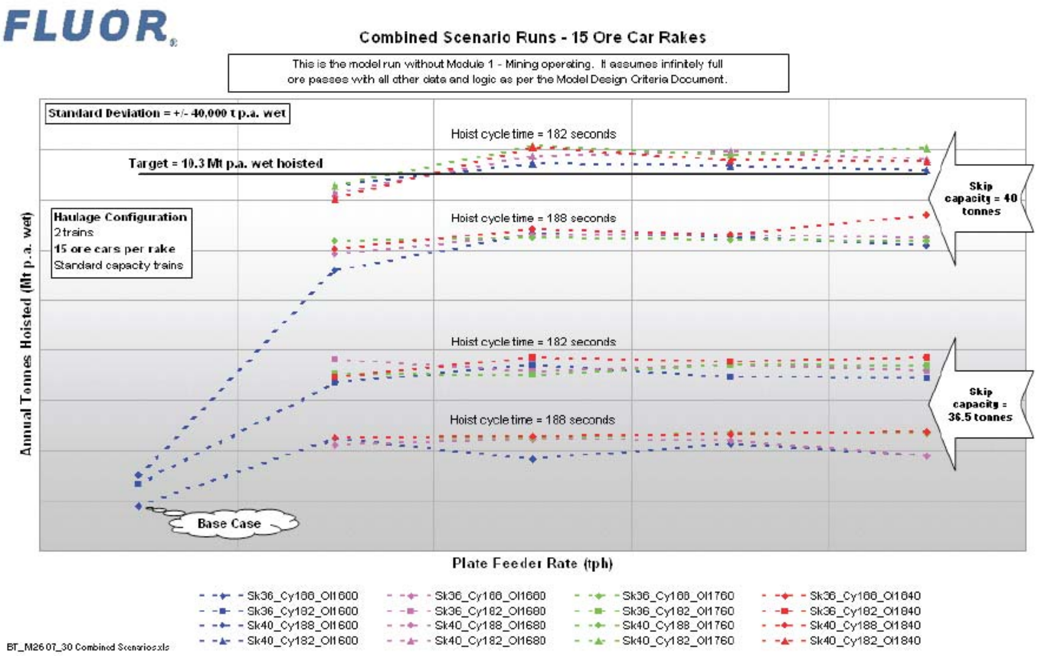
- the four different symbols represent combinations of skip
- capacity and cycle time:
    - diamonds = 36.5 tonne skip capacity and 188 second cycle time,
    - squares = 36.5 tonne skip capacity and 182 second cycle time,
    - circles = 40 tonne skip capacity and 188 second cycle time,
    - triangles = 40 tonne skip capacity and 182 second cycle time,
- the Module 2 to 6 Base Case is marked on the chart by theblue diamond on the LHS;
- the Base Case run with a 182 second cycle time is marked on the chart by the blue square on the LHS; and
- the Base Case run with a 40 tonne skip capacity is marked on the chart by the blue circle on the LHS.

The chart clearly highlights the impact of increasing the plate feeder rate from 1200 tph to 1400 tph and it also highlights that increasing the plate feeder rate to more than 1400 tph without making any changes to the hoisting system is of no advantage (the bottom set of lines with diamond symbols represents increasing the plate feeder rate and the overland conveyor rate but making no changes to the hoisting system).

These results also clearly demonstrate that the materials handling system could satisfy the study objective of seeing if ‘the
Clark Shaft can achieve and exceed a capacity of 10 Mtpa by using variations of the current materials handling configuration’. Another way of representing the output data is shown in Figure 12.

Combining the analysis from the two graphs, it can be determined that the following configuration would satisfy the study objective:

- Trains: two trains: 15 ore cars per rake, standard capacity trains (unchanged from the Base Case)
- Plate feeder rate: 1450 tph
- Skip capacity: 40 tonnes
- Skip cycle time: 182 seconds
- Overland conveyor rate: 1600 tph (unchanged from the base case)



BT_M26 07_30 Combined Scenarios.xls

FIG 11 - Combined scenario runs – 15 ore car rakes.

Expansion path

Combining the ‘what if’ analysis with engineering rigour and the understanding of the operation, a staged de-bottlenecking path that most appropriately meets the business and operational needs can be determined. The sequence and timing of expansion or modification can be determined without guessing or disrupting the operation. Another benefit of this staged or phased approach is that if circumstances change along the way due to market or other factors, the expansion or modification path can be reassessed, the model re-run and a new, more appropriate de-bottleneck path explored and agreed upon.

CONCLUSIONS

This project between OD and Fluor Simulation was a successful one. The team worked together to test complex changes to the operation before they were considered for further review and implementation. A carefully constructed and tested simulation model provides a sound base upon which informed business decisions can be made, whilst providing some key learning's for all involved. For example, the behaviour of the model with varying inputs can help build a solid understanding of how the asset will behave once built. It can also help identify the major points of leverage that the designers have available to them to positively impact the actual behaviour of the plant in the real world.

Time involved – do not underestimate

There can be difficulty in getting data. The strength of ODs Citect system meant that real-time and historical data for the ore handling from rail to surface could be extracted relatively easily and then manipulated to suit. This had two benefits; the first being speed of data extraction and accuracy and the second being the integrity of data, which did not need to be questioned given its source and the rigour behind the establishment of this system.

This data was then analysed into formats suitable for use by the simulation model, questions asked and opinions sought, before it was made available for use. As part of asking questions and checking the integrity, quite often the data is presented back to the client in a new and useful format, which brings insight or understanding to issues potentially clouded in the volume of data. Again this highlights that the entire project was a learning experience and that it's not just the usage portion of the project which delivers value to a client

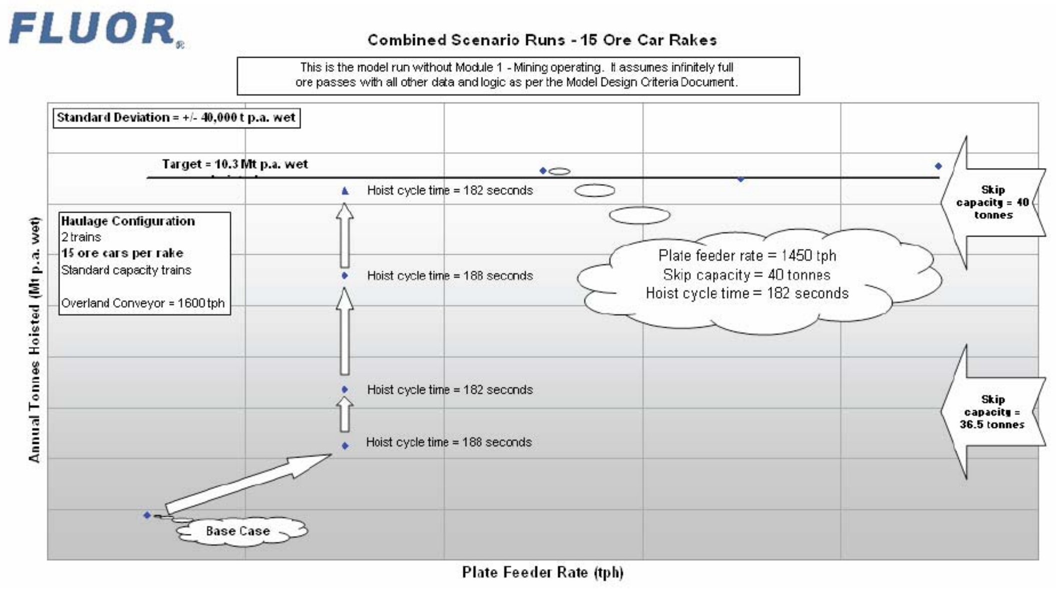


FIG 12 - Combined scenario runs – 15 ore car rakes.

Management tool

Simulation modelling is a powerful tool available to management. The rigour of the process and its consultative nature resulted in the sharing of a significant amount of insight and understanding of the process being modelled. When data is collected and manipulated, it is often reviewed and discussed with the entire team and the insights are shared by the site team.By doing this not only is understanding shared, but the whole team is moved through the modelling process, aware of what is going on and able to direct and influence the direction that the modelling process is taking.

Another powerful communication tool is animation. In this instance it was not only used to communicate the results, but also as a validation tool with the site team. The animation of the underground railway was based on the OD schematic drawing, so the arrangement and nomenclature used was immediately familiar to the site team. Within a matter of minutes, changes in the way the rail system was operated from 1997 to present day were highlighted, noted and summarised for review.

Remove the emotion from the decision process

The other part of the model building is the data gathering and in this instance the data came directly out of ODs real-time monitoring and management system. As this system had just been specified and installed as part of an extensive consultative process throughout the organisation, there was no need to question the system and its operation. The other strength in this exercise was that the data was used day-to-day by various levels throughout the organisation.

ENDNOTE

Fluor Simulation is an alliance between Fluor and TSG Consulting, which has been in existence since 1999 in Australia. TSG Consulting provides all of Fluor’s simulation services and has provided modelling expertise to successful companies both within Australia and around the world.

REFERENCES

Webb, D, 1998. Olympic Dam operations review, in *Proceedings Seventh AusIMM Underground Operators' Conference*, pp 87-94 (The Australasian Institute of Mining and Metallurgy: Melbourne).

APPENDIX

The graphs that were produced are a variation on a true whisker plot. Whisker plots are more correctly called box and whisker plots or box plots. A box and whisker plot is a way of summarising a set of data measured on an interval scale. It is often used in explanatory data analysis. This type of graph is used to show the shape of the distribution, its central value and its variability. In a box and whisker plot (see Figure 13):

- the ends of the box are the upper and lower quartiles, so the box spans the interquartile range;
- the median is marked by a vertical line inside the box; and
- the whiskers are the two lines outside the box that extend to the highest and lowest observations.

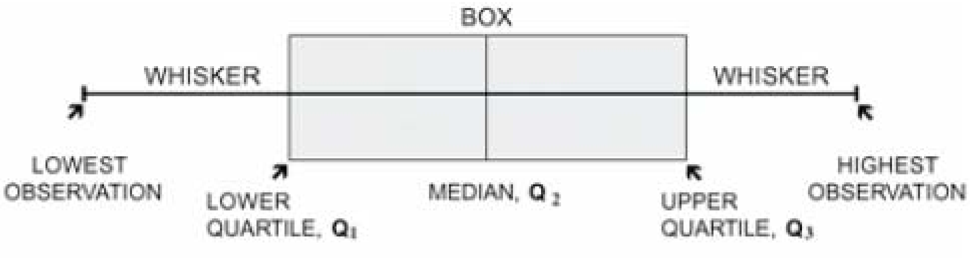


FIG 13 - Box and whisker plot.