Enterprise Digital Twins for Mining

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Simulation Science Solution Suite

Using Predictive Simulation to Enhance Decision Making

1. Plan Validation
   Use a bottom up approach to validate your high-level business targets

2. Optimisation
   Optimise your business processes through rapid scenario analysis

3. Diagnostics
   Diagnose problems from strategic targets down to the asset level

Solutions powered by

MineSim
MineSim is a predictive simulation software used to create a Digital Twin of open pit and underground mines. From validating production plans to optimising operations, MineSim delivers accurate results to drive improvement across the entire value chain.

WITNESS Horizon
A flexible, powerful, proven process simulation technology, Lanner's desktop modelling studio, WITNESS Horizon, enables rapid development of feature rich digital twins and simulation applications.
Why is it so difficult to develop a realistic, achievable plan?

Actual performance of mining operations often does not meet planned performance.

“61% of production targets are missed due to unplanned downtimes and operational delays.”

Based on BSC 1st principles research

TOP REASONS

1. Starting with an Unrealistic Plan
   - Not understanding knock-on effects & unintended consequences
   - Planning based on inadequate averages and incorrect performance assumptions

2. Unanticipated Delays
   - Operational delays
   - Misaligned maintenance regimes

3. Variability in System Performance
   - Differing performance of individual assets, operators, seasonality, etc.
   - Activity interdependencies lead to consequential losses

Production targets are not consistently achieved and Improvement initiatives do not yield full benefit
What is a digital twin? And how it can it help?

A virtual model of an operation, combining the physical and digital worlds providing an accurate way to identify problems before they occur, prevent lost production time, develop and test improvement opportunities, and plan for the future.

It tells you exactly what your operation needs to improve performance

**Enterprise Level**
Calculate higher level performance KPIs directly from underlying operational processes, ensuring accurate and meaningful results.

**Operational Processes**
Model product/material flow, operational processes and activities within the value chain revealing the interplay between activities, clearly indicating bottlenecks and determining system capacity.

**Individual Activities**
Visualise the details of each activity exposing periods of lost time and how much time each asset spends in a certain area or state

**Individual Assets**
Model the detail of each asset using its physical properties (size, speed, etc.) and its performance characteristics (e.g. utilization, efficiency, etc.) using actual industry benchmarks or site-specific historic data to create statistical distributions for key inputs

“By 2021, 50% of large industrial companies will be using digital twin technologies.

Those using digital twins today are enjoying a 10% improvement in business effectiveness.

Gartner (2017)
But why not use a normal equation-based model?

Digital Twins utilising Dynamic Discrete Event Simulation (DES) have significant advantages over equation-based modelling.

**Pros:**
- **Dynamic**, derives all system constraints and responds to change over time
- **Non-linear**, captures reality and not theoretical truths
- **Precise**, account for variation ad uncertainty
- **Dynamic**, derives all system constraints and responding to change over time
- **Non-linear**, captures reality and not theoretical truths
- **Precise**, account for variation and uncertainty

**Cons:**
- **Complex**, it reflects the intricacies of your operations
- **New technology**, not well understood
- **Precise**, account for variation and uncertainty
- **Non-linear**, captures reality and not theoretical truths
- **Precise**, account for variation and uncertainty

**Equation-Based Modelling (Spreadsheets)**

**Pros:**
- **Quick**, a fast way to get a broad answer
- **Easy**, most people have the skills for basic Excel modelling
- **Comfortable**, most people are familiar with the technology

**Cons:**
- **Static**, unable to respond to system changes
- **Need for key assumptions**
- **Quickly becomes unmanageable**

**Example:**
- Equation-based modelling predicts average production output of 100 tons per day
- A predictive simulation includes variation from the average and reveals an actual output of 86.95 tons per day (predictions overstated by 15%)*

*BSC Digital Twin

*Based on BSC Load and Haul simulation project
Introducing BSC Simulation Science

Simulate the Future to Make the Right Decisions Today

- **Improve Planning Accuracy**: Factor in the interdependencies between activities across the value chain providing higher fidelity and robust production plans with no unintended consequences.

- **Understand the Impact of Unplanned Events**: Quantify and manage the impact of unplanned events across the value chain.

- **Optimise Plans**: Evaluate material extraction sequences, fleet configurations and allocations, and dispatch strategies to maximize throughput efficiency.

- **Include Real-World Mining Operational Factors**: Per pass loading, material campaigning, dispatch strategies.

- **Rapid Configuration**: Prebuilt IP and analyses makes setting up model a quick process.

- **Powerful Insights**: VDTs, bottleneck analysis.
Primary Use Cases for a Digital Twin in Mining

**Plan Validation**

Use a bottom-up approach to forecast production targets

**Illustrative Outputs:**
- Distributions for daily, weekly, monthly, or annual production, LoM production profiles

**Illustrative Inputs:**
- Production schedule / plan
- Planned cycle time component distributions (e.g. fill factors, loading times, hauling speeds) to account for variability
- Planned operating hour component distributions (e.g. maintenance schedules, mean time between failure, mean time to repair) to account for variability

**Optimisation**

Optimise the operation through scenario analyses

**Illustrative Outputs:**
- Distributions for production, LoM production profiles
- Objective function to optimize

**Illustrative Inputs:**
- Cycle time component distributions
- Operating hour component distributions

**Diagnostics**

Diagnose problems from strategic targets down to asset level

**Illustrative Outputs:**
- Resource plan for optimal configuration
- Operator-Level KPIs

**Illustrative Inputs:**
- Actual production / outputs
- Planned production / outputs

**Illustrative Outputs:**
- Attribution analysis of operator-level KPIs on overall production / costs / revenue

**Illustrative Inputs:**
- Actual cycle time, operating hour component distributions
- Planned cycle time, operating hour component distributions
High Fidelity Visualisation

**Digital Replica of the Operation**

The simulation is displayed as a 3D render of the operation for easy understanding of underlying dynamics of the activities.

**Activity Ribbon**

View the activities of, and interdependencies between equipment and personnel over time. Events of interest are highlighted for further investigation.

**Recreate Complex Mining Sequences**

3D visualisation shows the sequencing of the simulated mining sequence, exposing any inefficiencies in the mine plan.

**Derive Key Operational KPIs**

Supplying the simulation with operator-level inputs allows key operational KPIs, such as queuing time and utilisation to be derived, rather than treated as an input assumption.
Simulate Variability

Using ranges, instead of single-point values, for inputs allows the impact of variability across the value chain to be determined. It also provides a range of outputs so that KPIs can be measured at different confidence levels.

Advanced Analytics

Analyse the performance of the value chain in the simulation, from basic system production and throughput analyses, to advanced process control analytics.
Powerful Analyses Empower Decision Making

Rapidly Generate Scenarios

Vary fleet sizes and allocations, alter equipment throughput and downtime parameters, change the physical layout of the operation easily to test multiple ‘What-If’ scenarios.

Value Driver Tree

Use Value Driver Trees (VDTs) to aggregate and relate the thousands of events from the simulation into an intuitive, visual analysis framework. VDTs can be built to link operational metrics through to financial outcomes.

Identify Bottleneck Activity

A key strength of simulation is that equipment/resource utilisation is derived, not assumed. By analysing the utilisation of each equipment/process over time, the bottleneck of the value chain can be objectively identified.

Activity Schedule

Visualise the key activities per mining block or mining face, open pit or underground for a multitude of mining methods.
Engagement Model

Our digital twin solutions are not built to simply inform a one-off series of decisions, but to provide clients with a valuable digital asset, that is a measurable source of strategic advantage.

1. Scoping
   - Understand the questions to be answered.
   - What data is available?
   - Introduction to Simulation Orientation Session
   - Outcome: Simulation Scope of Work

2. Model Configuration
   - Simulation model is built and
   - Includes data integration mechanisms, user interface and reporting
   - Testing to ensure representative and accurate model behaviour.

3. Insights & Analyses
   - Use the model to provide the insights and analyses required.
   - Run required ‘What-If’ scenarios.

4. Training & Handover
   - Handover through a series of well-structured training sessions, and associated training material.
   - User Acceptance Testing – run through validated base case and scenarios to ensure results expected and accepted by business.

5. Business Support & Enhancements
   - Operationalize the tool within the organization.
   - Address minor changes, enhancements or resourcing support during major planning cycles.

1 Week

2 - 6 Weeks

1 – 3 Weeks

1 Week

Ongoing / Ad-hoc
BSC’s Digital Twins have Helped Several Blue Chip Organisations Improve Performance and Achieve Prosperity

**BHP**
- Determined cycle times for USD 100M improvements

**AngloAmerican**
- 20% cost reduction

**De Beers Group**
- Determined exact fleet size, 18 months before start-up

**Gold Fields**
- 80% planning confidence

**Rail Network Queue Model**
Simulating for the impact of queuing on the cycle times of their trains across the rail network

**Haul Fleet Optimization**
Simulating, and improving, truck cycle times for an open pit coal mine resulting in 20% reduced hauling costs

**Plan Validation**
Simulation of the loading and hauling operation of a Greenfields diamond mine. Exact fleet size for optimal operations determined 18 months in advance.

**Mining Capability Simulation**
Simulating 12 years of production to re-base one of the world’s largest underground gold mines

Some of our customers:

"The simulation work that BSC has done for us has been pivotal in helping us establish a robust and confident basis for South Deep’s rebase plan."
– Nick Holland, CEO Gold Fields

"The project exposed a lot of unknowns to us especially with respect to how best the facility can be optimized."
– Manager, Anglo American Rapid Loading Terminal

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Plan Validation: Underground Diamond Mine

Challenge
• An underground diamond mine needed a 14% production increase
• An established EPCM built a model and confirmed this would be possible with existing facilities
• What was the probability of success?

Solution
• BSC simulated the entire value chain from material extraction through to processing
• Simulation revealed only a 50% probability of achieving target production increase and a 400 ton production buffer would be needed

Value
Prevented the client from investing at least USD 100 million in a plan with low probability of success.
Optimisation: Open Pit Coal Mine

Challenge
• A colliery was seeking cost reduction opportunities to increase value.
• One of the largest costs within the operation, hauling, was targeted for cost saving opportunities.
• Key question to be answered:
  • Under what conditions could the colliery park one of their five trucks whilst maintaining current production levels?

Solution
• BSC constructed a Discrete Event Simulation of the loading and hauling activities at the colliery.
• Two haul routes were investigated, with the number of active haul trucks, truck speeds, and truck fill factors varied for each simulation run.
• Truck speed was determined to have the greatest impact on overall throughput of the mining value chain

Value
With an increase in average haul speed of just 5 km/hr, it would be possible for the mine to haul the material required using one fewer truck

This led to a 20% cost saving for the hauling activity.
Diagnostics: Quantifying the Impact of Congestion on Truck Performance

**Challenge**

- An Australian underground copper mine was experiencing a reduction in truck performance (TKM per hour) on days when they had more trucks operating.
- Mine personnel suspected that traffic congestion within the declines (the ramps the provide access from the surface to the underground workings) was responsible for this reduction in truck efficiency.
- The mine wanted to know if congestion was causing the reduction in truck performance, and if so, how much of an impact it was having?
- How could the interactions between trucks and other vehicles in the declines be modelled?

**Solution**

- In less than 3 weeks, BSC developed a Digital Twin Predictive Simulation of the trucking operations at the mine, including modelling the traffic and congestion from other equipment travelling up and down the two declines.
- Operational variability, often a key factor in underperformance, was factored into the analysis by providing the simulation with ranges for the various truck KPIs (such as loading and dumping times, hauling speeds, breakdowns, etc.).
- The simulation found that truck performance was 8 times more sensitive to the availability of ore than it was to congestion, and that an increase in truck idle time (due to a lack of ore to haul) was leading to the reduction in TKM per Hour on days when more trucks were operating.

**Value**

The insights from the simulation provided the operation with a basis on which they could reduce their trucking costs by 31%, while still hauling the tonnages required to surface.
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