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Head of Mining
WorleyParsonsTWP
Contents

• Underground Mining Trends
• Mine Life-cycle
• Key Success Factors for Mine Planning and Design
• Mine Planning Process and Tools
• Examples of Outputs
• Expected developments in Underground Mining
• Conclusion
Underground Mining Trends

- Low commodity prices/tight margins
- Fewer projects meeting hurdle rates
- Access to funding/risk aversion
- Deeper underground deposits
- Higher opex costs
- Safety and regulation
- But demand for commodities will be lasting
- Increased underground focus
  - Mature pits
  - Environmental pressures
Mine Life-cycle

- **Resource Definition**: Target Identification, Exploration, Resource Estimate
- **Project Evaluation Phase**: Concept/Scoping, Pre-feasibility, Feasibility
- **Mine Construction Phase**: Detailed design, Project Execution
- **Mine Production Phase**: Build-up, Steady state
- **Mine Closure**: Production decline, Rehab and closure
Value Curve

- **Exploration**: Value = Cost
- **Development (Dev)**: Value = NPV
- **Construction**: Value = Market
- **Production**: Value = Capitalization
- **Closure**: 

![Diagram showing value curve with stages and key metrics.](image-url)
<table>
<thead>
<tr>
<th>Phase</th>
<th>Objective</th>
<th>Key Focus Areas</th>
<th>Costs</th>
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<tr>
<td>CONCEPT/PEA</td>
<td>• To identify major options for opportunity realisation</td>
<td>• Is this the right opportunity for the client?</td>
<td>Capital Cost</td>
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<td>• Confirm alignment with the business case</td>
<td>• Is the opportunity consistent with the client’s overall business strategy?</td>
<td>+ / -25%</td>
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<td>• Assess the potential value of the opportunity</td>
<td>• Does the potential value from the opportunity justify further investigation?</td>
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<td>• Define the work required to assess the opportunity</td>
<td>• The thoroughness of evaluation of alternative technology, costing and implementation approaches.</td>
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<td>• Establish a plan for the Pre-Feasibility phase</td>
<td>• Integrity of Pre-feasibility planning.</td>
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<td>• Have areas of opportunity and risk been investigated in later stages to enhance value?</td>
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<td>Phase</td>
<td>Objective</td>
<td>Key Focus Areas</td>
<td>Costs</td>
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| PRE-FEASIBILITY | • The best project size, scope, technical and production solution has been selected and is a viable business concept aligned to business strategy.  
• Demonstration that all the discarded project options have been studied and are clearly inferior and have no probability of re-emerging as viable options.  
• A workable plan for taking the concept through the Feasibility development stage. | • Have all of the options been adequately considered and reviewed on an equal basis?  
• What criteria were used to select the preferred option?  
• Have all opportunities for optimisation been reasonable pursued?  
• Are the risks and possible mitigators well understood?  
• Does the potential value from the opportunity still justify further investigation?  
• Integrity of Feasibility planning. | Capital Cost  
+ 25% to –15% |
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<th>Phase</th>
<th>Objective</th>
<th>Key Focus Areas</th>
<th>Costs</th>
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| FEASIBILITY | • Develop a Proven Business proposition at the appropriate level of detail and accuracy for implementation funding. | • Is there a thorough understanding of the value and risks associated with the opportunity prior to moving into Implementation?  
• Is there an acceptable risk profile?  
• Is there a workable plan for taking the Project through the implementation & Operational readiness stages?  
• Is the opportunity recommended for approval? | Capital Cost + 15% to – 5% |
Typical Project Organogram
Key Success Factors for Mine Planning and Design

- Quality/quantity of inputs
- Understanding of value chain and link between inputs and outputs
- Experience and skill
  - Mining operations and projects
  - Planning tools
- Team integration
- Consistency and applicability of design criteria
- Benchmarking/callibration
Mine Planning and Design Inputs

- Geology
  - Block Model
  - Geometric and structure model
  - Stratigraphic model

- Geotechnical
  - Rock Mass ratings
  - Empirical design “rules-of-thumb”

- Ventilation
  - Empirical design “rules-of-thumb”
  - Regulatory design criteria
  - Mining equipment specifications

- Mining Engineering
  - Mining method
  - Development and stoping rates
  - Preferred equipment specs
  - Targeted production schedule and volumes

- Infrastructure
  - Preferred access methodology
  - Requirements for services/transport
  - Capacities and constraints

- Strategic Goals
  - Life-of-mine
  - Payback Period
  - Financial goals
Mining Method Selection

Common Methods
• Block Cave
• Sub-level cave
• Open-stoping
• Sub-level open-stoping
• Cut and fill
• Drift and fill
• Shrinkage
• Bord-and-pillar
• Step bord-and-pillar
• Narrow flat tabular

Design Considerations
• Ore body geometry
• Rock Mass properties
• Required production volumes
• Opex/Capex cost
• Safety/Productivity
• Skills available
• Equipment available
• Grade control
Access Methodologies

• Declines
  – Drill and blast
  – TBM
• Ramps
• Shafts
  – Blind-sink
  – Raise-bored
  – Bored
• Combinations

• Criteria:
  – Depth/Geometry
  – Timing
  – Bottom Access
  – Production Volume
  – Cost and capital availability
Project Construction Time

- Development time in months
- Depth in metres

- Drill and Blast
- TBM
- Conventional Shaft
- Bored Shaft
Advantages of TBM Access Development

Seems obvious
Quicker
One pass
Safer
Continuous and reliable
But slow to catch on in mining
Hard rock applications and non-isotropic/non-homogenous material
High rock stress and fracturing
Geometry and size of equipment
Lack of hands-on experience
Seen as expensive and elegant
Mine Planning Software Tools

• Gemcom – Surpac/Mineshed/Minex
• CAE – 5D Planner / Enhanced Production Scheduler (EPS)
• MINERP – CADSmine / No scheduler (Reporting done in spreadsheets)
• MINERP – MINE2-4D / Enhanced Production Scheduler (EPS)
DESIGN CRITERIA OVERVIEW

- 29.486 Moz
- LoM – 43 years (2052)
- Building up to 330 Kt/m
- To produce up to 800,000 ounces/ year (25 tonnes)
Project Footprint
Production Profile

![Production Profile Graph]

- BP12 Level 1
- Phase 2
- Phase 3
### Mine Design Criteria

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<th>Criteria</th>
<th>Remarks</th>
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<td>Stoping Design</td>
<td>Sequential Grid Mining Method</td>
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<tr>
<td>Mining Levels</td>
<td>113,116,120</td>
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<td>ORD development rate</td>
<td>45m/month</td>
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<td>Reef development rate</td>
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<td>Mining Crews per raise line (between levels)</td>
<td>5 maximum</td>
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<td>Ledging Face Advance</td>
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<td>Stope Face Advance</td>
<td>7.2 m/month (average)</td>
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<td>Ledging crews (between levels)</td>
<td>Dependant on available raise lines – with not more than 3 crews per raise line</td>
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<td>Stope Width</td>
<td>120 cm</td>
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<td>Panel Length</td>
<td>25 m to 35 m</td>
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<td>MCF (as per BP2013)</td>
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<td>Plant recovery factor</td>
<td>97.4%</td>
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Project Carbon Leader reef monthly m²

- Average – 4500 m²/month

Project Carbon Leader produced monthly kilogram

- Average – 120kg/month

Project Carbon Leader reef monthly tonnes milled

- Average – 23000 tonnes/month

Project Carbon Leader monthly total metre

- Average – 253m/month
Thickness and Grade Distribution

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Isometric View of Design Options

Longitudinal Sub Level Open Stoping

Longitudinal Retreat
Animation output

Different colours represent different months schedule.

Existing infrastructure

Existing mining
## Production Report

Production Report fed from outputs of Enhanced Production Scheduler

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<td>Total Tonnage 2 Product</td>
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<td>Sludge (Not incl. in production)</td>
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<td>2,173,130</td>
<td></td>
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### Organized by Technology MINC<br>DEMINC<br>INSTITUTE OF MINES<br>TECNOLOGIA<br>INSTITUTO MINERAL"
Vertical shaft access
Longitudinal Sub Level Stoping / Bench and Fill Stoping
Expected Developments in Underground Mining

• Increased mechanization and automation
• Tunnel and shaft boring
• Environmental/safety pressures
• Margin pressures
• Better quality design and planning
• More standardization in design and planning
Conclusion

- Mine design and planning has become more critical in projects and operations in recent years.
- Quality of tools have improved with better computer graphics and processing speeds.
- Projects now require full designs and plans using software tools for auditability.
- These designs and plans are only as good as the inputs provided and the skills of the engineers and planners. Actual hands-on mining experience is critical in applying the tools correctly.