Operations Research in Open-Pit Mining

Komarudin bin Sayuti
Overview

Operations Research = Advanced Analytical Methods

Better Decisions

Maximize Profit
Minimize Delay
Maximize Productivity
Minimize Distance
Selected applications

Operations Research

Applications

Shortest path (Google Map)
Airline ticket price
Ship/Airline Scheduling
Steward/ess Scheduling
Layout seat plan
Fuel Distribution
Maintenance Scheduling
Mining overview

1. Prospecting
   - Visual inspection & physical measurements of the earth’s properties
   - to discover mineral deposits

2. Exploration
   - Drilling holes to estimate the mineral concentration and its variability.
   - to determine the value of the deposit

3. Development
   - Determining the mining method
   - Estimating production capacity and infrastructure capital;
   - performing detailed engineering design

4. Exploitation
   - Ore is removed from the ground via surface and (or) underground mining methods.
   - It is transported to the surface in trucks or in shafts.
   - it may be stockpiled or sent directly to a processing plant

5. Reclamation
   - Restoring the area in which mining occurred to its natural state
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Operations Research
Mining overview

Operations
Research

Surface/Open-Pit Mining

Underground mining
OR in Open-Pit Mining
The determination of the **Ultimate Pit Limit** (UPL)
Maximization of the total profit whilst satisfying the operational requirement of safe wall slopes.
Balancing the ore-to-waste (stripping) ratio (SR) with the cumulative value in the pit boundaries.
• **Block Sequencing Problem.**
  • Discounting to more accurately reflect the value of a block as a function of its extraction date (NPV maximization).
  • Higher cutoff grades in the initial years of the project lead to higher overall NPVs
  • Subject to slope and geometric constraint

Figure 2: Sequencing rules can be based, for example, on the removal of five blocks above a given block (left) or on the removal of nine blocks above a given block (right).
Block Sequencing Problem

\[
\begin{align*}
\text{max} & \quad \sum_{b \in B} \sum_{t \in T} v_{bt} y_{bt} \\
\text{subject to} & \quad \sum_{t \in T} y_{bt} \leq 1 \quad \forall b, \\
& \quad C \leq \sum_{b \in B} c_b y_{bt} \leq \bar{C} \quad \forall t, \\
& \quad y_{bt} \leq \sum_{\tau=1}^{t} y_{b'\tau} \quad \forall b, b' \in B_b, t, \\
& \quad y_{bt} \in \{0, 1\} \quad \forall b, t.
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\]

- Nilai finansial block b thd waktu
- Kapan block b di-extract
  - Memaksimumkan NPV
  - Block b hanya di-extract pada satu periode waktu
  - Kapasitas extraction terbatas
  - Precedence constraints

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Strategic

Tactical

Operation

Surface/Open-Pit Mining

Pit Design Problem

Block sequencing

Production Planning

- **Mine Capacity Problem.**
- Determines the type and the size of equipment
- Minimize investment cost while maximizing extraction financial value (NPV)
- Subject to mine characteristics and equipment capabilities
Surface/Open-Pit Mining

- **Pit Design Problem**
- **Block sequencing**
- **Production Scheduling**
- **Equipment Scheduling**

**Dump Truck-Loader Dispatching Problem**
- Maximize productivity, minimize delay
- Determining the truck assignment in real time
- Subject to capacity constraint

**Strategic**

**Tactical**

**Operation**
Surface/Open-Pit Mining

- Pit Design Problem
- Block sequencing
- Production Scheduling
- Equipment Scheduling

- Refueling and Daily Check Scheduling Problem
- Maximize productivity, minimize delay
- Determining the policy of refueling and truck assignment and daily check
- Subject to capacity pit stop capacity

Strategic  
Tactical  
Operation
• Water truck scheduling
• Minimize penalty of visibility distraction
• Subject to water truck capacity and nozzle velocity
Surface/Open-Pit Mining

- **Pit Design Problem**
- **Block sequencing**
- **Production Scheduling**
- **Equipment Scheduling**
- **Crew Scheduling**

- **Personnel Rostering/Scheduling**
- Minimize personal cost
- Subject to coverage requirement and personal constraint

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Legend:
- **S**=Service
- **F**=Free Day
- **U**=Unavailability
- **O**=On Call
- **P**=Pay Off Time Account
- **H**=Holiday
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