MINING LEARNING SERIES

Mining Machines & Production Calculations

A practical guide to equipment, productivity, fleet matching and worked examples

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LEARNING OUTCOMES

After studying this note, you should be able to identify major surface and underground mining machines, calculate cycle time and productivity, estimate fleet size, distinguish availability from utilisation, calculate drilling, loading, hauling and conveying outputs, and check whether a production plan is realistic.

How to Use This Study Note

Every worked example follows the same method: list the known values, choose a formula, keep units consistent, substitute values, calculate, round sensibly and interpret the answer. The examples are simplified for learning; real mine planning uses measured data, manufacturer information, safety limits and site-specific engineering models.

The calculation method

Step	Action
1. Define	State exactly what must be calculated.
2. List data	Write every value with its unit.
3. Convert	Use consistent units such as minutes, hours, tonnes and metres.
4. Calculate	Substitute values into the correct formula.
5. Check	Test magnitude, units, constraints and assumptions.
6. Interpret	Explain what the answer means for the production system.

Useful conversions

Conversion	Relationship
Time	1 hour = 60 minutes = 3 600 seconds
Mass	1 tonne = 1 000 kg
Volume	1 m^3 = 1 000 litres
Speed	km/h = distance in km / time in h
Rate	t/h = tonnes / operating hours
Percentage	decimal factor = percentage / 100

SAFETY FIRST

A production target never overrides payload, speed, slope, braking, ground-control, guarding, ventilation or other safety limits. Only trained and authorised personnel may operate mining machines.

1. Mining Machine Systems

Mining machines operate as a connected system. A drill prepares holes; blasting or cutting breaks rock; loading equipment fills trucks or conveyors; haulage moves material; crushers reduce size; and processing equipment receives the feed. The slowest or least reliable stage can limit the entire system.

Function	Surface examples	Underground examples
Drill / cut	Rotary blast-hole drill, down-the-hole drill, surface miner	Jumbo face drill, long-hole production drill, continuous miner
Load	Hydraulic excavator, rope shovel, wheel loader	LHD / Scooptram, slusher, gathering arm
Haul	Rigid mining truck, articulated truck, conveyor	Underground truck, LHD, rail, conveyor
Support	Dozer, grader, water bowser, service truck	Scaler, bolter, utility vehicle, shotcrete machine
Break / size	Blast, dozer ripping, mobile crusher	Blast, breaker, feeder-breaker, underground crusher

Capacity versus production

Term	Meaning
Rated capacity	Manufacturer or design capacity under stated conditions.
Payload	Mass carried during one cycle.
Theoretical production	Output assuming continuous ideal operation.
Effective production	Expected output after time losses and operating factors.
Actual production	Measured output achieved during the period.



Loading and hauling must be matched as one production system. | Source: Toromont Cat

2. Drilling Machines and Calculations

Drilling machines create blast holes or openings for excavation and support. Performance depends on rock strength, bit type, hole diameter, depth, penetration rate, rod handling, positioning, flushing, maintenance and operator practices.

Core formulas

Quantity	Formula
Penetration rate	Penetration rate (m/min) = metres drilled / drilling minutes
Drilling time	Drilling time (min) = hole depth (m) / penetration rate (m/min)
Total drilled metres	Total metres = number of holes × average hole depth
Effective drilling rate	Effective rate (m/h) = drilled metres / total operating hours
Drill output per shift	Shift metres = effective rate × effective drilling hours

Worked example: metres per shift

Known: 24 holes; average depth = 10 m; penetration rate = 0.60 m/min; non-drilling time = 4 min per hole; shift = 8 h; planned delay = 60 min.

Step	Calculation
1. Total metres	24 × 10 = 240 m
2. Drilling time per hole	10 / 0.60 = 16.67 min
3. Cycle time per hole	16.67 + 4 = 20.67 min
4. Available time	(8 × 60) - 60 = 420 min
5. Possible holes	420 / 20.67 = 20.32, therefore 20 complete holes
6. Expected metres	20 × 10 = 200 m per shift

INTERPRETATION

The planned 24 holes cannot be completed under these assumptions. The plan needs more drilling time, another rig, shorter delays or safely improved cycle performance.

3. Blasting and Fragmentation Calculations

Blasting calculations connect rock volume, mass and explosive quantity. They are planning indicators only. Blast design and charging must be performed by competent, authorised persons under mine procedures and law.

Core formulas

Quantity	Formula
Rock volume	Volume (m^3) = burden × spacing × hole depth × number of holes
Rock mass	Mass (t) = volume (m^3) × rock density (t/m^3)
Powder factor by mass	Powder factor (kg/t) = explosive mass (kg) / rock mass (t)
Powder factor by volume	Powder factor (kg/m^3) = explosive mass (kg) / rock volume (m^3)
Specific drilling	Specific drilling (m/t) = drilled metres / tonnes broken

Worked example

Known: burden = 3 m; spacing = 3.5 m; hole depth = 10 m; 20 holes; density = 2.6 t/m^3; explosives = 1 260 kg.

Step	Calculation
1. Volume per hole	3 × 3.5 × 10 = 105 m^3
2. Total volume	105 × 20 = 2 100 m^3
3. Rock mass	2 100 × 2.6 = 5 460 t
4. Powder factor	1 260 / 5 460 = 0.231 kg/t
5. Specific drilling	(20 × 10) / 5 460 = 0.0366 m/t

Why fragmentation matters

- Oversize can slow loading, hauling and crushing.
- Excess fines may create dust, handling or processing problems.
- Poor floor conditions can reduce loader and truck productivity.
- Blast movement and dilution can affect ore control.



Accurate drilling affects fragmentation, safety and downstream productivity. | Source: Austmine / Epiroc

4. Loading Machines and Productivity

Loaders include excavators, rope shovels, wheel loaders and underground LHDs. Production depends on bucket capacity, fill factor, material density, cycle time, machine availability, operating efficiency and the match with the receiving truck or crusher.

Core formulas

Quantity	Formula
Actual bucket volume	Actual volume = rated bucket volume × fill factor
Bucket payload	Payload (t) = actual bucket volume (m^3) × loose density (t/m^3)
Cycles per hour	Cycles/h = 60 / cycle time in minutes
Theoretical loader output	Output (t/h) = bucket payload × cycles/h
Effective loader output	Effective output = theoretical output × efficiency factor

Worked example: loader output

Known: bucket = 12 m^3; fill factor = 0.90; loose density = 1.8 t/m^3; cycle time = 0.75 min; operating efficiency = 80%.

Step	Calculation
1. Actual bucket volume	12 × 0.90 = 10.8 m^3
2. Bucket payload	10.8 × 1.8 = 19.44 t
3. Cycles per hour	60 / 0.75 = 80 cycles/h
4. Theoretical output	19.44 × 80 = 1 555.2 t/h
5. Effective output	1 555.2 × 0.80 = 1 244.16 t/h

CHECK MACHINE LIMITS

Calculated bucket payload must be checked against rated payload, stability, material characteristics and equipment limits. A volume-based answer can overload a machine when material density is high.

5. Haul Trucks and Cycle-Time Calculations

A truck cycle normally includes queue, spotting, loading, loaded travel, dumping, empty travel and delays. Travel time should reflect distance, grade, road condition, speed limits and equipment performance.

Core formulas

Quantity	Formula
Travel time	Time (min) = distance (km) / speed (km/h) × 60
Truck cycle time	Cycle = queue + spot + load + loaded travel + dump + empty travel + delays
Cycles per hour	Cycles/h = 60 / cycle time (min)
Truck output	Truck output (t/h) = payload × cycles/h × efficiency
Shift output	Shift tonnes = truck output × scheduled shift hours

Worked example: one truck

Known: one-way distance = 4 km; loaded speed = 24 km/h; empty speed = 32 km/h; load = 4.5 min; dump and spot = 2.0 min; queue/delay = 3.0 min; payload = 90 t; efficiency = 85%.

Step	Calculation
1. Loaded travel	4 / 24 × 60 = 10.0 min
2. Empty travel	4 / 32 × 60 = 7.5 min
3. Cycle time	4.5 + 10.0 + 2.0 + 7.5 + 3.0 = 27.0 min
4. Cycles per hour	60 / 27.0 = 2.222 cycles/h
5. Effective truck output	90 × 2.222 × 0.85 = 170.0 t/h
6. Eight-hour output	170.0 × 8 = 1 360 t/shift

DO NOT USE AVERAGE SPEED BLINDLY

Loaded and empty speeds differ. Real travel models also consider rolling resistance, grade resistance, acceleration, braking, intersections, speed limits and road condition.

6. Loader-Truck Matching and Fleet Size

Pass matching

Quantity	Formula
Number of passes	Passes = truck payload / loader bucket payload
Truck loading time	Loading time = passes × loader cycle time
Match factor	Match factor = number of trucks × loading time / truck cycle time
Required trucks	Trucks ≈ truck cycle time / loading time
Fleet output limit	System output is limited by the loader, trucks or downstream receiver.

Worked example

Known: truck payload = 90 t; bucket payload = 18 t; loader cycle = 0.80 min; total truck cycle = 28 min.

Step	Calculation
1. Passes per truck	90 / 18 = 5 passes
2. Loading time	5 × 0.80 = 4.0 min
3. Ideal truck count	28 / 4.0 = 7 trucks
4. Match factor with 6 trucks	6 × 4.0 / 28 = 0.857
5. Match factor with 7 trucks	7 × 4.0 / 28 = 1.000
6. Match factor with 8 trucks	8 × 4.0 / 28 = 1.143

Interpretation

- Match factor below 1: the loader may wait for trucks.
- Match factor near 1: idealised balance, though variability still causes queues or idle time.
- Match factor above 1: trucks may queue at the loader.
- The economic optimum is not always exactly 1 because standby, variability, cost and production risk matter.

INTEGER AND PAYLOAD CHECKS

Passes must be a practical whole number and should not exceed truck or loader limits. A 4.6-pass calculation normally requires checking whether four passes underload or five passes overload the truck.

7. Availability, Utilisation and Efficiency

Time definitions must be stated before calculating performance. Mines may use different reporting conventions, so compare metrics only when the numerator and denominator are defined consistently.

Metric	Formula	Example meaning
Physical availability	Available time / scheduled time × 100%	Was the machine mechanically available?
Utilisation of available time	Operating time / available time × 100%	How much available time was used?
Operating efficiency	Productive time / operating time × 100%	How much operating time produced useful work?
Overall time effectiveness	Productive time / scheduled time × 100%	How much scheduled time became productive time?
Mean time between failures	Operating time / number of failures	Average operating interval between failures.
Mean time to repair	Total repair time / number of repairs	Average repair duration.

Worked example

Scheduled time = 600 h; breakdown time = 90 h; operating time = 420 h; productive time = 350 h; 6 failures.

Metric	Calculation	Answer
Available time	600 - 90	510 h
Availability	510 / 600 × 100	85.0%
Utilisation	420 / 510 × 100	82.35%
Operating efficiency	350 / 420 × 100	83.33%
Overall effectiveness	350 / 600 × 100	58.33%
MTBF	420 / 6	70 h/failure
MTTR	90 / 6	15 h/repair

AVOID DOUBLE COUNTING

If delay categories overlap, the calculated available, operating or productive time will be wrong. Use one approved time model and make every hour belong to the correct category.

8. Crushing, Conveying and Plant Feed

Crushers and conveyors often form the continuous part of a production system. Their capacity must match variable mine feed, surge storage, particle size, density and downstream plant requirements.

Core formulas

Quantity	Formula
Crusher utilisation	Operating hours / available hours × 100%
Crusher throughput	Throughput (t/h) = tonnes crushed / operating hours
Conveyor mass flow	Mass flow (t/h) = volume flow (m^3/h) × bulk density (t/m^3)
Belt volume flow	Volume flow (m^3/h) = cross-sectional load area (m^2) × belt speed (m/s) × 3 600
Stockpile change	Closing tonnes = opening + inflow - outflow

Worked example: conveyor

Known: material cross-sectional area on belt = 0.18 m^2; belt speed = 2.5 m/s; bulk density = 1.6 t/m^3; loading factor = 85%.

Step	Calculation
1. Ideal volume flow	0.18 × 2.5 × 3 600 = 1 620 m^3/h
2. Effective volume flow	1 620 × 0.85 = 1 377 m^3/h
3. Mass flow	1 377 × 1.6 = 2 203.2 t/h
4. Four-hour tonnage	2 203.2 × 4 = 8 812.8 t

Bottleneck check

SYSTEM CAPACITY

If the crusher can process only 1 800 t/h, the conveyor's calculated 2 203.2 t/h cannot be sustained without surge capacity or control. The system is limited by the crusher, not by the belt calculation.

9. Underground Production Cycles

A conventional drill-and-blast development or stoping cycle may include drilling, charging, blasting, clearance, ventilation, examination, scaling, support, loading and hauling. Activities can be sequential, partly overlapping or distributed across shifts.

Activity	Typical production measure
Face drilling	Holes/round, drilled metres, penetration rate and drilling time.
Charging and blasting	Round volume, tonnes, powder factor and compliance with blast plan.
Ventilation and re-entry	Clearance time and verified safe atmospheric conditions.
Mucking / loading	Tonnes moved, bucket cycles, LHD cycle time and drawpoint performance.
Ground support	Bolts installed, metres supported, cycle time and quality compliance.
Development advance	Metres advanced per round, shift, day or month.

Worked example: monthly advance

Known: planned advance = 3.6 m per round; 2 rounds/day; 26 operating days/month; cycle achievement = 85%.

Step	Calculation
1. Theoretical daily advance	3.6 × 2 = 7.2 m/day
2. Effective daily advance	7.2 × 0.85 = 6.12 m/day
3. Monthly advance	6.12 × 26 = 159.12 m/month

Worked example: underground LHD

Payload = 12 t; cycle time = 8 min; operating efficiency = 75%. Cycles/h = 60 / 8 = 7.5. Output = 12 × 7.5 × 0.75 = 67.5 t/h.



Underground loader output depends on payload, travel route, cycle time, drawpoint condition and delays. | Source: ProActivo / Epiroc

10. Cost, Fuel and Energy Calculations

Quantity	Formula
Unit operating cost	Cost per tonne = total operating cost / tonnes produced
Fuel rate	Fuel consumption (L/h) = litres used / operating hours
Fuel per tonne	L/t = litres used / tonnes moved
Energy per tonne	kWh/t = electrical energy used / tonnes produced
Maintenance cost per hour	Maintenance cost / operating hours
Cost variance	Actual cost - budget cost
Production variance	Actual tonnes - planned tonnes

Worked example

A fleet moves 48 000 t in one week. Fuel used = 72 000 L. Fuel price = R23.50/L. Other operating cost = R1 260 000.

Step	Calculation
1. Fuel per tonne	72 000 / 48 000 = 1.50 L/t
2. Fuel cost	72 000 × R23.50 = R1 692 000
3. Total operating cost	R1 692 000 + R1 260 000 = R2 952 000
4. Cost per tonne	R2 952 000 / 48 000 = R61.50/t

Production is not the only objective

- Overloading may increase short-term tonnes but damage equipment and increase risk.
- Excess speed can raise tyre, fuel, road and braking costs.
- Idle time wastes fuel and adds operating hours without production.
- Preventive maintenance can reduce production today to protect future availability.
- Energy, water, emissions and component life belong in optimisation decisions.

USE THE CORRECT CURRENCY BASIS

State whether costs include fuel, labour, tyres, maintenance, ownership, depreciation, contractors, overheads and processing. Cost-per-tonne values are meaningless without a defined boundary.

11. Integrated Production Example

A mine plans to move 9 000 t in a 10-hour shift. Trucks carry 100 t. Average truck cycle time is 30 min. Truck operating efficiency is 80%. The loader can deliver an effective 1 100 t/h. Determine truck output, fleet size and system capacity.

Step	Calculation	Result
1. Cycles per truck-hour	60 / 30	2 cycles/h
2. Effective truck output	100 × 2 × 0.80	160 t/h per truck
3. Required average system rate	9 000 / 10	900 t/h
4. Minimum trucks by rate	900 / 160	5.625 → 6 trucks
5. Six-truck capacity	6 × 160	960 t/h
6. Loader capacity check	Loader = 1 100 t/h; trucks = 960 t/h	Trucks limit the system
7. Expected shift output	960 × 10	9 600 t/shift

Sensitivity check

Changed condition	New result
Cycle increases to 34 min	Truck output = 100 × (60/34) × 0.80 = 141.18 t/h
Six trucks at 34 min	Fleet output = 6 × 141.18 = 847.06 t/h
Shift output	847.06 × 10 = 8 470.6 t, below the 9 000 t target
Trucks needed at 34 min	900 / 141.18 = 6.375 → 7 trucks

Planning conclusion

BUILD RESILIENCE

Six trucks meet the target only under the original assumptions. A four-minute cycle increase causes a shortfall. The planner should test realistic variability, standby strategy, loader performance, road delays, maintenance and downstream capacity before committing to the target.

12. Key Terms and Revision

Quick glossary

Term	Meaning
Availability	Share of scheduled time when equipment is mechanically available.
Bottleneck	Stage that limits total system output.
Cycle time	Time required to complete one full operating cycle.
Fill factor	Actual bucket fill divided by rated struck or heaped volume on the stated basis.
Match factor	Indicator comparing truck service demand with loader service capacity.
Payload	Mass carried by a truck, loader bucket or other unit.
Productivity	Useful output per unit of time or input.
Rolling resistance	Resistance caused mainly by tyre-road interaction and road condition.
Utilisation	Share of available time during which equipment operates.
Unit cost	Cost divided by a defined production quantity, such as rand per tonne.

Revision questions

- 1. Explain rated, theoretical, effective and actual production.
- 2. Calculate drilling time for a 12 m hole at 0.8 m/min.
- 3. Calculate tonnes from 1 500 m^3 at 2.7 t/m^3.
- 4. A 10 m^3 bucket has 85% fill and density 1.9 t/m^3. Find payload.
- 5. Calculate truck cycle time using separate loaded and empty speeds.
- 6. Explain match factors below, equal to and above 1.
- 7. Calculate availability from scheduled and breakdown hours.
- 8. Calculate conveyor mass flow from area, speed and density.
- 9. Calculate cost per tonne and fuel litres per tonne.
- 10. Design a one-shift production plan and identify its bottleneck.

CALCULATION DISCIPLINE

Always show the formula, substitution, unit and final interpretation. A number without units or assumptions is not a complete engineering answer.

13. References

Sources were checked on 17 August 2026. Equipment specifications change by model and configuration; always use the current manufacturer manual and approved mine data.

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Image credit - Toromont Cat. Surface loading and hauling photograph used in Section 1. https://www.toromontcat.com/fr/exploitation-miniere

Image credit - Austmine / Epiroc. Underground production drill photograph used in Section 2. https://austmine.imiscloud.com/

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Learn Today, Achieve Tomorrow. Use these examples to build calculation skill, then replace assumptions with verified site data, equipment limits and approved engineering procedures.