Minimizing Quarrying Costs by Correct Shotrock Fragmentation and In-pit Crushing

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Jarmo Eloranta

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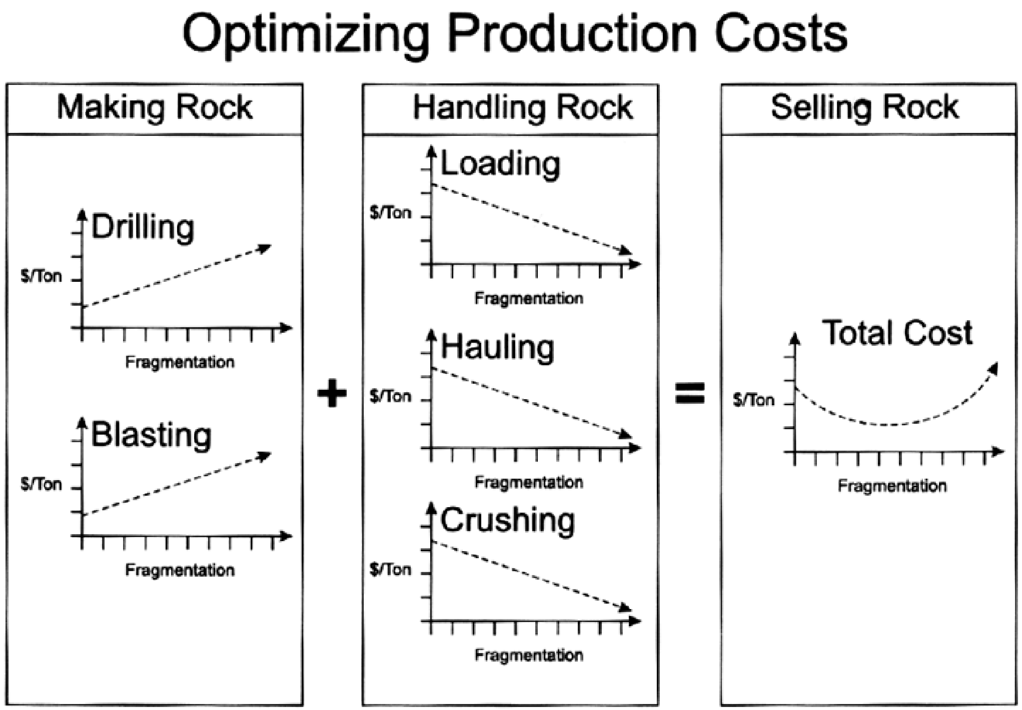
- Quarry process in general
- Comparison of different shotrock fragmentations
- Comparison of different crushing methods
- Conclusions
- Enclosures

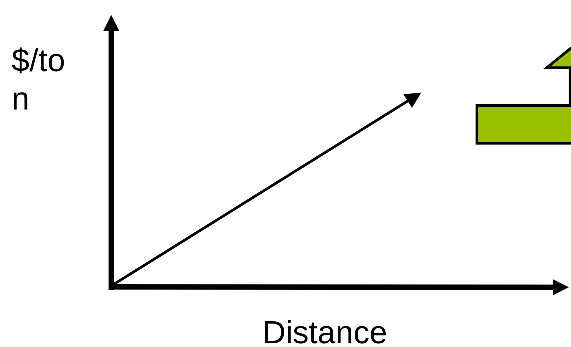
Challenge in Quarry Development



'real' optimum

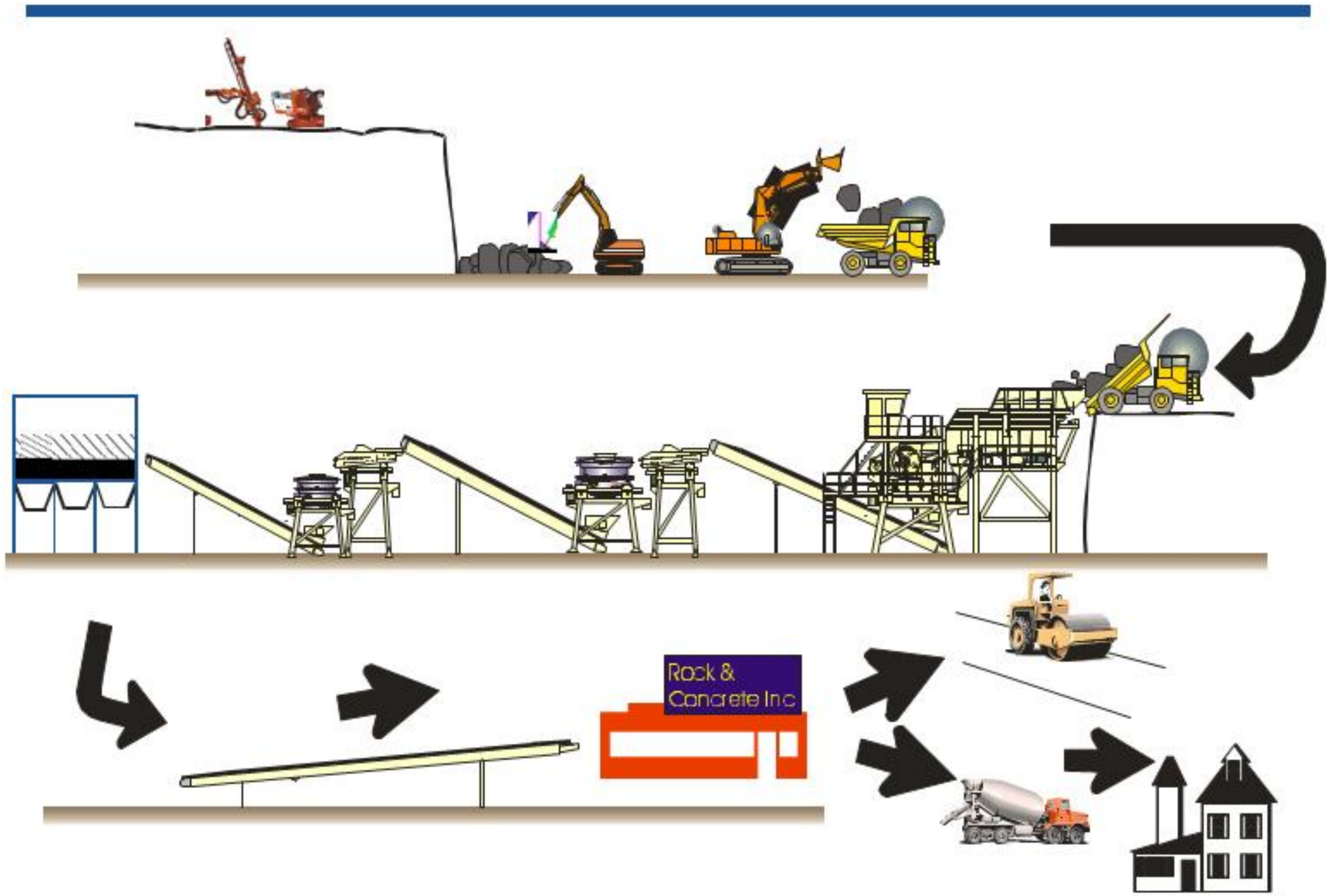
Source: Technical University Trondheim, Norway

What about the hauling distance?

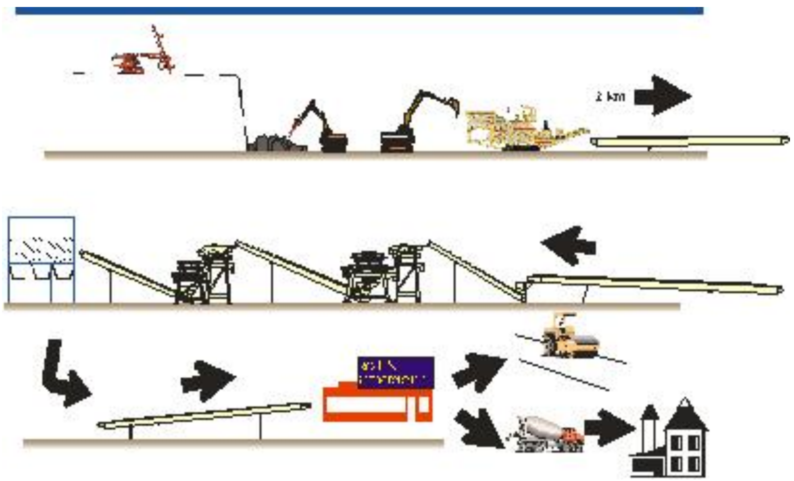


Quarry Process

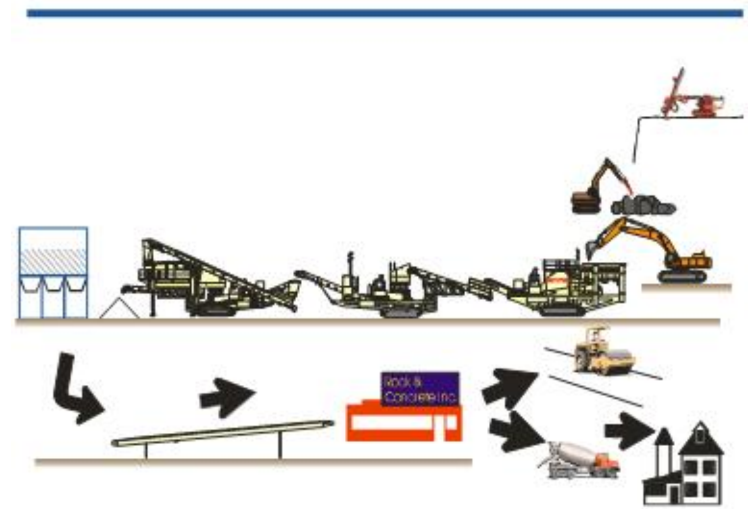
Stationary Crushers



Quarry Process
Mobile Crusher(s)

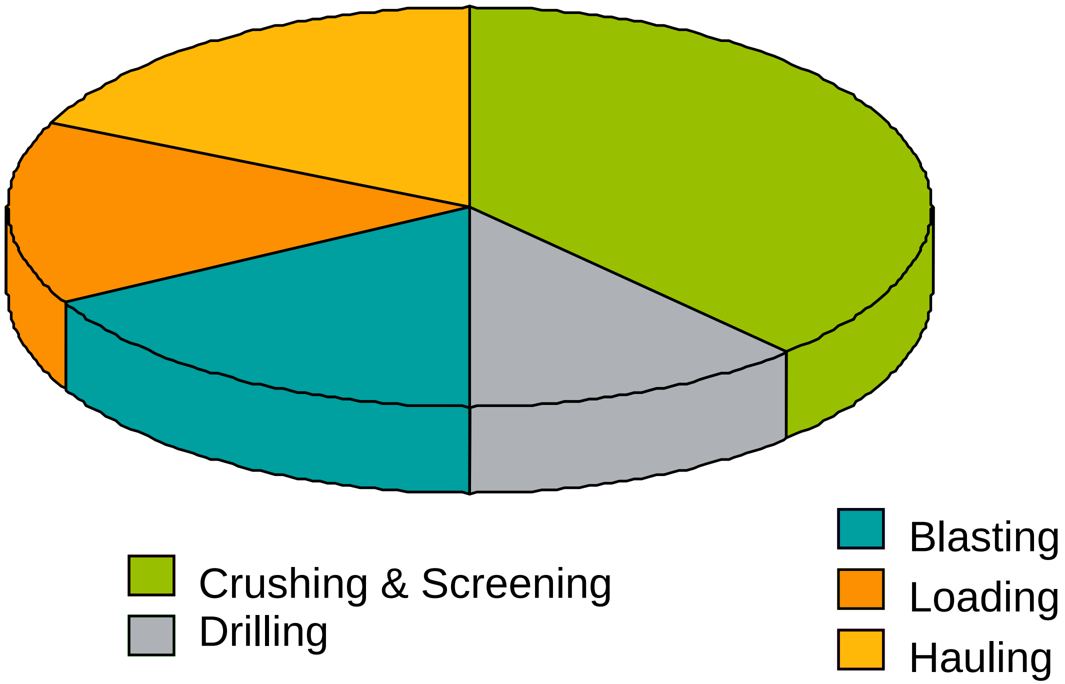


Mobile primary crushing



All crushers mobile

Example of Quarry Cost distribution



Approach Based on Two Phases

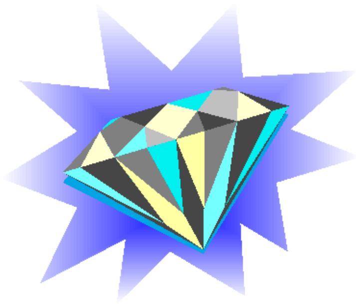
- **Comparison of different shotrock fragmentations, including:**
  - drilling and blasting
  - boulder handling
  - loading
  - hauling
  - crushing (traditional stationary)

Optimum drilling and blasting

Cost Effective Quarry Practise

- **Comparison of different crushing methods, including:**
  - stationary
  - inpit, semimobile
  - inpit, fully mobile

Optimum crushing



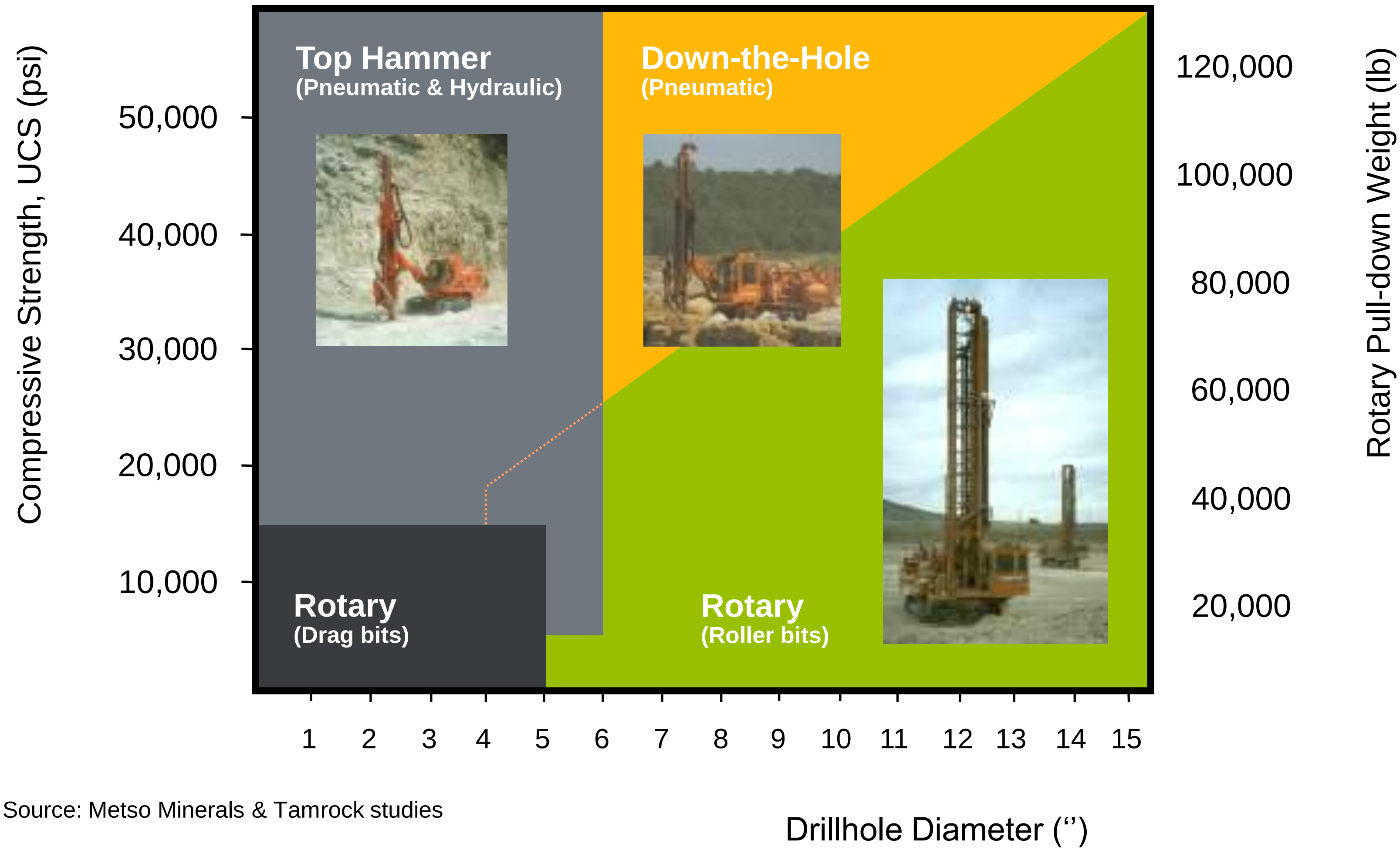
Comparison of Different Shotrock Fragmentations

Starting Point: Stationary Three-stage Plant with a Capacity of 1600t/h. Final Product 0-20mm

MAIN DATA	Case 1	Case 2	Case 3	Case 4	Case 5
Drillig: Nr.of units Drilling pattern (m2)	 3 9	 4 6,4	 5 5,8	 6 4,5	 8 3,3
Blasting: Specific charge (kg/m3) **K50 (mm), L**	 0,53 **410**	 0,76 **290**	 0,9 **250**	 1,15 **200**	 1,56 **150**
Number of operators	18-22				
Loading by excavators Bucket size (m3) Nr.of units	 12 2-7 depending on blast configuration (or bigger buckets)				
Hauling by trucks: Pay-load (t) Distance (km) Nr.of units	 50 2 8-10 depending on blast configuration				
Crushing: Primary crusher type Nr.of primary units Nr.of sec.&tertary units	 Nordberg C160 jaw 2 5				
General Drillability & blastability Work index (kWh/t) Drill hole dia (mm) Bench height (m) Explosive Interest rate (%) / Quarry life (y) Fuel price ($/liter) / Energy ($/kWh) Wages ($/hour)	 45 / 0,7 15 89 10 Anfo 10 / 20 0,5 / 0,1 17				

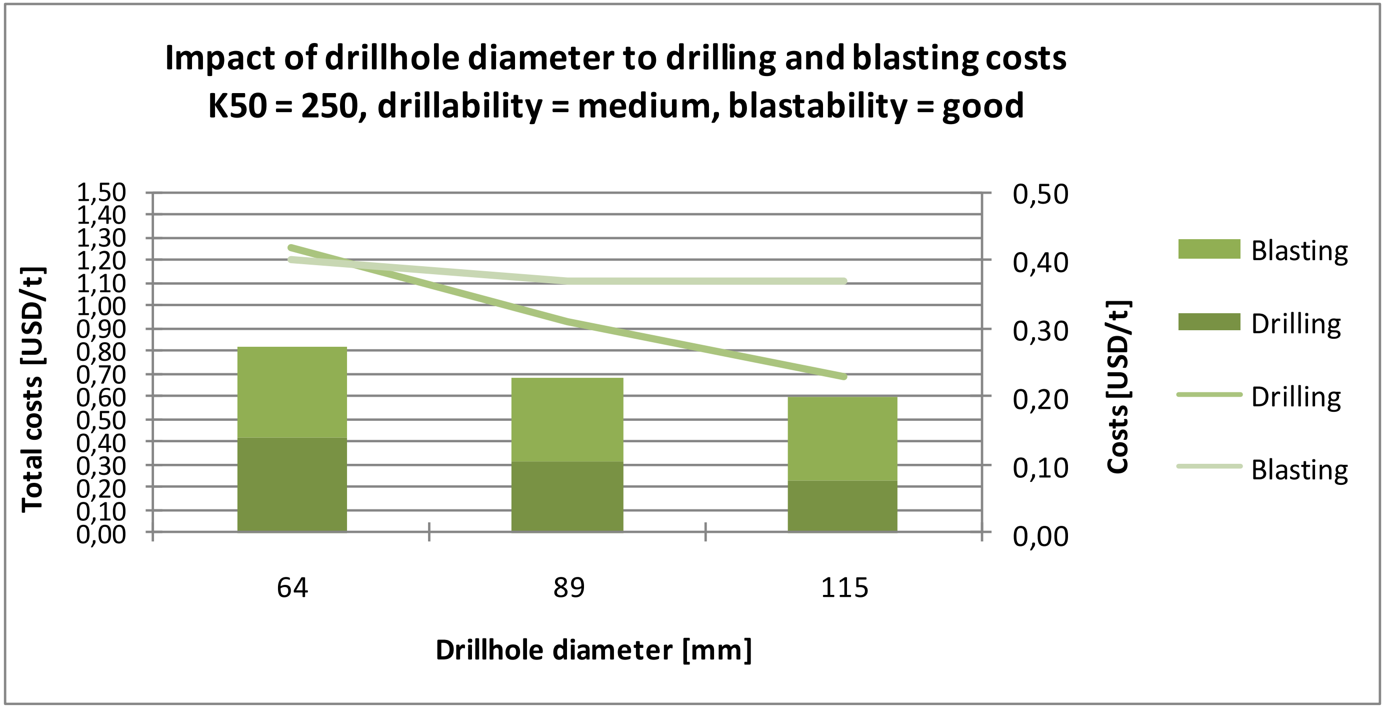
All together more than 50 different cases were analysed

General Selection of Drilling Method



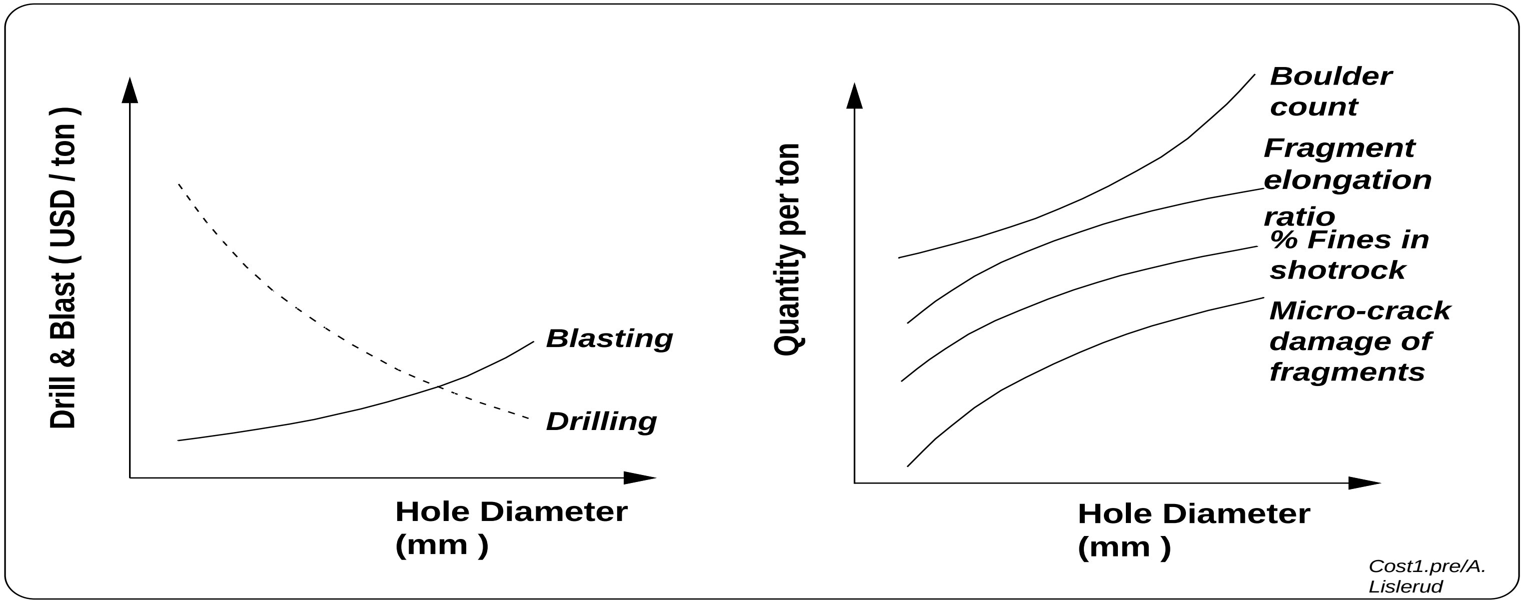
Source: Metso Minerals & Tamrock studies

Impact of drillhole diameter to drilling and blasting costs



Source: Metso Minerals & Tamrock studies

Impact of Drillhole Diameter



Source: Metso Minerals & Tamrock studies

Fines in feed

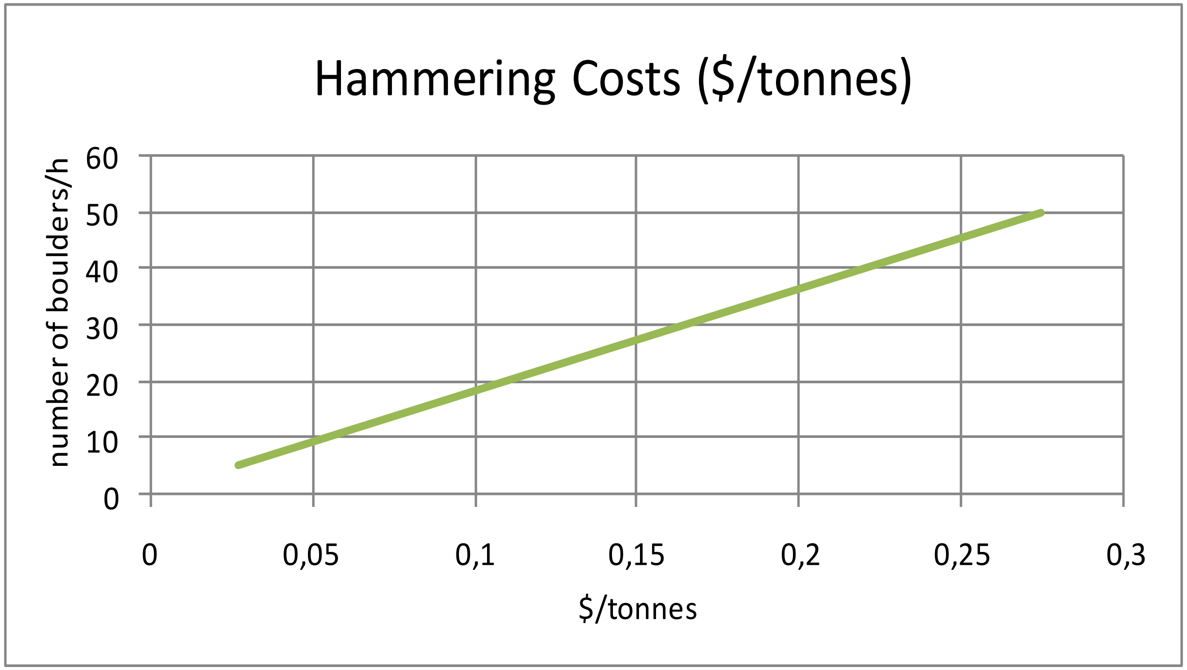
Boulder Handling

Sort boulders from muck pile

Downsize the boulders

Minimize boulder count using tighter drill patterns or reduced uncharged height

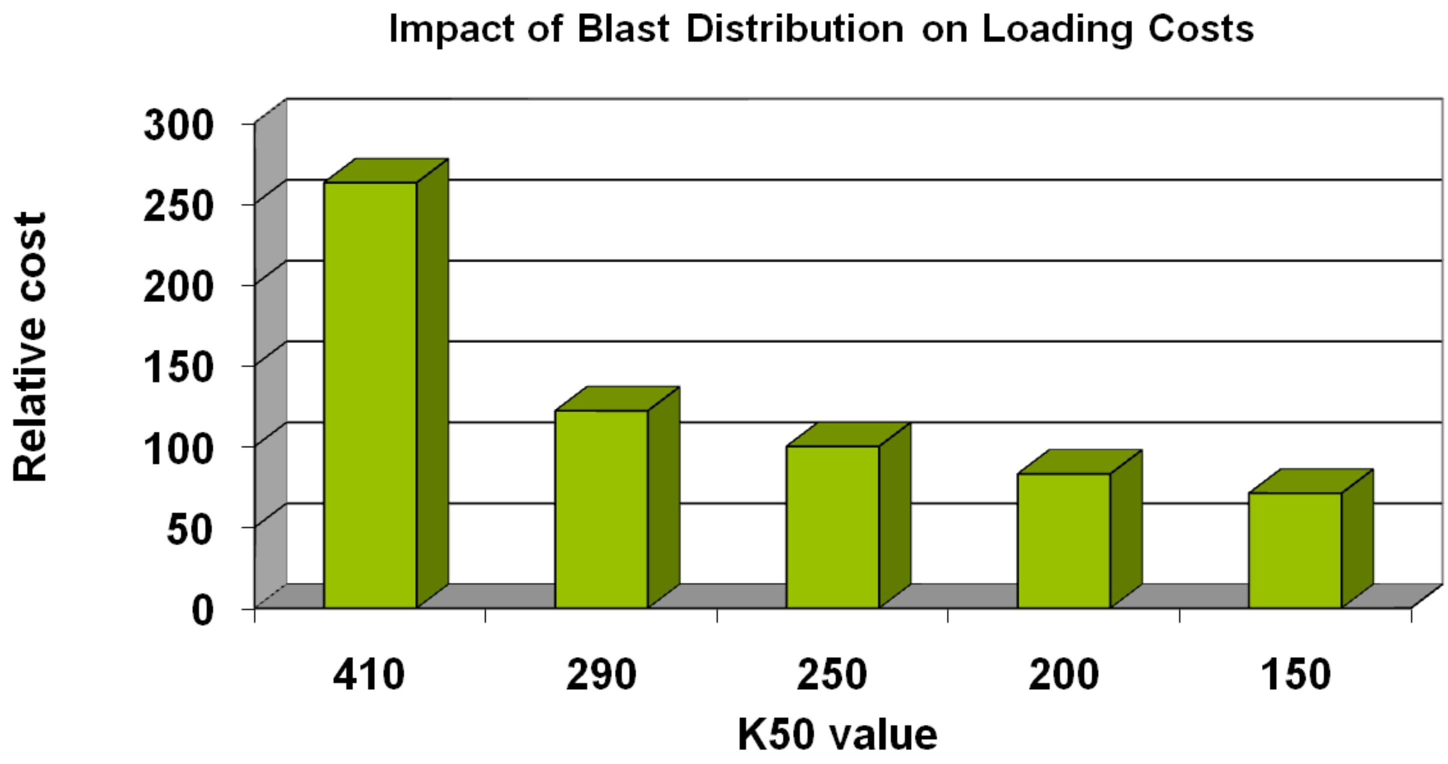
Example of Direct Costs Caused by Boulders.
Customer case, breakage before loading



Key Issue

- Removal of bolder breakage outside process
- -> improved plant utilization

Impact of Blast Distribution on Loading Costs



K50 definition

Loading Operations; Examples

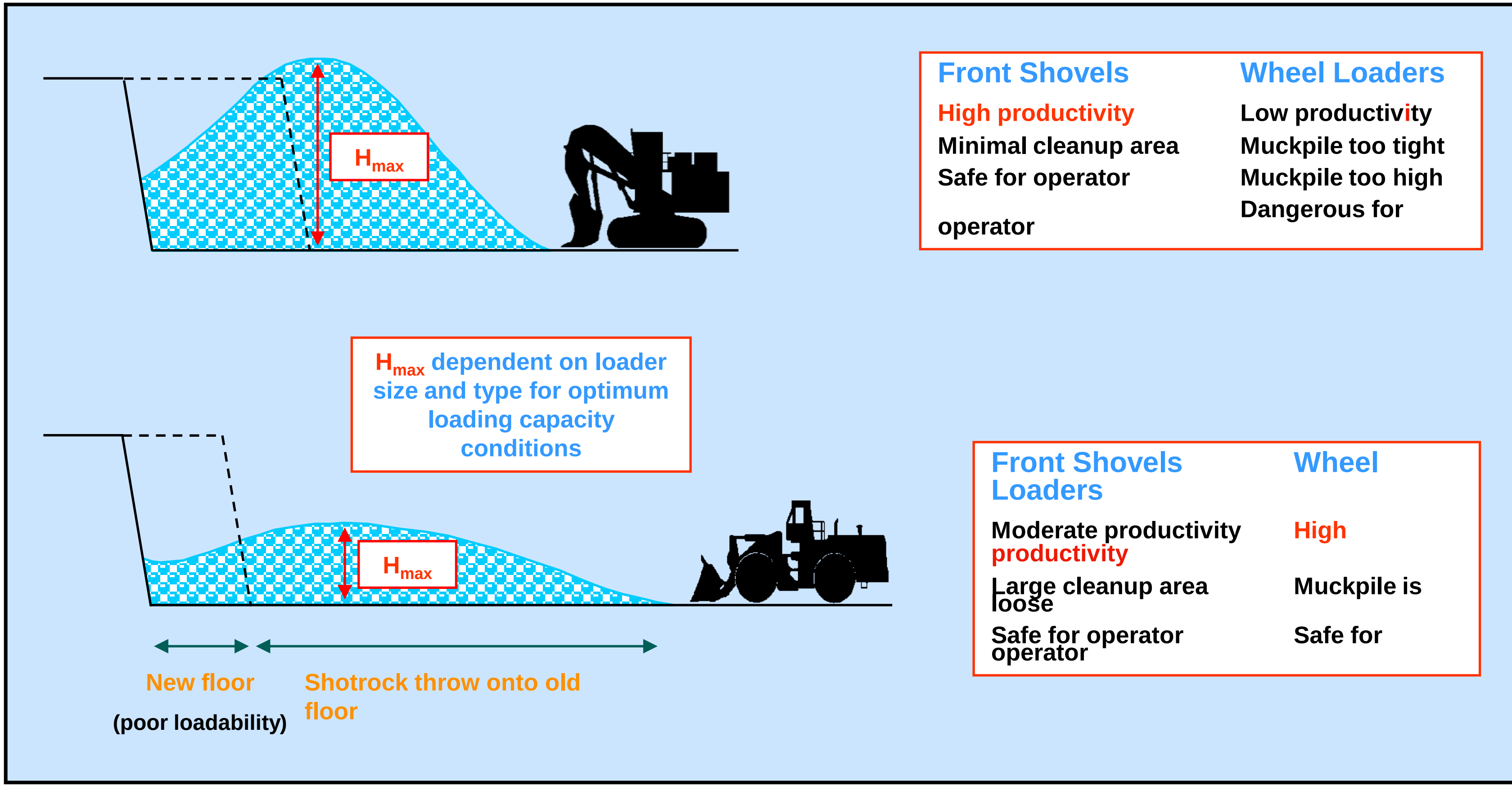
Auxiliary machines required for quarry floor cleanup after blasting for loaders with poor mobility

Typical toe problem requiring auxiliary hyd. excavator work and/or use of secondary blasting

Tight muckpile (poor diggability) due to insufficient heave and throw

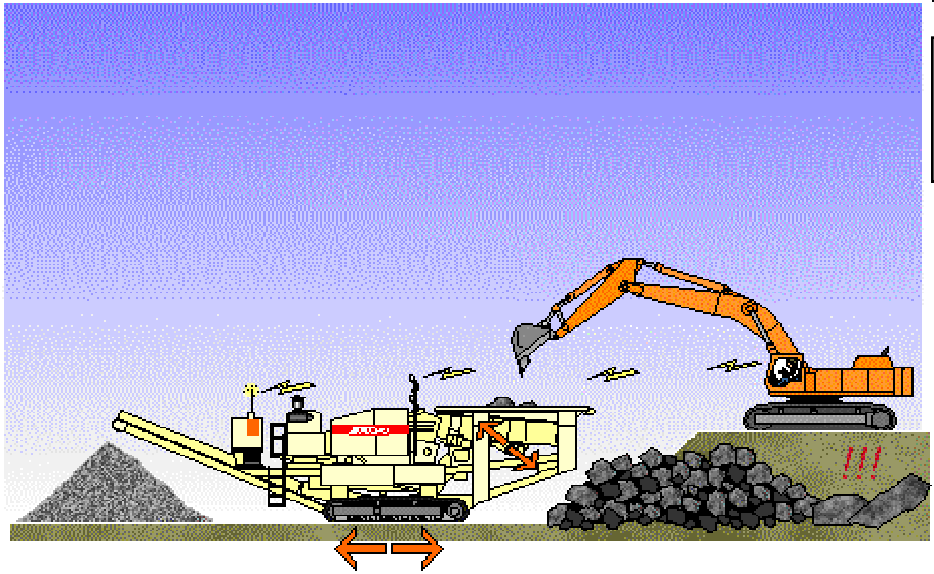
Source: Metso Minerals & Tamrock studies

Optimum Shotrock Profiles for Loading Operations



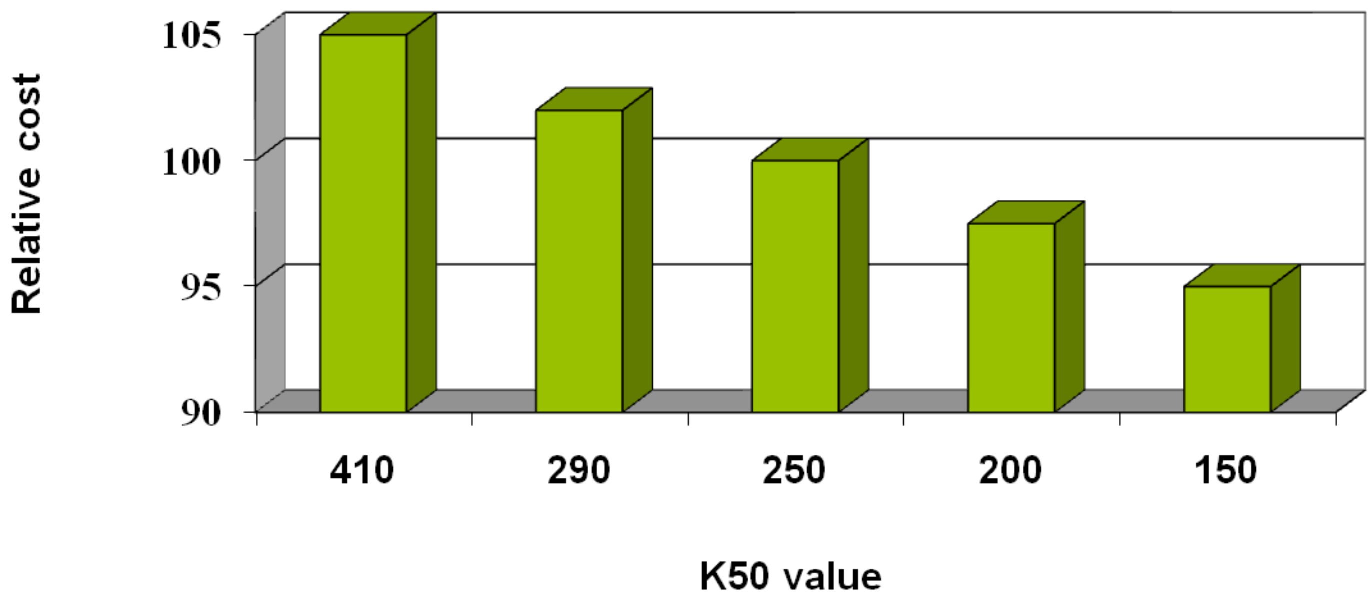
Source: Metso Minerals & Tamrock studies

And Feeding by Excavator



Cat recommendations

Impact of Blast Distribution on Hauling Costs with Dumbers

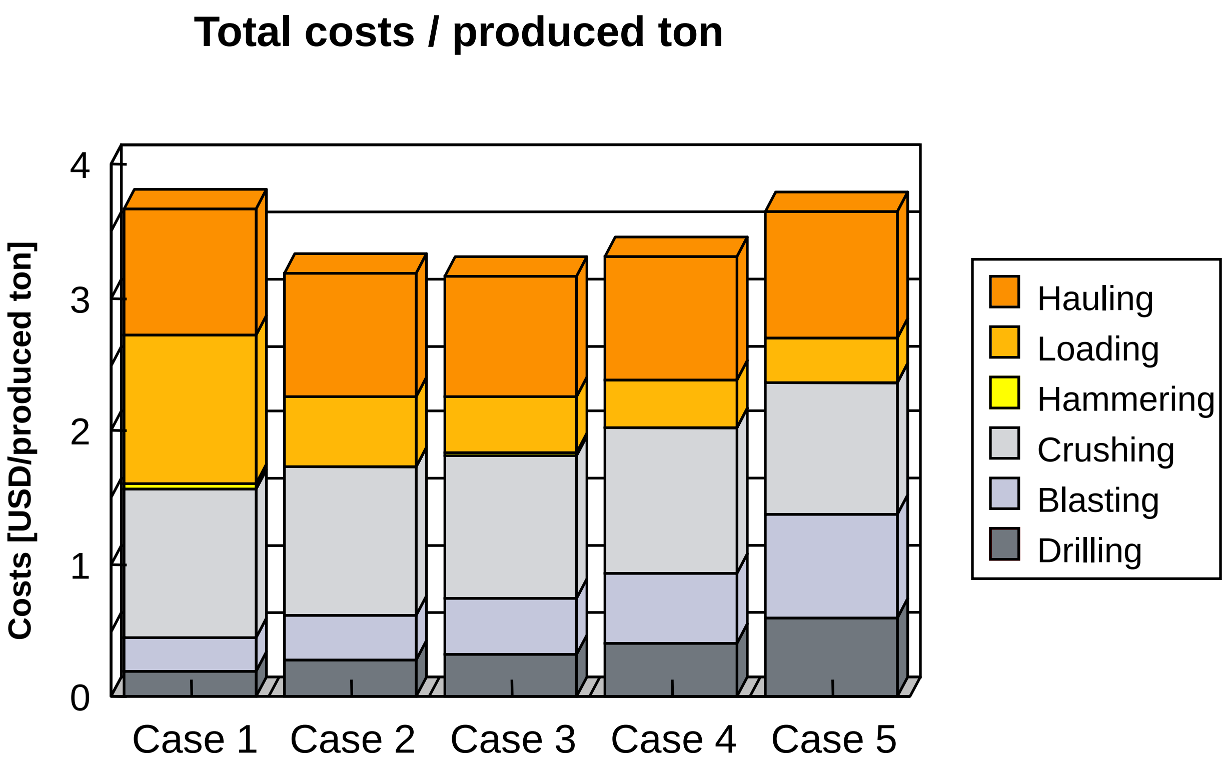


Why Coarser Blast Distribution Impacts on Loading and Hauling Costs?

- Material is more difficult to load due to:
  - more likely toe problems
  - bigger boulders
- Scope of equipment changes due to more difficult and/or longer cycle times
- With respect to the equipment there is
  - more wear
  - more maintenance

Results

K50 is 50% point of fraction distribution



Case	K_{50} (mm)
Case 1	410
Case 2	290
Case 3	250
Case 4	200
Case 5	150

Conclusions of Shotrock Fragmentation

- From the total product cost point of view, there is an optimum shotrock fragmentation. In the case study, the optimum was k_{50} ~ 250 mm.
- The crushing cost share is almost unchanged with different K_{50} values because the blast impacts only on primary crushing
- Even smaller drillhole diameters than used here (89mm) can be economical, because:
  - Smaller drillhole diameters produce fewer fines. In many cases this is considered waste
  - There are fewer boulders to be handled
  - There are fewer micro cracks in the blasted rock, due to more ‘gentle blasting’. In many cases, this generates better final aggregate quality
- Boulder management is important

Comparison of Different Crushing Methods

Starting Points for Crushing Method Comparisons

- **k_{50}=250mm is being used as shotrock fragmentation**
- **The following quarrying methods are under comparison:**
  - stationary:
    - Material is transported by dump trucks into crushing plants
  - inpit, semimobile
    - material is transported by dump trucks into the semimobile primary jaw crusher, and from there by conveyors to the secondary & tertiary crushing plants
  - inpit, fully mobile
    - primary crushing done at a quarry face with a highly mobile track mounted jaw crusher, and taken from there by conveyors into the secondary and tertiary crushing plants. No dump trucks are used.

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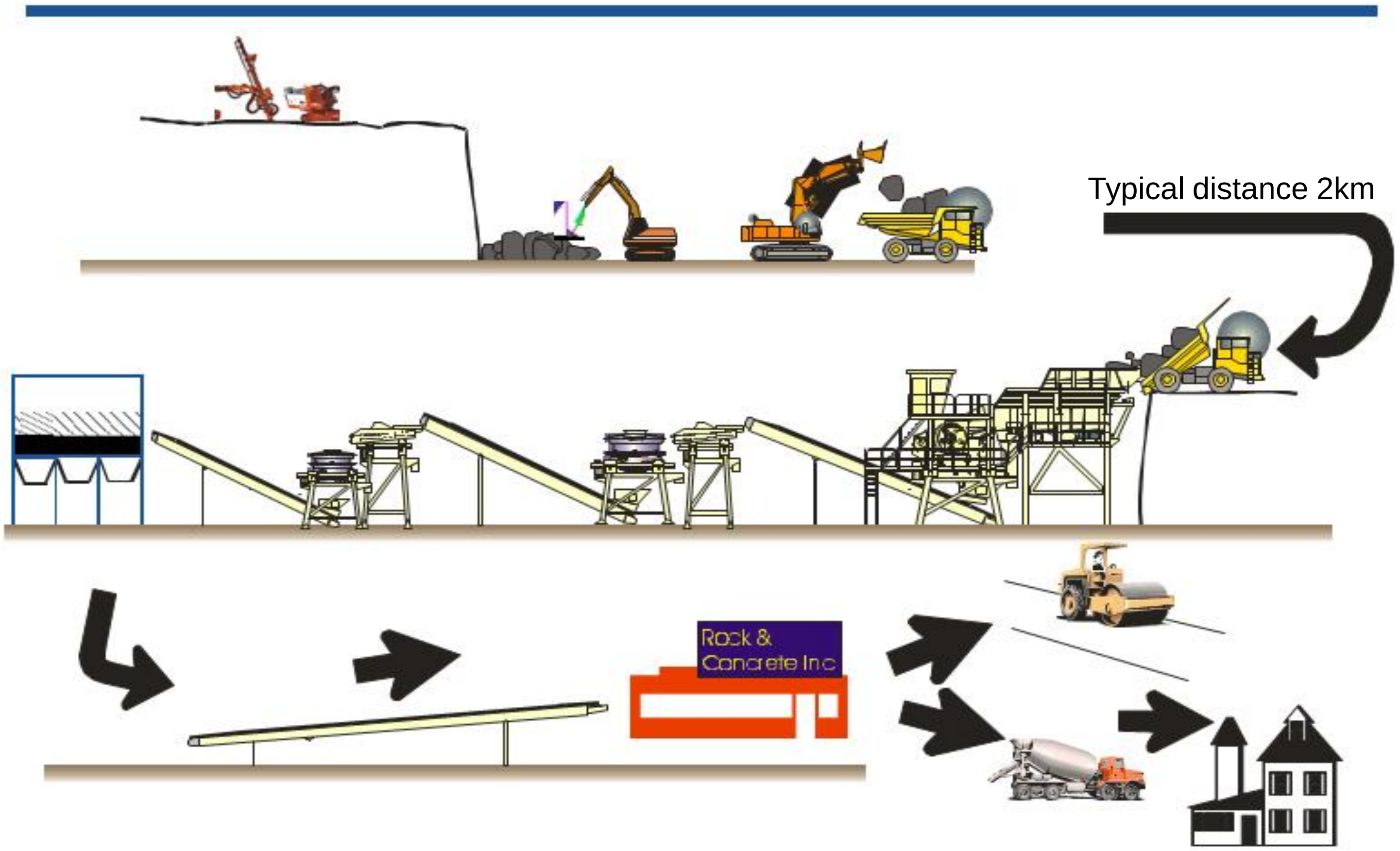
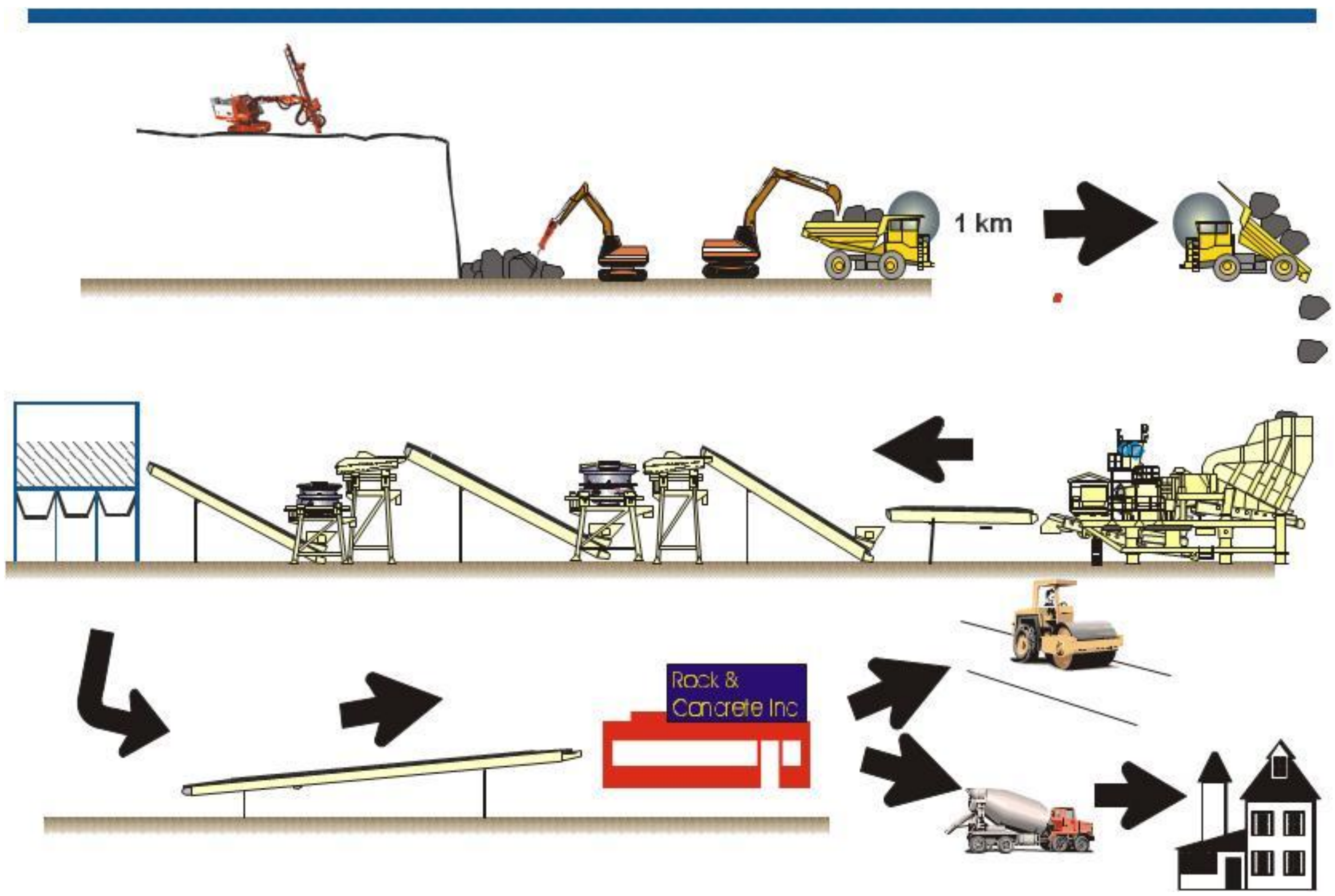
Stationary Crushers

Primary crusher cannot normally be moved



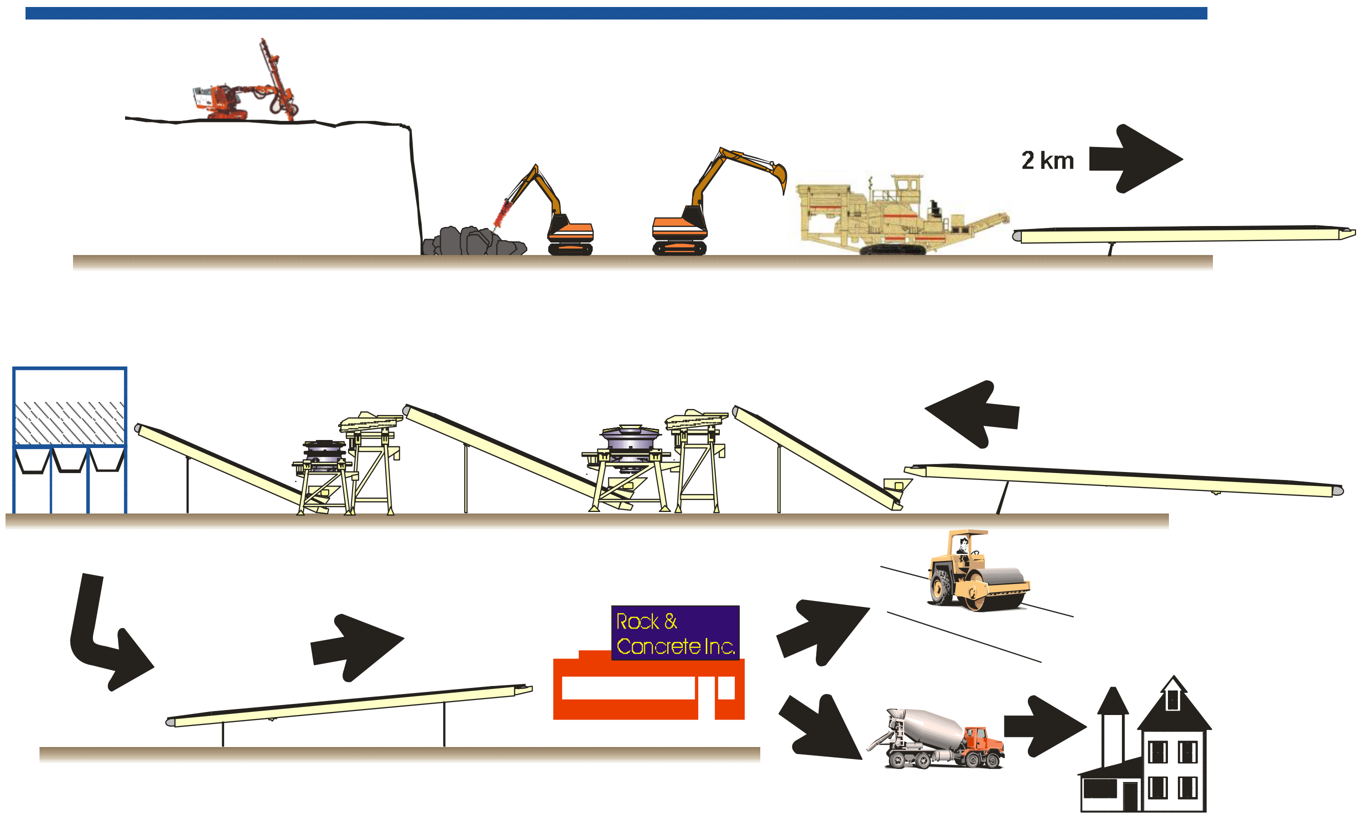
Semimobile Inpit Crushing

Primary crusher can be moved but only on a non-frequent basis.



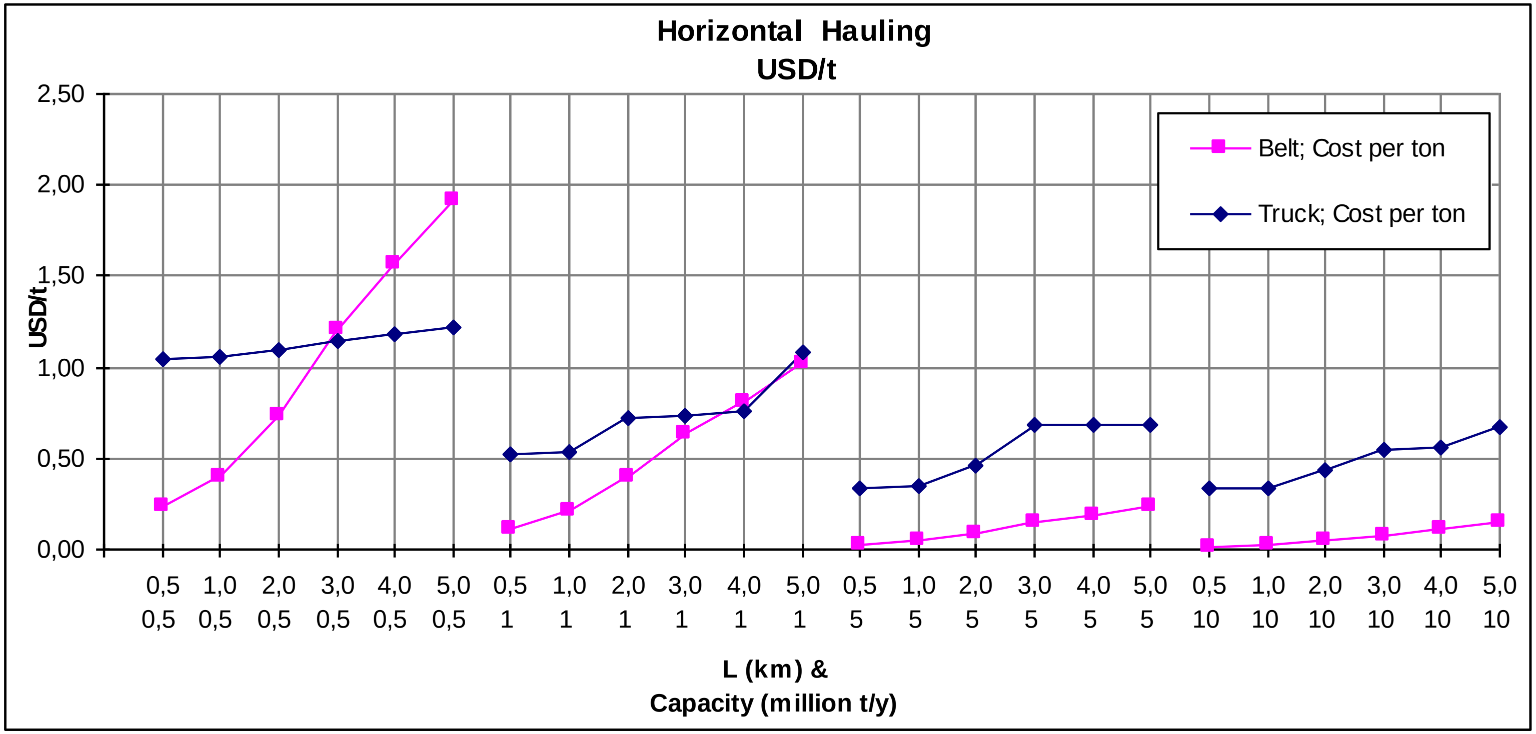
In-pit Fully Mobile Crushing

Primary crusher is track mounted, compact and movable within 5-10 minutes.



In-pit Fully Mobile Crushing
Movable and steerable Lokolink conveyor system is a key component

Truck Transport Versus Conveyor Belt



Cost comparison between conveyor belt transport and dump truck haulage hauling distance and annual capacity.

Truck Transport Versus Conveyor Belt

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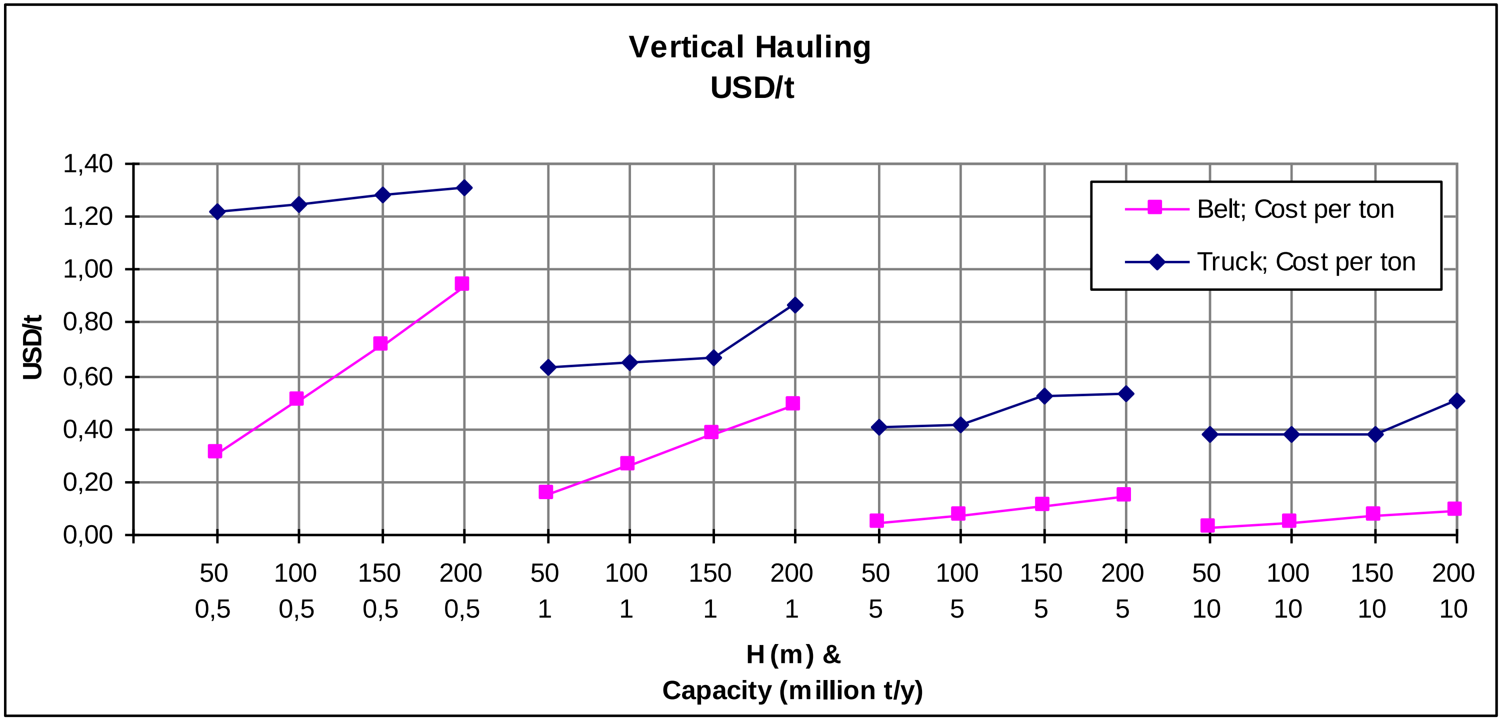


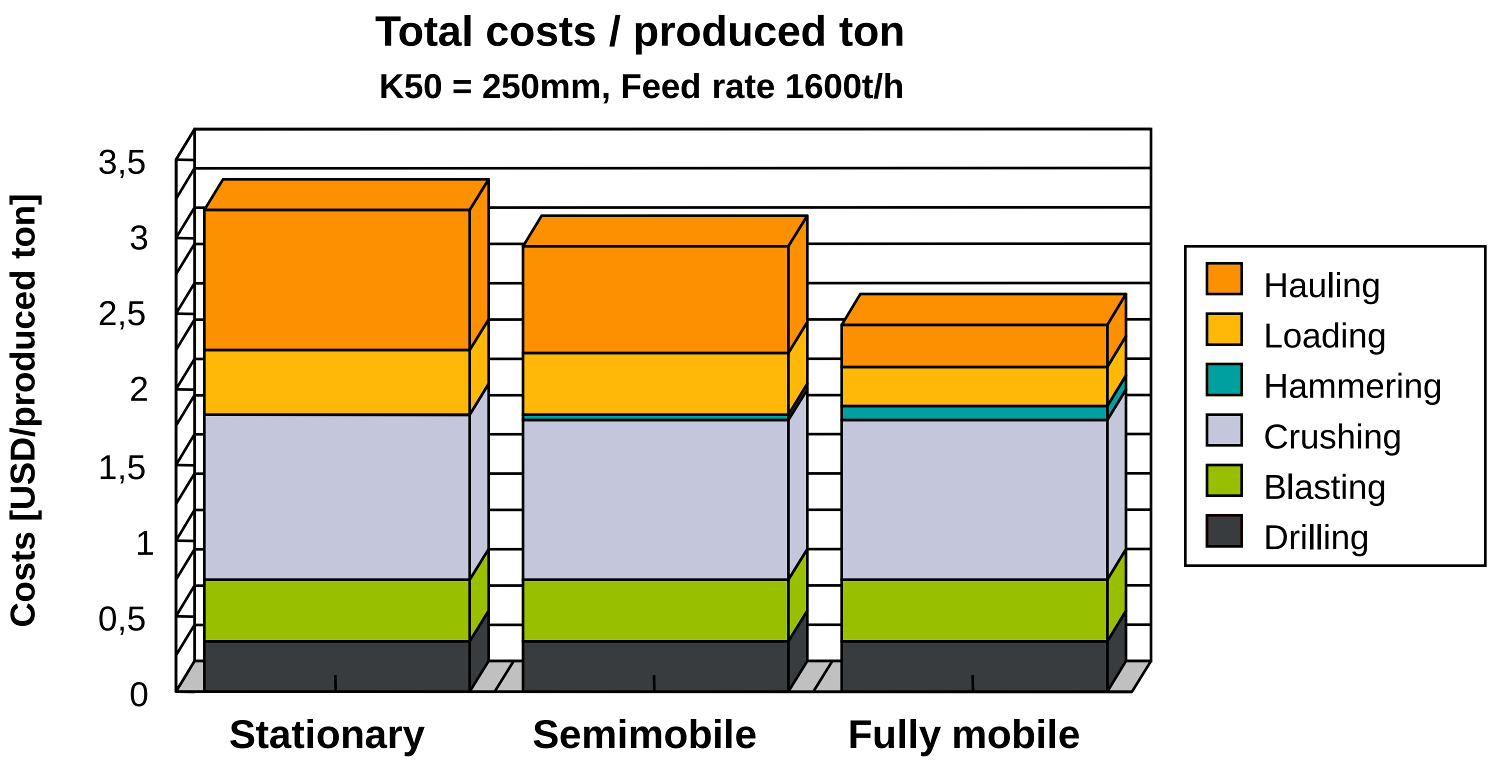
Cost comparison between conveyor belt transport and dump truck haulage as a function of vertical hauling distance and annual capacity given a haulage length to height ratio of 8 : 1.

Starting Point: Three Different Plant Configurations with a Capacity of 1600t/h. Final Product 0-20mm

	Stationary plant	Semimobile primary plant	Fully mobile in-pit primary plant
Primary crusher type Size Number of units	Fixed Jaw C160 2	Semimobile Jaw C140 2	Track mounted Jaw C125 2
Loaders, excavators: Bucket size (m3) Number of units	 12 2	 5,5 3	 5,5 2
Dump trucks: Size (t) Number of units Haulage distance (km)	 50 8 2	 35 7 1	 - - -
Conveyor length (km)	-	1	4
Number of operators	20	20	11
Secondary & tertiary crushers and screens *)	Secondaries: 2 * Nordberg OC 1560 Tertiaries: 3 * Nordberg HP500 Seven Screens: 10-20m2		
Other variables	As in previous drilling & blasting example		

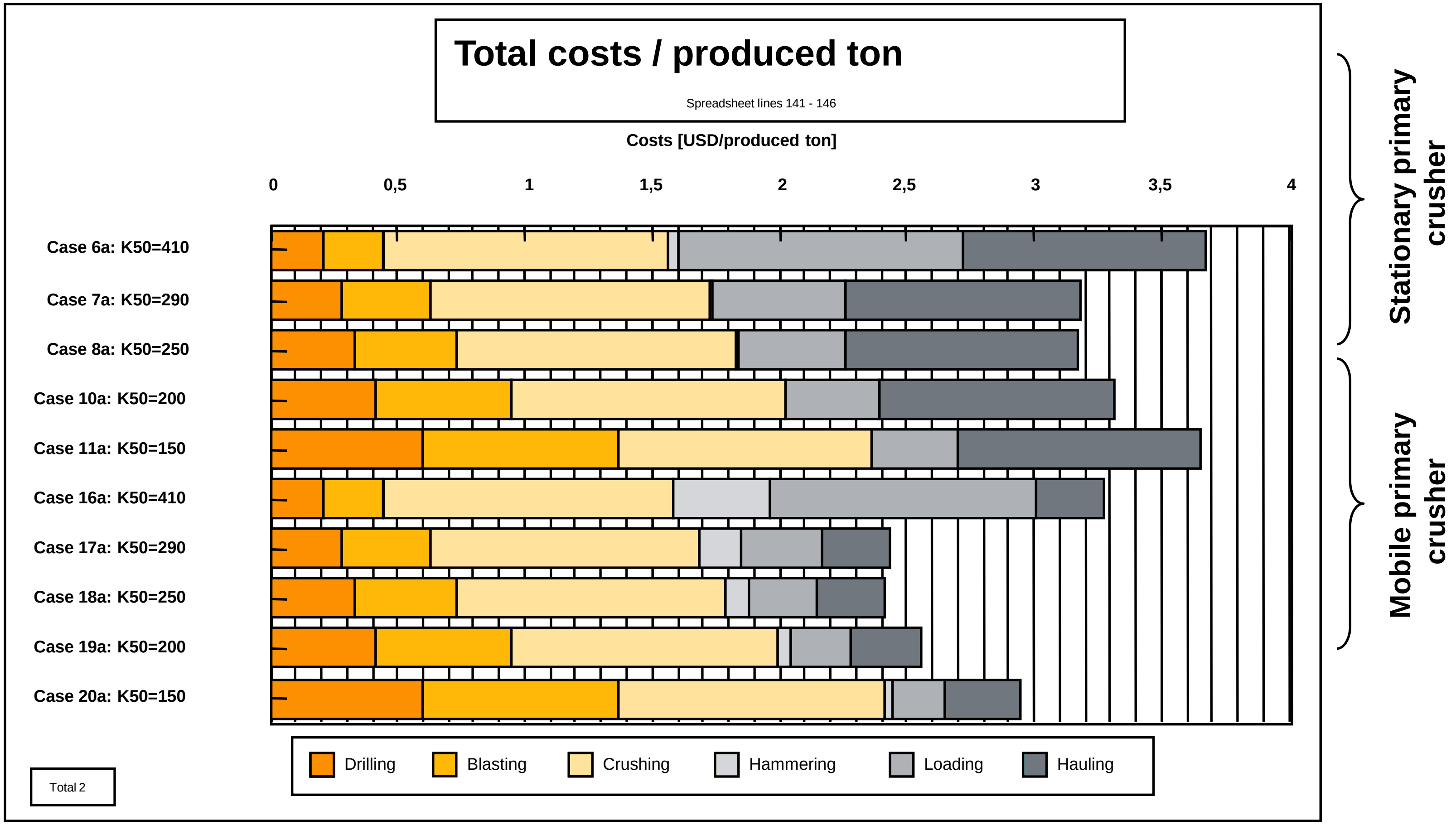
*) = K10 in Hong-Kong

Results



Difference between stationary and fully mobile is about 25%.

Another Example



Tools Available

1) Process Integration and Optimization (PIO) Services

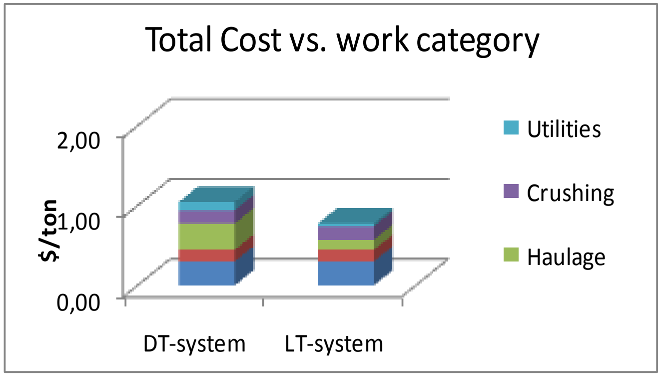
This is **not a case of**…

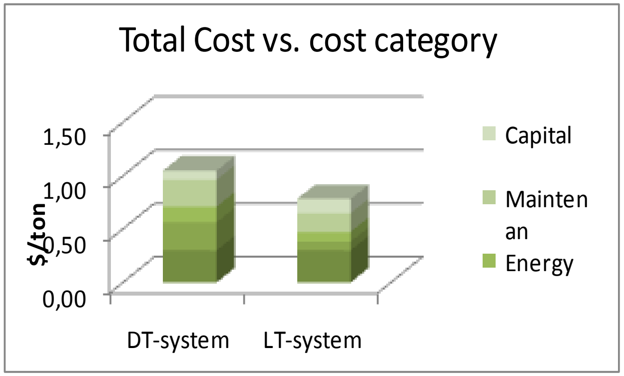
- Increasing the powder factor to increase plant throughput
- Opt(blast) +…+ Opt(crush) ≠ Max($$$)

It is…
The development of a quarrying and processing strategy which minimizes the overall cost per tonne treated and maximizes company profit.

Opt(blast +…+ crush&screen) = Max($$$)

2) Calculation & simulation tools





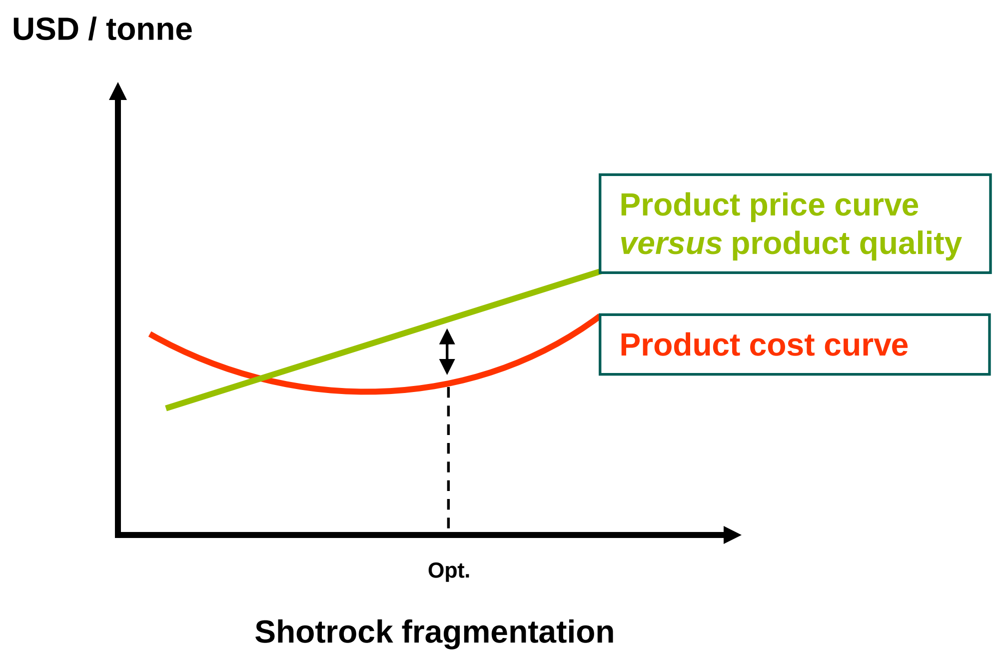
Conclusions for Quarry Development

- From the total product cost point of view, there is an optimum shotrock fragmentation.
- Oversize boulder frequency has a significant impact on capacity and cost.
- A smaller drillhole diameter produces fewer fines. In many cases, this is considered waste.
- The crushing cost share is almost unchanged with different K_{50} values when the crushing method is the same. The optimum selection is dependent on:
  - Rock type due to abrasion
  - 'Case-specific factors' like the life of the quarry, investment possibilities etc.
- Whole quarry process optimization instead of the suboptimization of individual components
- Inpit crushing can generate remarkable benefits

Enclosures

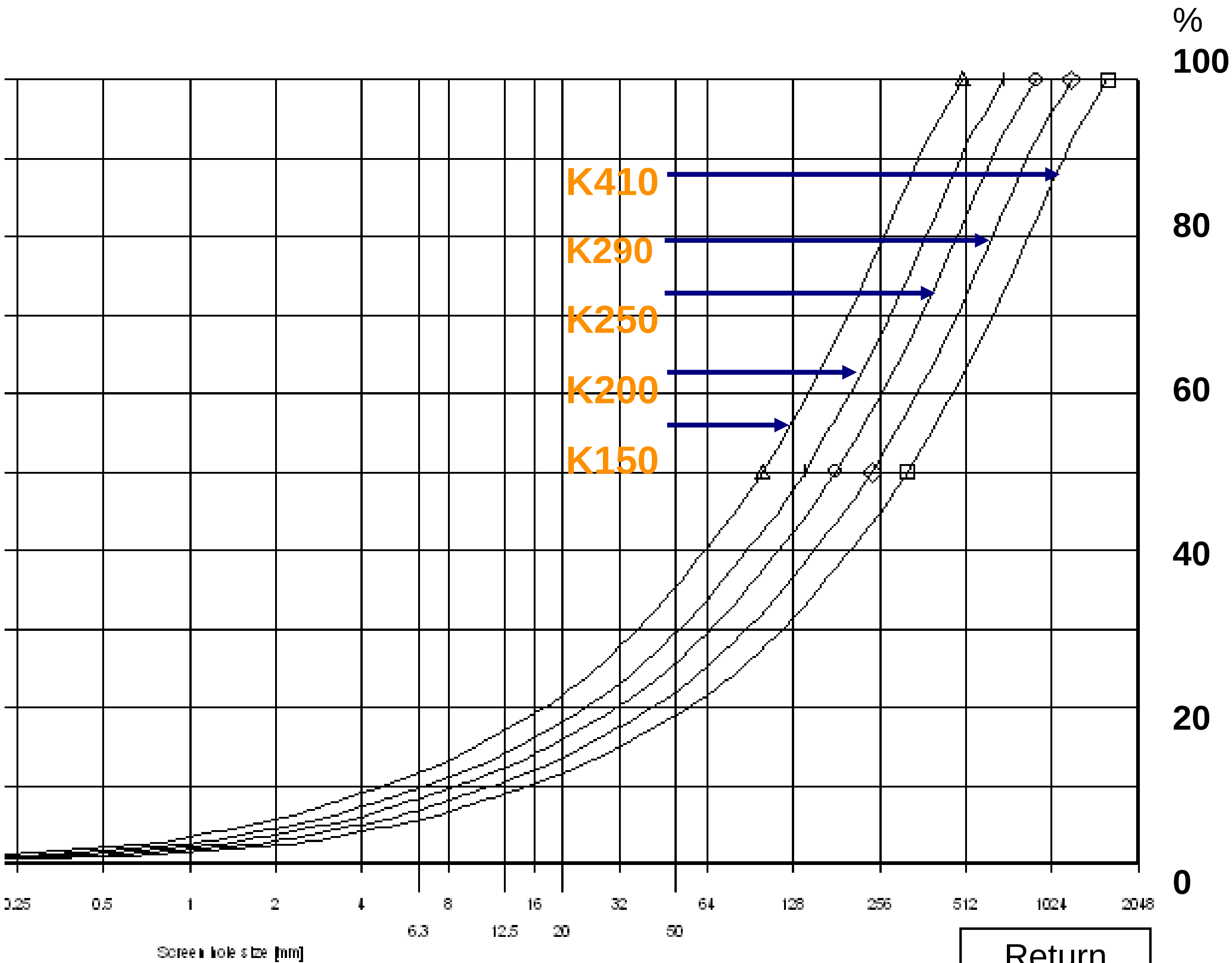
- Operational targets for a typical aggregate producer
- K50 feed sizes
- Example: Norwegian case

Operational Targets for a Typical Aggregate Producer



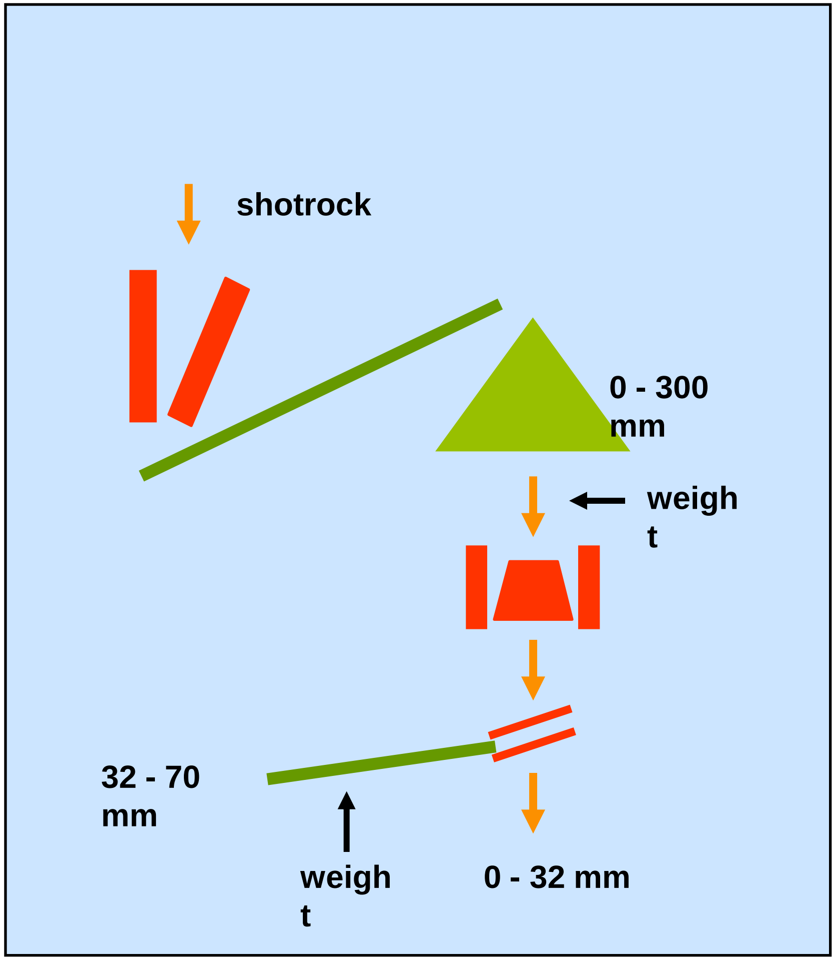
Return

K50 Feed Sizes



Return

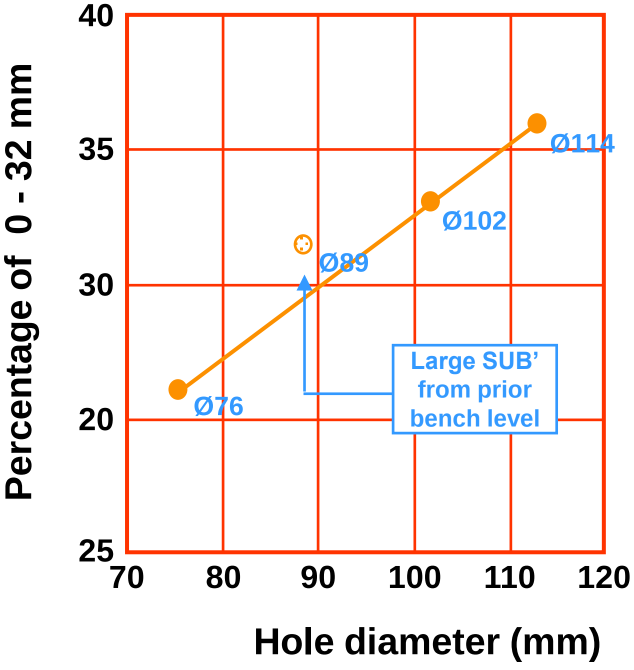
Example: Norwegian Case



Source: Metso Minerals & Tamrock studies

Return

Rock type	Anorthosite
Explosive	Slurrit 50-10
Blast size tonnes	~50 000



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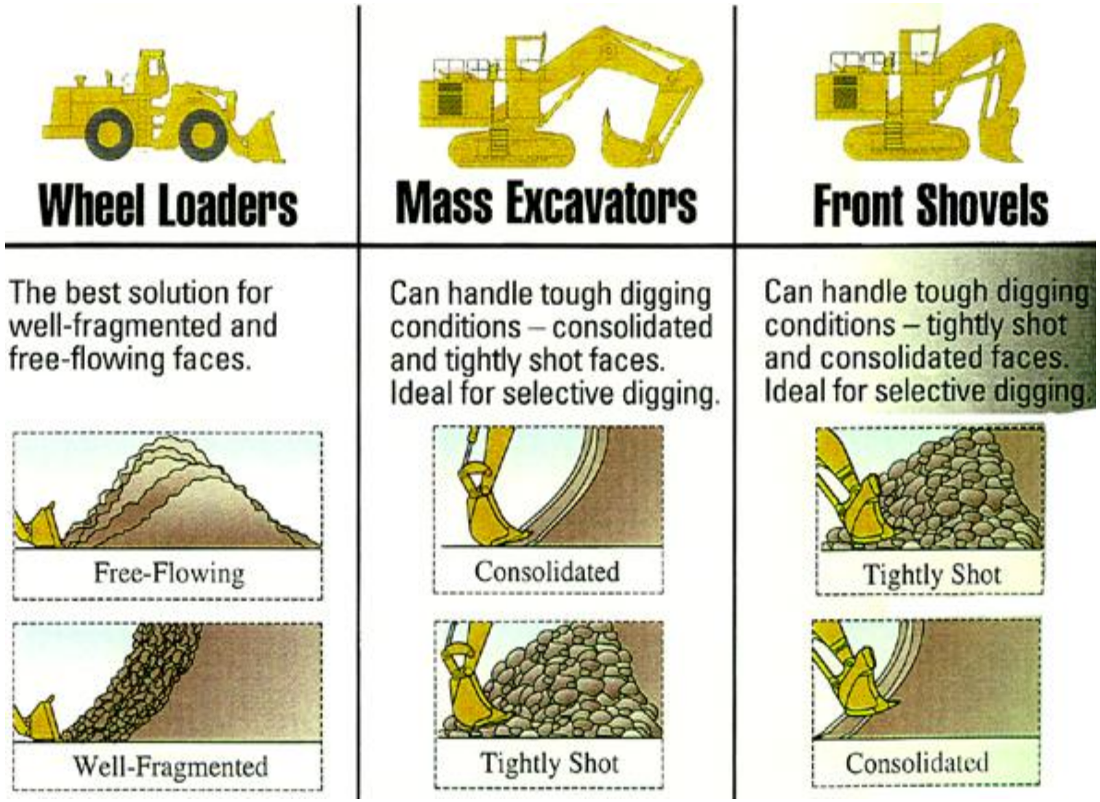
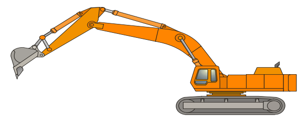
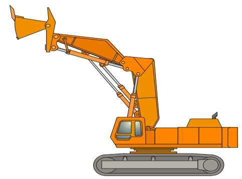
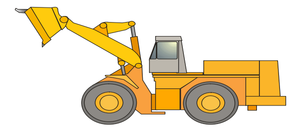
Basic Selection of Loading Equipment



Source: Cat presentations

Guidelines to choose loading tools for primary Nordberg LT's

	BACKHOE EXCAVATOR	FACE SHOVEL	WHEEL LOADER
CONTROL OF OVERSIZE	Very good	Good	Mediocre
FEED CONSISTENCY	Very good	Very good	Mediocre
SIZE vs CAPACITY	Size is selected according to the capacity requirement	Oversize machine is needed to be able to reach to the feed hopper	Size is selected acc. to the capacity and distance
DIGABILITY	Very good	Very good	Good
REACH	5..10 m	5..10 m	50...100 m
GENERAL COMMENT	In normal blast provides the lowest cost per tonne	Can be considered with fine blast where bigger capacity justifies bigger machine	Provides the possibility to mix feed from different parts of the face