Optimizing the "Crunch" process

Per Svedensten

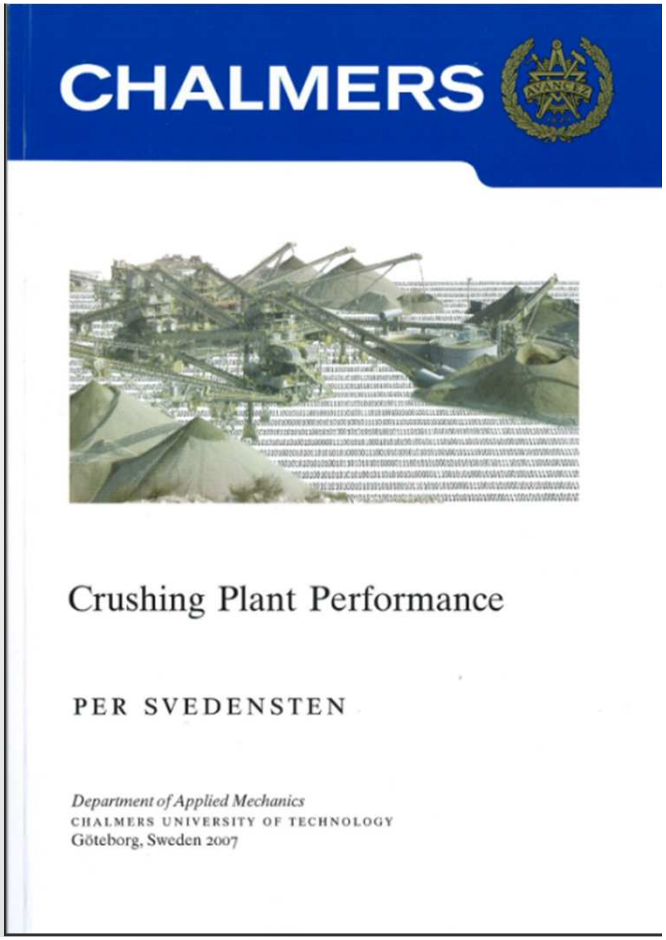
QUARRY ACADEMY

Improving Processes. Instilling Expertise.

ORICA VOLVO SANDVIK

Optimizing the Process

- Methods to combine and simulate technical and economic performance
- Optimum crushing plant performance is difficult to achieve due the process characteristics. Different compared to all other industrial processes.
- Optimizing method for best performance
- Partly implemented in PlantDesigner 10



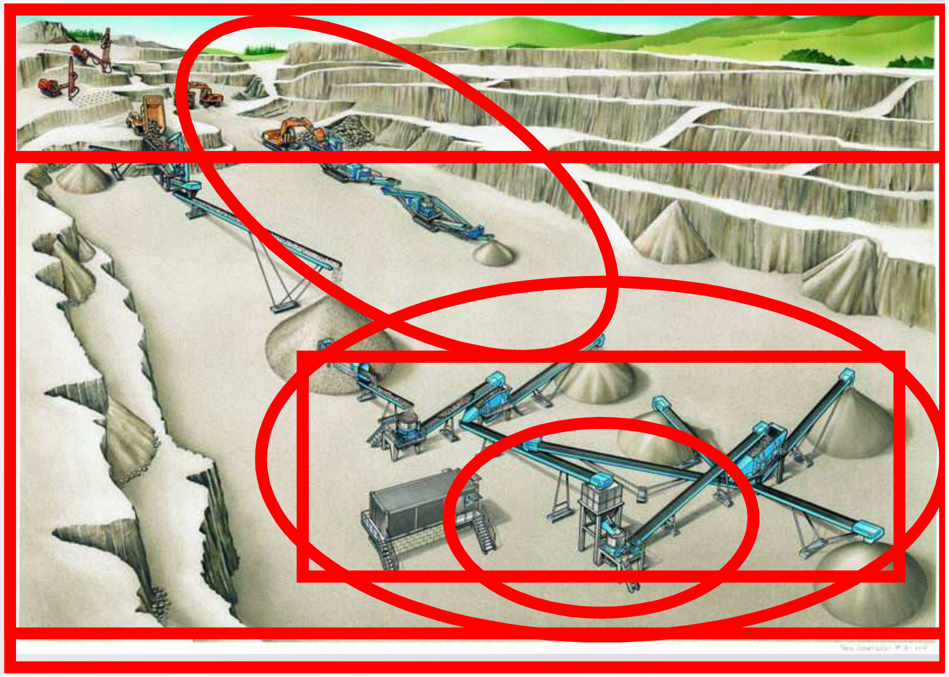
Value adding chain

Crushing Plant Optimization

Point of interest

- Crushing stage
- Crushing plant
- Quarry process

- Today:
- Optimizing a crusher
- Optimize the feed
- Optimize the process



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Agenda

- Cone Crusher Optimization
- Case Study: Optimal Blasting for Crushing Plant Performance
- Crushing Plant Design
- Case Study: Optimizing a Crushing and Screening Process

Optimization of a Final Crushing Stage

- The crushers are the last size reduction stage in the value chain.
- Over crushing is common.
- The connection between crusher setting and yield is often unknown
- The rock cannot be repaired.
- We need to control the crusher carefully.

Optimization of a Final Crushing Stage

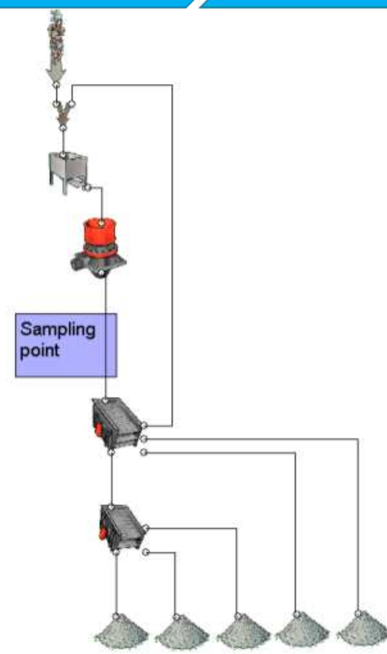
Planning → Sampling → Analysis → Optimization

- Optimization of one parameter (CSS) can be done by sampling and analysis
- The invested time and lost production will quickly be repaid by increased productivity
- Combine product yield and economic aspects
- This can be done by taking samples and making the analysis in MS Excel

Optimization of a Final Crushing Stage

Planning | Sampling | Analysis | Optimization

- Material from crusher is sampled
- Measure the capacity at each crusher settings. CSS will effect the final product capacity, especially in a closed circuit.
- Production of 4 valuable products
  - 2-4 mm
  - 4-8 mm
  - 8-16 mm
  - 16-22 mm
- By-product with no value
  - 0-2 mm



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Optimization of a Final Crushing Stage

Planning | **Sampling** | Analysis | Optimization

- Run the crusher at different settings
- Take at least one sample at each setting. (Multiple samples are often useful)
- Special Attention to Safety when taking samples!!
- Position of point were samples are taking.
- Ensure that the conveyor will not start by accident.

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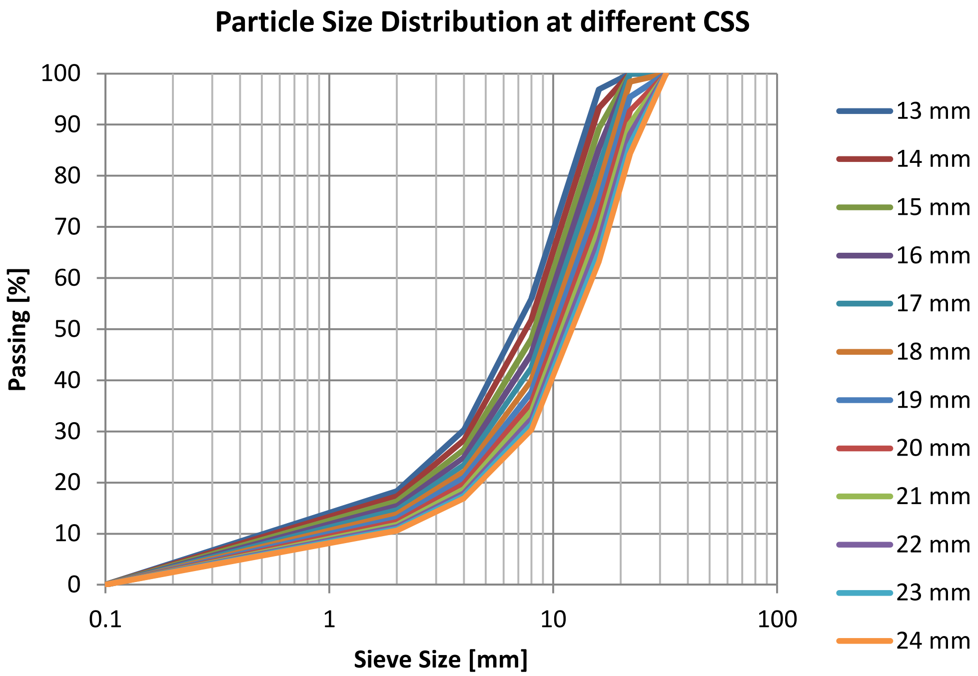
Optimization of a Final Crushing Stage

Planning → Sampling → **Analysis** → Optimization

- Particle Size Distribution Plots
- If taking single samples on each CSS the risk of getting inconsistent results might make the graph look strange.
- Impossible to determine optimum setting by only using particle size distribution graphs



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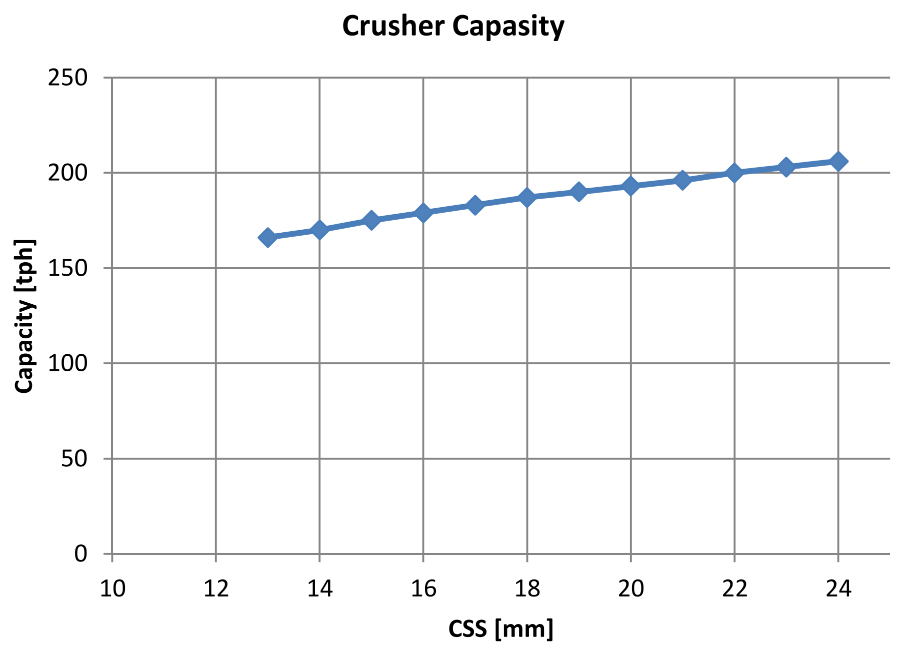
Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → Optimization

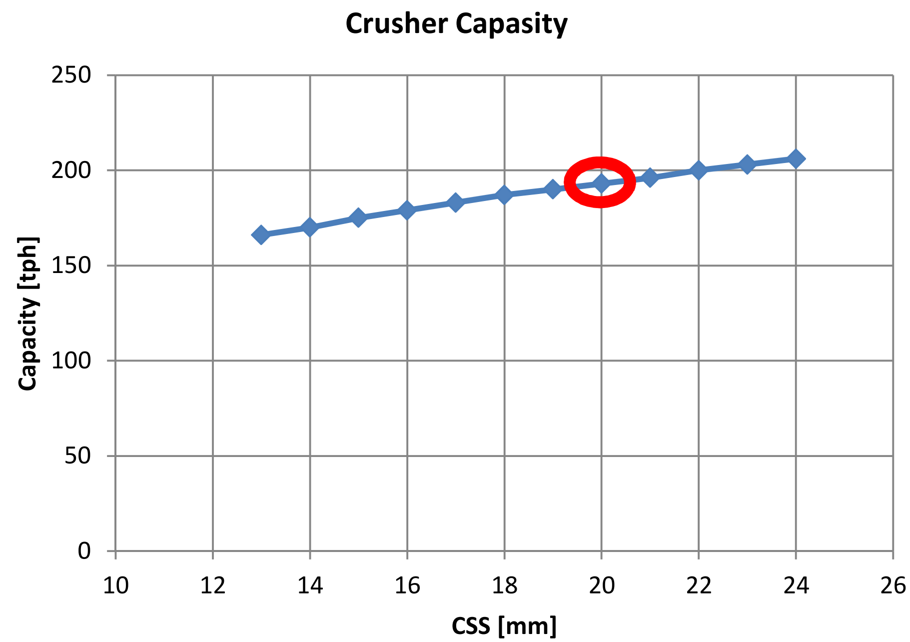
- Impossible to determine optimum setting by only using particle size distribution graphs



Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → Optimization

- Combine the particle size distribution and capacity.
- Percentage of final product times the capacity gives the production capacity of each product.
- Example 2-4 mm at CSS 20mm:
  - Percentage of crusher production: 20% - 11% = 9%
  - Crusher capacity 193 tph
  - Total Production: 193 tph x 9% = 17 tph



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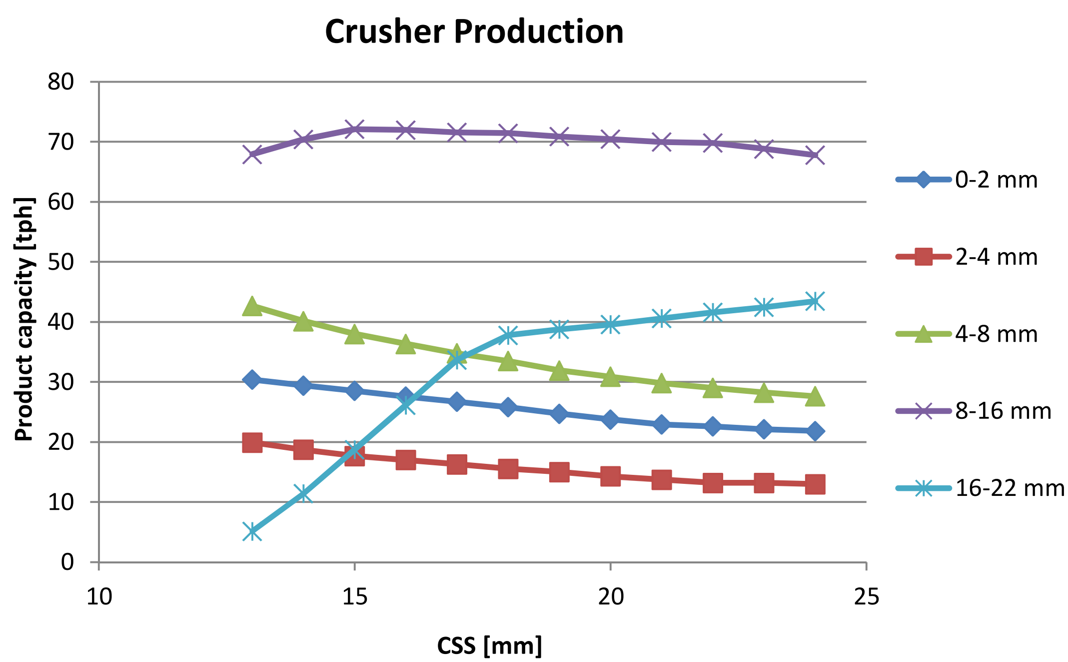
Optimization of a Final Crushing Stage

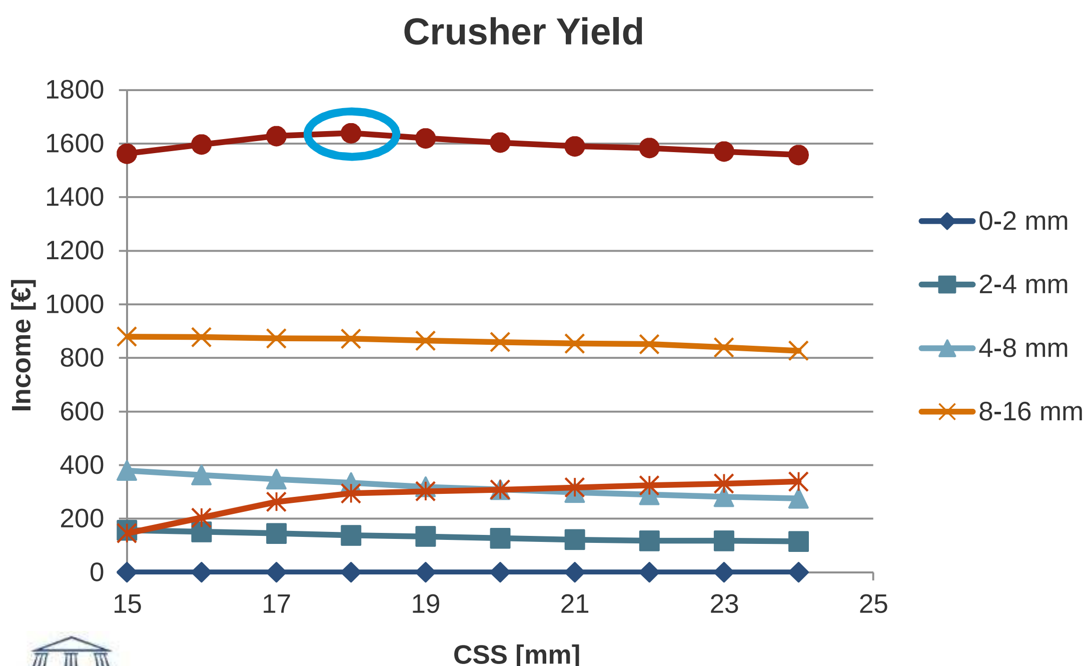
Planning → Sampling → **Analysis** → Optimization

- Entering all the values into MS Excel makes this easy to get production capacities.
- Still difficult to determine the optimal setting



Optimization of a Final Crushing Stage

Planning → Sampling → Analysis → **Optimization**



- Use the price* per ton for all products:
  - 0-2 mm: € 0 (by-product)
  - 2-4 mm: € 8.90
  - 4-8 mm: € 10.00
  - 8-16 mm: € 12.20
  - 16-22 mm: € 7.80
- Make an income graph by combining prices with capacity

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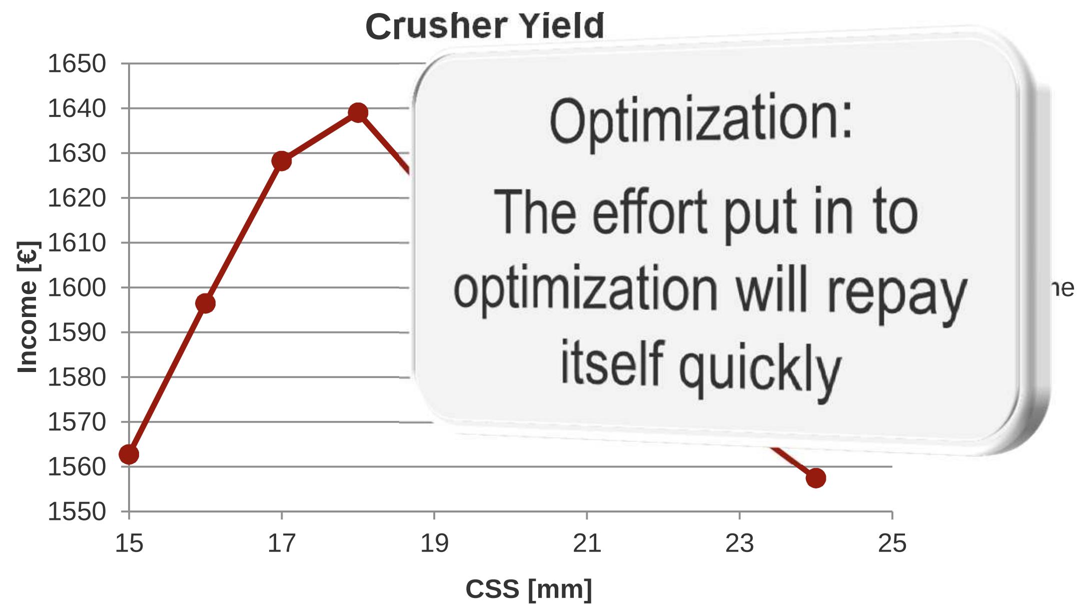
*All prices are estimates based on publicly available data

Optimization of a Final Crushing Stage

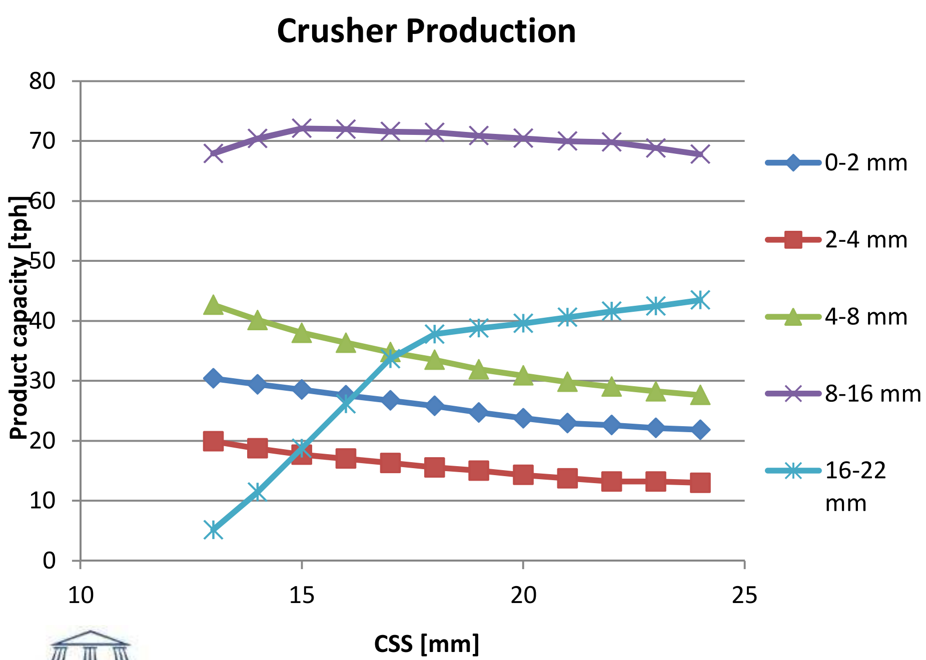
Planning → Sampling → Analysis → Optimization

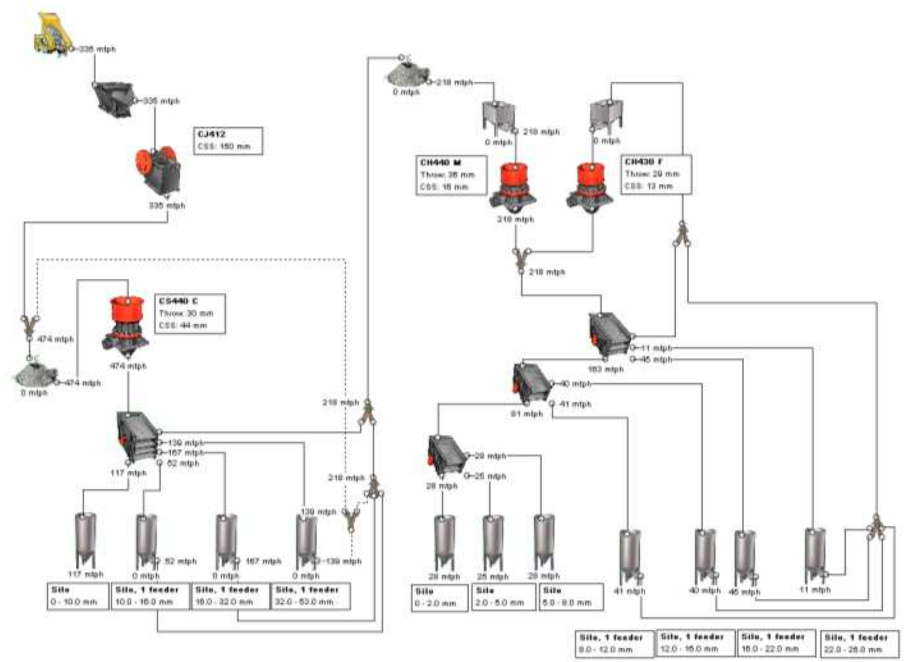
- What difference does it make?
- Running the crusher 2 mm off:
  - Decrease the profit by 43€/h
  - Running the crusher at 1600 hours per year: 43*1600=68800 €



Crusher Performance Map

Planning → Sampling → Analysis → Optimization





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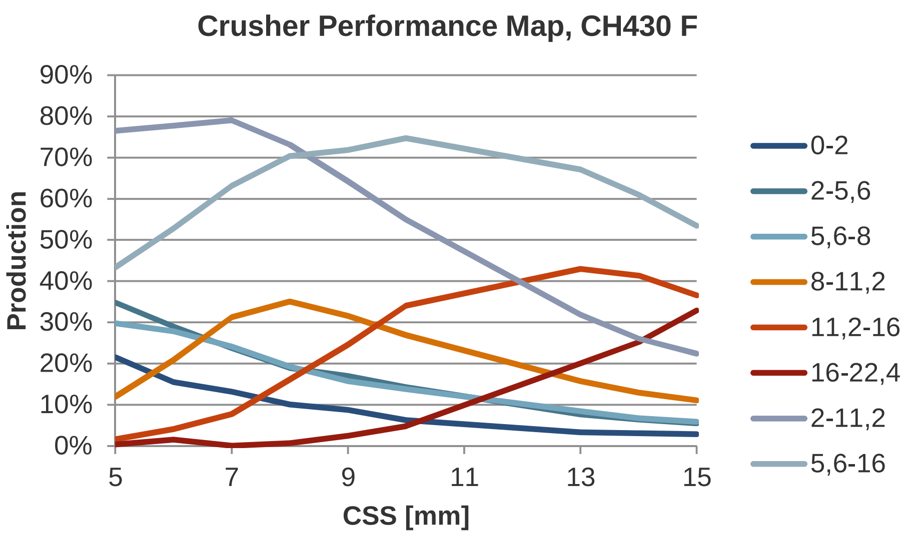
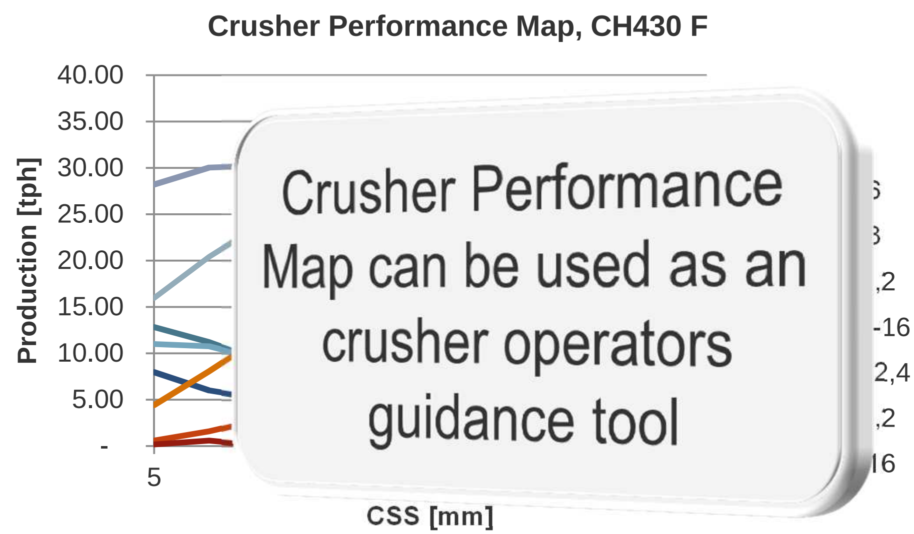
Crusher Performance Map

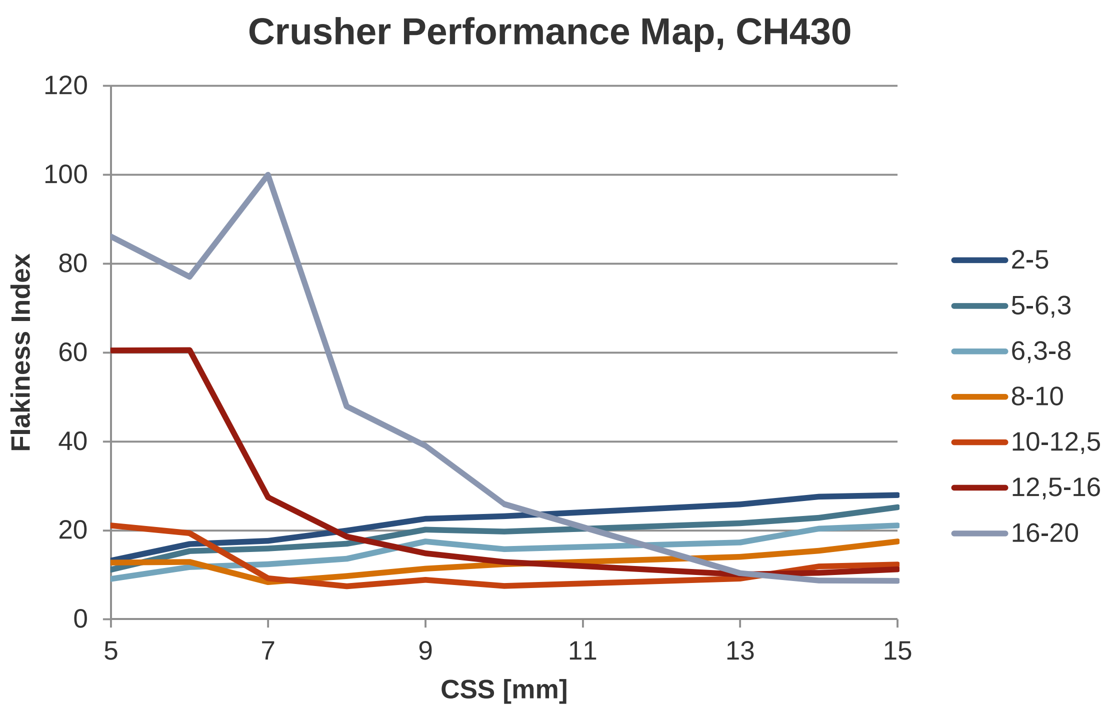
Crusher Performance Map from real data





Crusher Performance Map

Crusher Performance Map from real data



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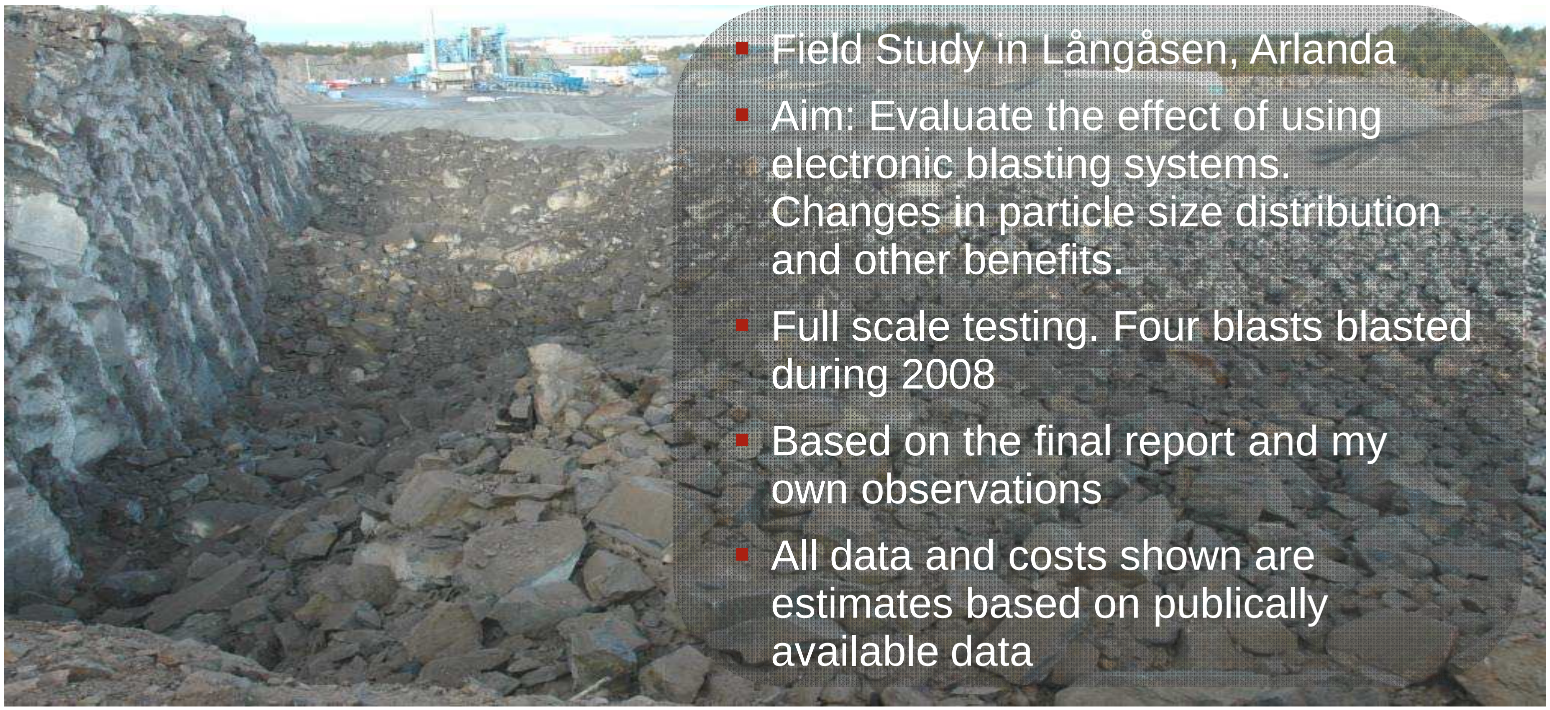
Questions?

MinBaS II
Optimized blasting



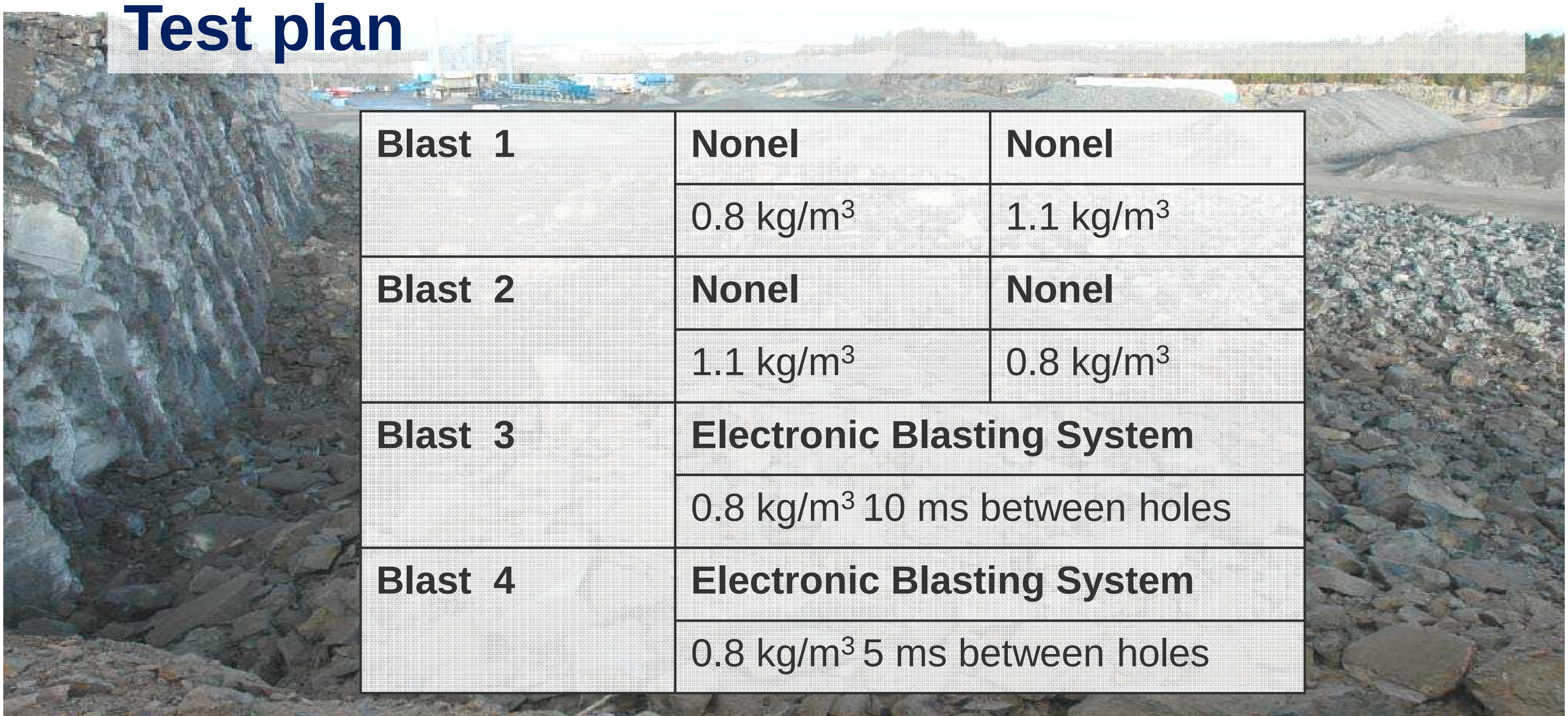
- Field Study in Långåsen, Arlanda
- Aim: Evaluate the effect of using electronic blasting systems. Changes in particle size distribution and other benefits.
- Full scale testing. Four blasts blasted during 2008
- Based on the final report and my own observations
- All data and costs shown are estimates based on publically available data

The Study

- Comparisons between the cost and earnings for different blasting strategies.
- Conclusions and recommendations

The Quarry
Långåsen, Arlanda

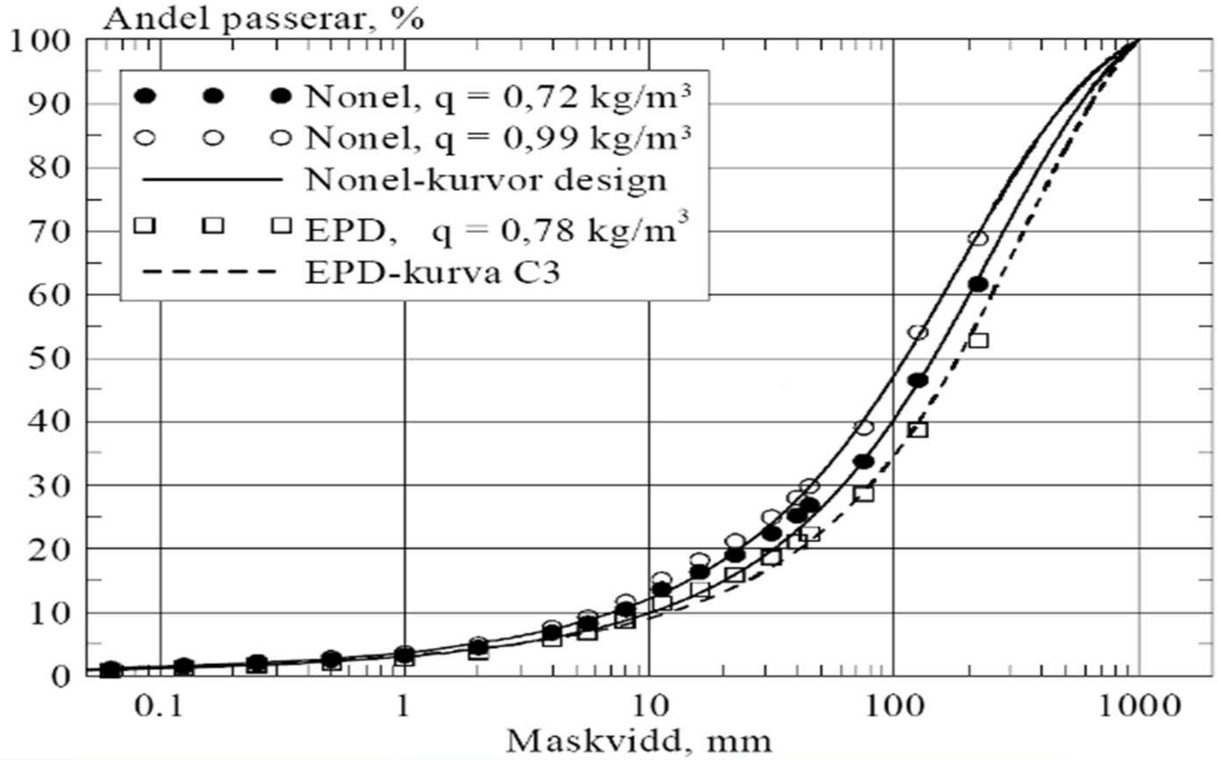
Blasted Material
Test plan



Blast 1	**Nonel**	**Nonel**
	0.8 kg/m^3	1.1 kg/m^3
Blast 2	**Nonel**	**Nonel**
	1.1 kg/m^3	0.8 kg/m^3
Blast 3	**Electronic Blasting System**	
	0.8 kg/m^3 10 ms between holes	
Blast 4	**Electronic Blasting System**	
	0.8 kg/m^3 5 ms between holes	

Blasting result

Measuring the Particle Size Distribution



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Blasting result

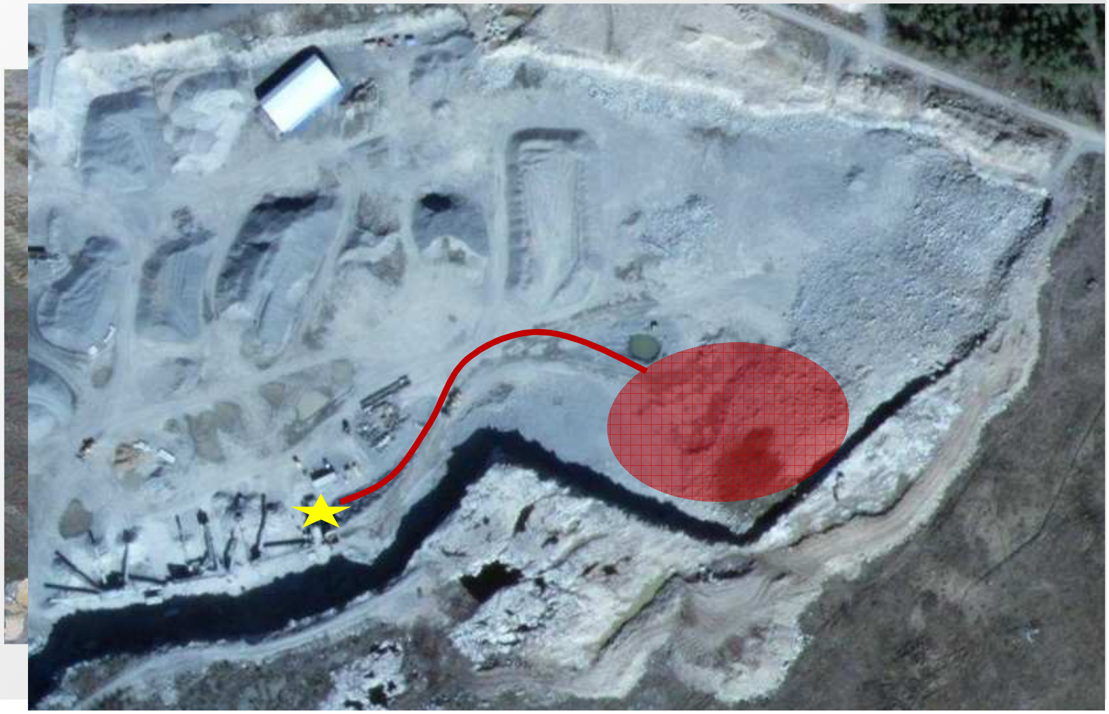
Cost analysis

	Nonel norm. q [€/ton]	Nonel high q [€/ton]	EPD norm. q [€/ton]
Drilling and Blasting	0.67	0.92	0.72
Added cost for detonators	0.00	0,00	0.22
Bolder Management	0.22	0.16	0.11
Sum [€/ton]	**0.89**	**1.08**	**1.05**

Loading and Hauling

Conditions and Measurments

- Loading and Hauling to primary crusher
    - Wheel loader carries the material from the muck pile to the crusher
- Conducted studies
    - Measurment of wheel loaded loading times
    - Measurment of loaded material [tph]
    - Manual timing during several days



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Loading and Hauling

Cost analysis

	Nonel norm. q	Nonel high q	EPD norm. q
Contractor [€/h]	333	333	333
Loading Capasity [tph]	298	316	313
Cost [€/ton]	1.12	1.05	1.06
Sum incl Drilling and Blasting [€/ton]	0.89+1.12= =2.01	1.08+1.05= =2.13	1.05+1.06= =2.11

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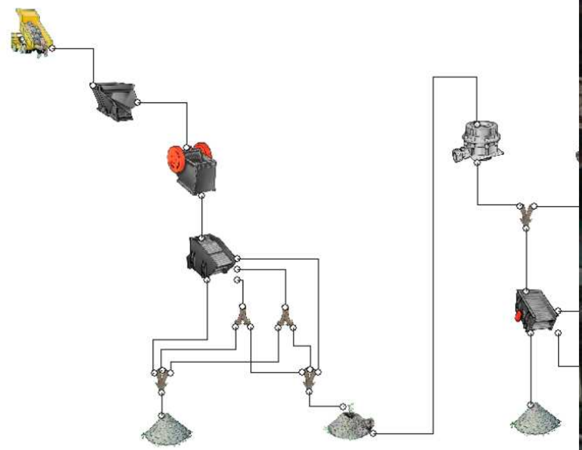
Crushing and Screening

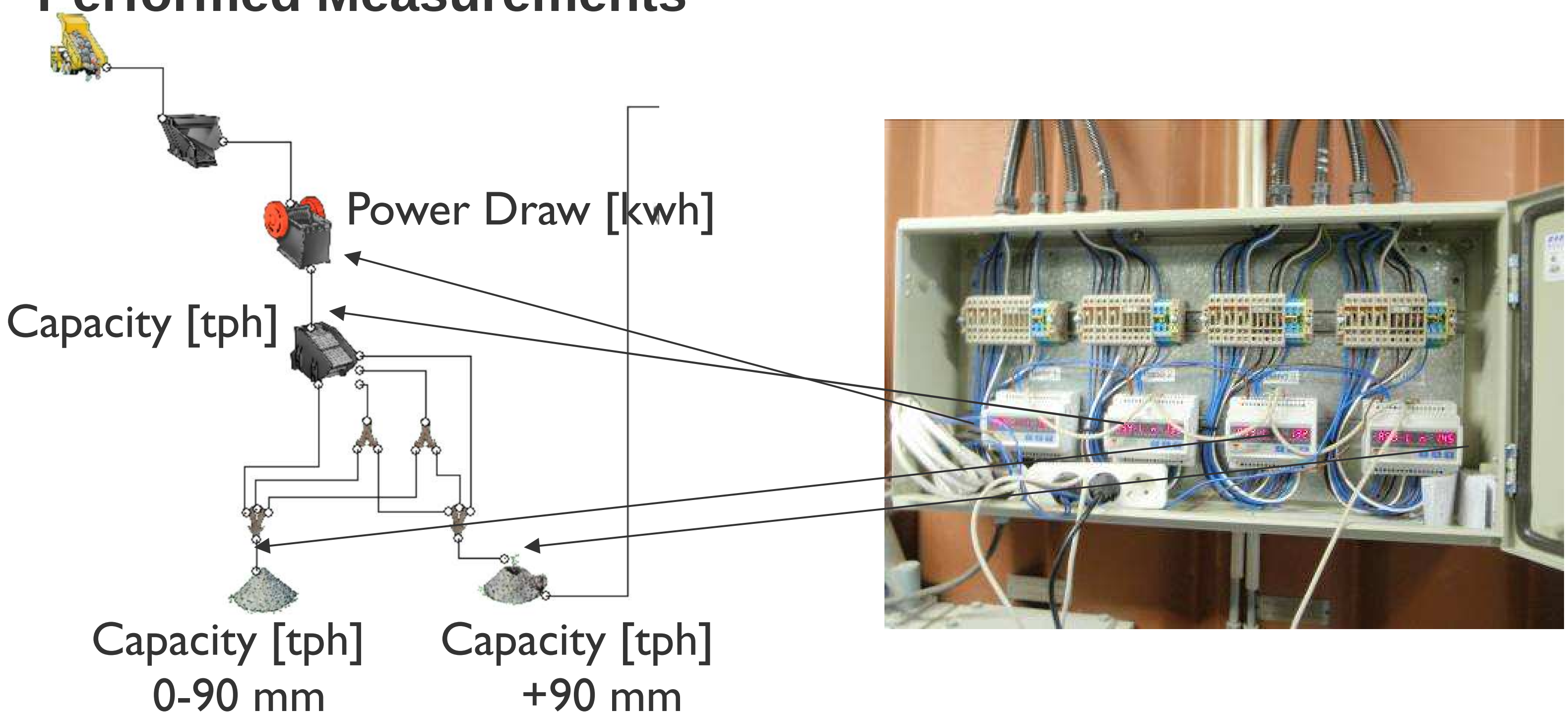
Plant Setup and Conditions for the Study



0-90 mm   +90 mm

Crushing and Screening

Performed Measurements



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Crushing and Screening

Cost analysis

	Nonel norm. q	Nonel high q	EPD norm. q
Power Draw (kWh/ton)	**0.3**	**0.25**	**0.35**
Energy Cost (0.22 €/kWh)	**0.07**	**0.06**	**0.08**
Fixed Cost [€/h] **[€/ton]**	**555** **1.80**	**555** **1.70**	**555** **1.70**
Cost [€/ton]	**1.87**	**1.76**	**1.78**
Sum incl D&B och L&H [€/ton]	0.89+1.12+1.87= **=3.88**	1.08+1.05+1.76= **=3.89**	1.05+1.06+1.78= **=3.89**

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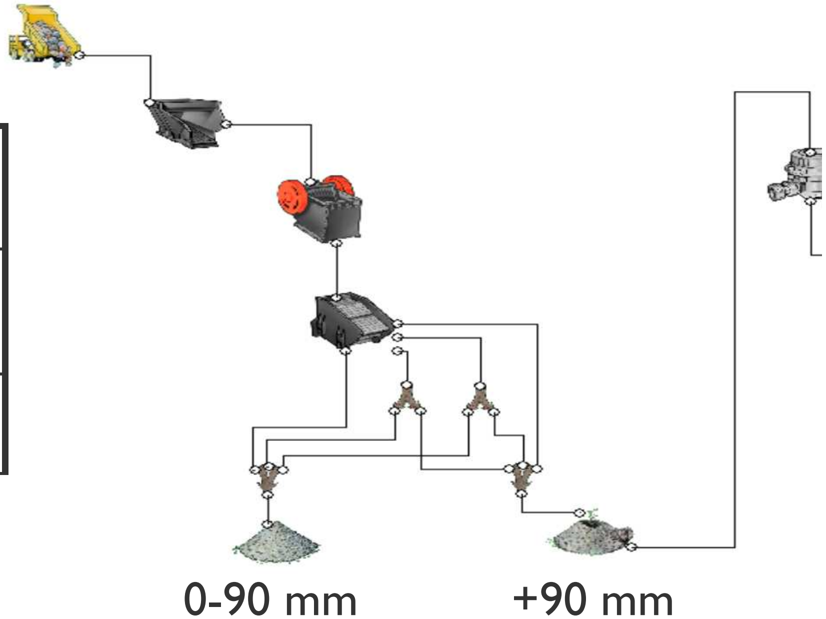
Quarry Production

Total cost $/h

	Nonel norm. q	Nonel high q	EPD norm. q
Production rate [tph]	298	316	313
Cost [€/h]	**1343**	**1412**	**1425**

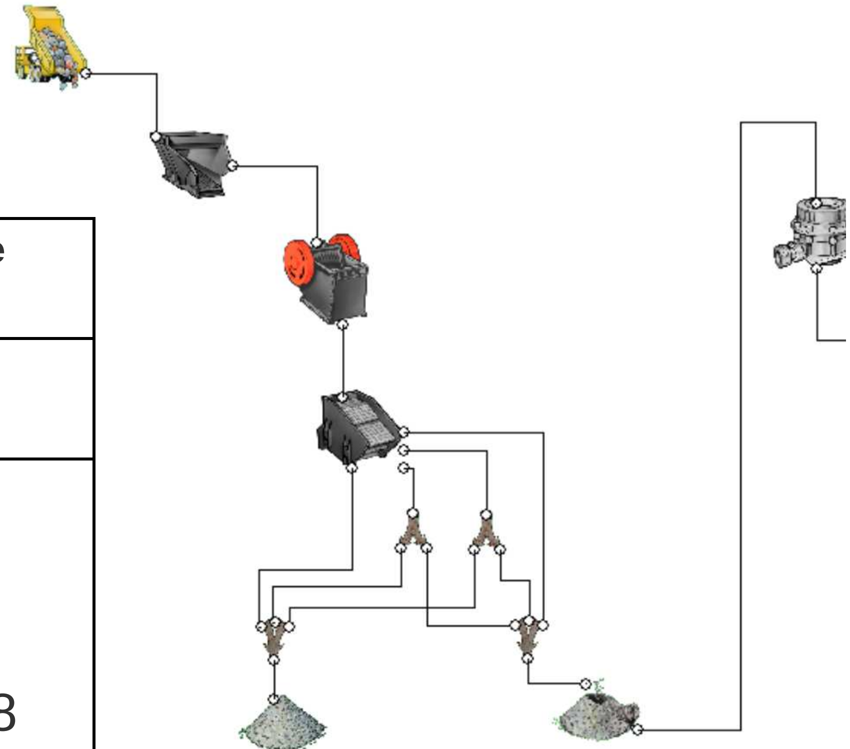


Distribution between 0-90 mm and +90 mm is partly controlled by the blasting result

Quarry Production

Product Price

Fraction [mm]	Price [€/ton]	Crushing stage	Ave. Price [€/ton]
0-90	8.89	1 (Prim.)	8.89
0-4	14.33	3-4	15.78
4-8	15.44		
8-11	17.67		
11-16	16.78		
16-32	15		



0-90 mm
8.89 €/ton

+90 mm
15.78 €/ton

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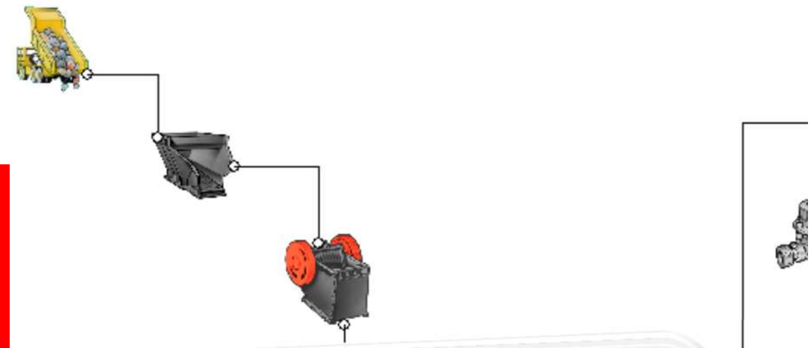
Quarry Production

Revenue €/h

	Nonel norm. q	Nonel high q	EPD norm. q
Production rate [tph]	**298**	**316**	**313**
Cost [€/h]	1343	1412	1425



Minimizing cost does not necessarily maximize profit

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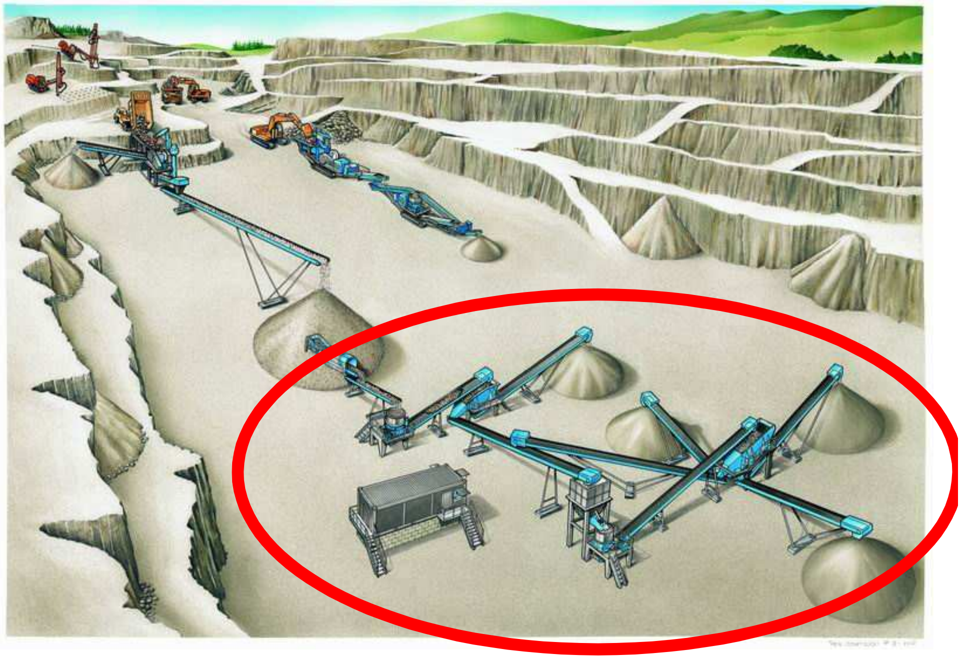
Conclusions

- From the tested blasting alternative Electronic Blasting System is the most beneficial.
- Extensive investigations and analysis are necessary in order to determine the optimal solution. Many areas are effected by the blasting result.
  - Drilling and Blasting
  - Bolder Management
  - Loading and Hauling
  - Crushing and Screening
- Only studying the costs is not sufficient in order to optimize the process. Most expensive solution did also generate the most profit.


Questions?

What about Optimizing the Crushing and Screening Process?

- Optimizing a single crusher can be done manually as seen earlier
- Optimizing several crushers?
  - Combination of equipment setting
  - Production situation, what products are demanded and what are not?



Processes

Infrastructure for optimization

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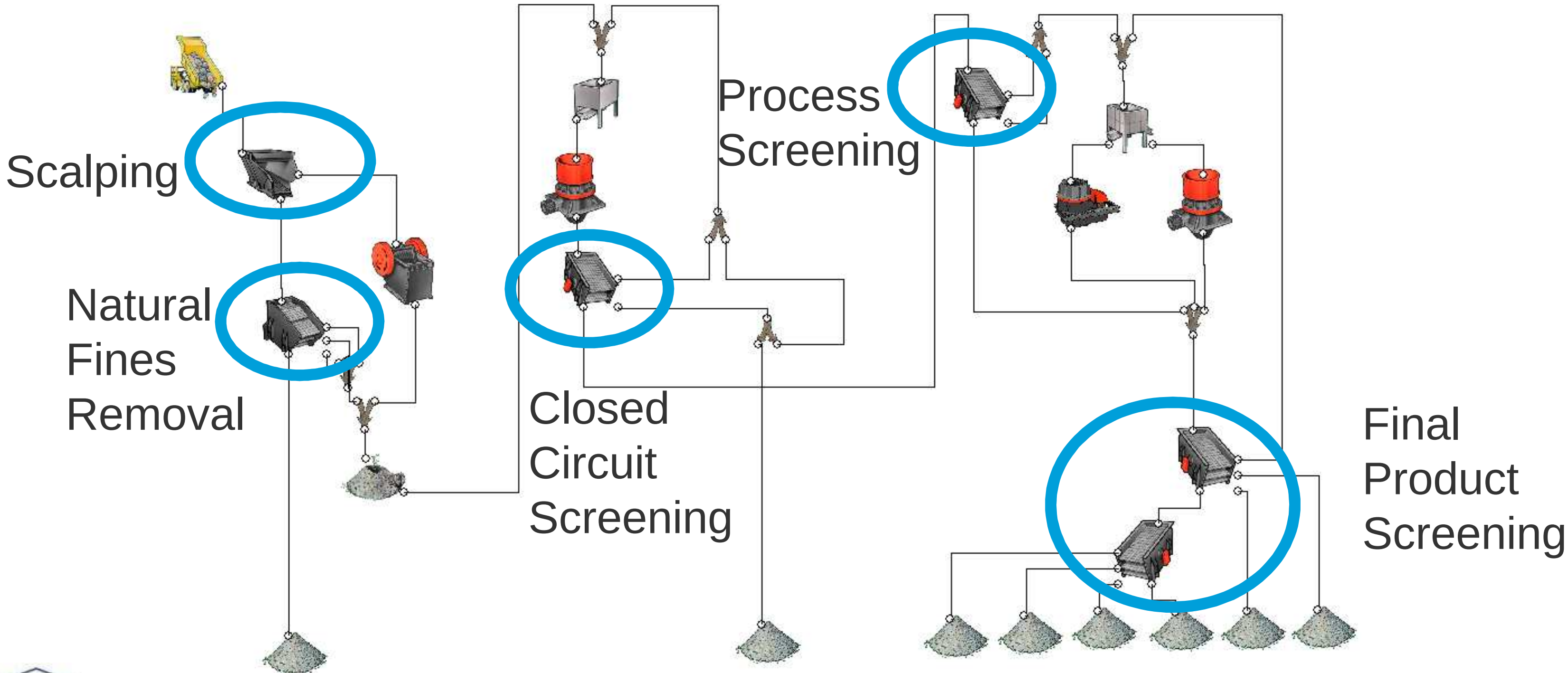
Processes

- Putting Crusher and Screens together to form processes
  - Screening duties
  - Open and Closed Circuits
  - Benefits and disadvantages with different circuit configurations.
  - Special Circuits
  - Combining Circuits to form plants

Processes

The different screening tasks



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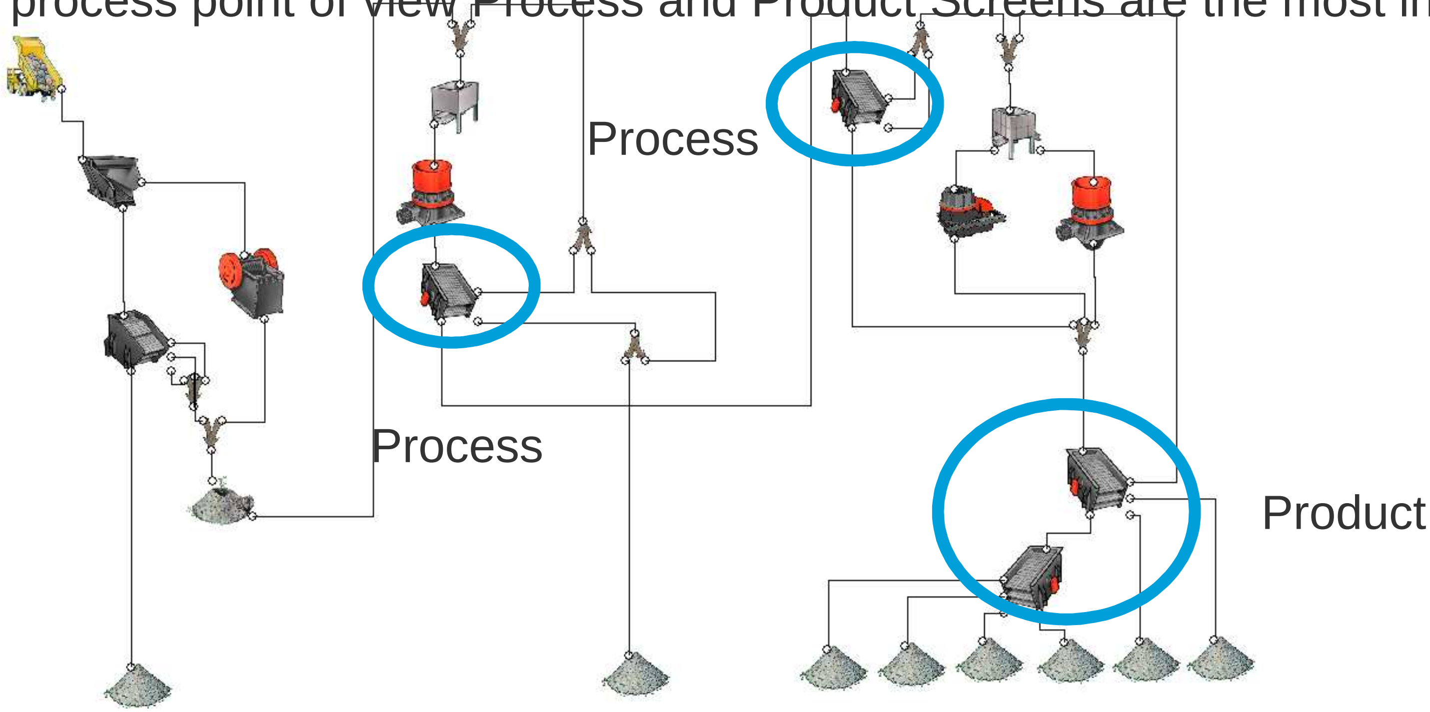
Processes

The different screening tasks

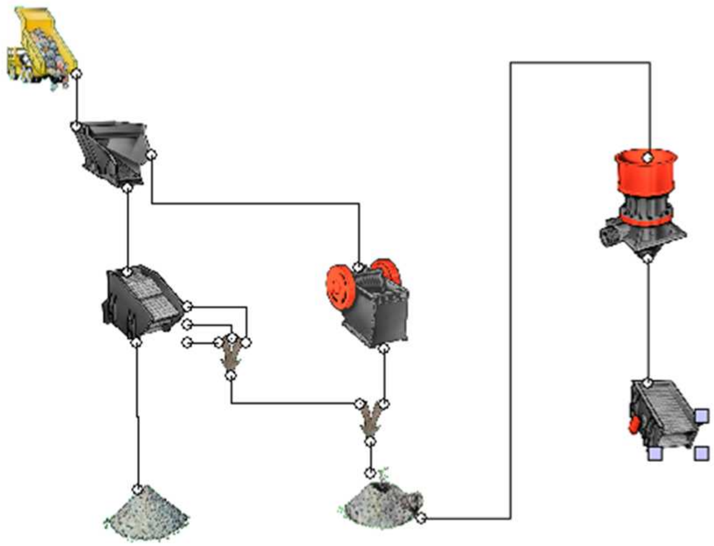
From a process point of view Process and Product Screens are the most interesting



Processes

Open Circuit

- The material will not pass the crusher more then once
- Limited size of crushers and screens
- Material will have improved quality
- Top size control
- Primary and Secondary Applications



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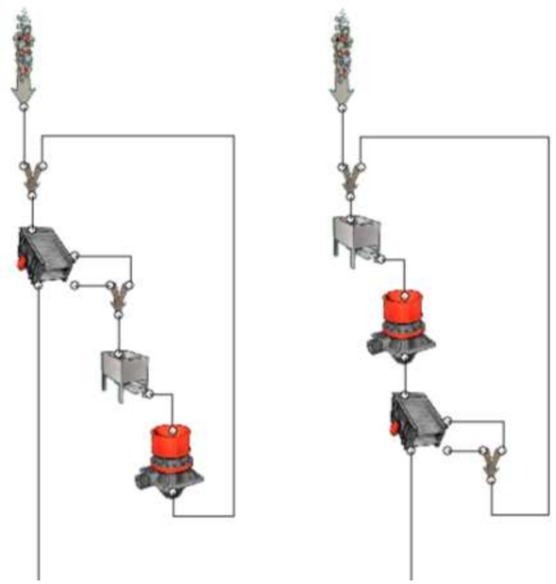
Processes

Closed Circuit

- All or parts of the material will pass the crusher at least one time.
- Screens placed in order to return over size material to crusher.
- Top size control.



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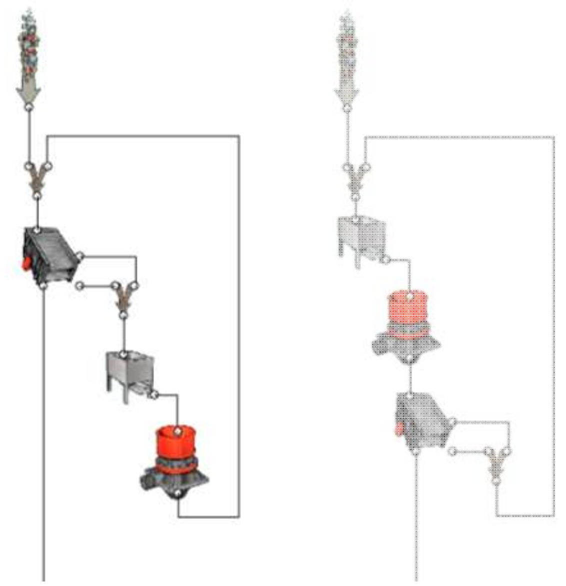
Processes

Closed Circuit

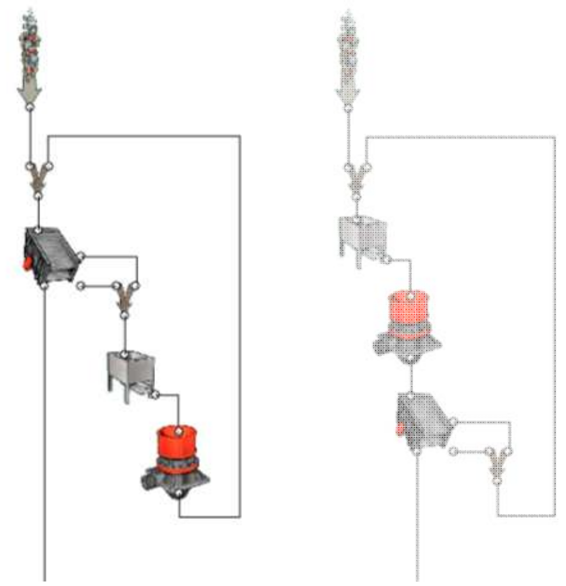
- Pre crusher screening
  - Finished material removed before crusher
  - Consider the quality of the by passed material



Processes

Closed Circuit

- Post Crusher Screening
  - Large crusher needed
  - Will improve the product quality
  - More material in the crusher generates more wear
  - Closed side setting will have a great effect on the circulating load, might effect overall circuit capacity



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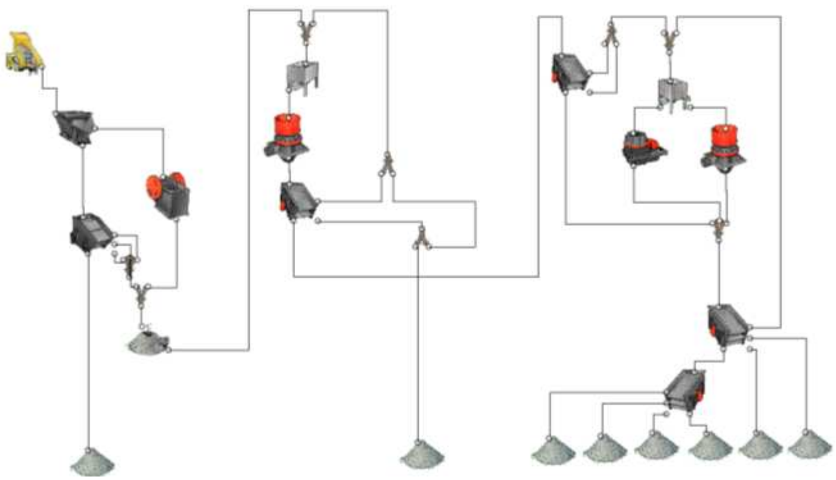
Processes

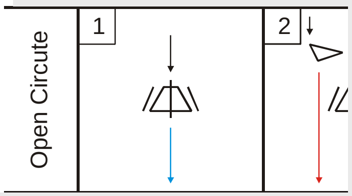
Open and Closed Circuits

- When designing crushing plats a combination of different crushing circuits are needed.
- Combining Crushing Stages to optimum performance is very difficult.
- Saving in one stage might cost more in the next.
- Simulation program is needed.



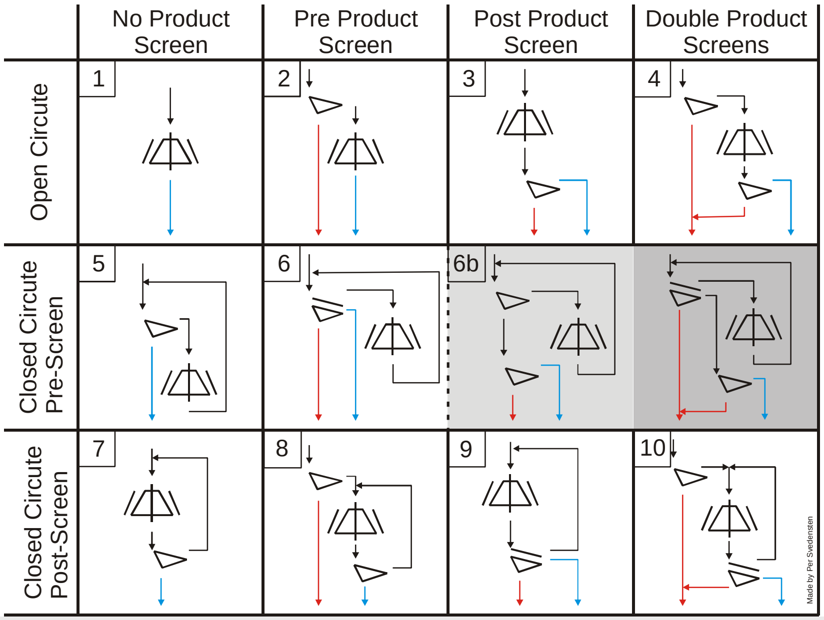
Processes

Selecting and Combing Circuits



Processes

Selecting and Combing Circuits



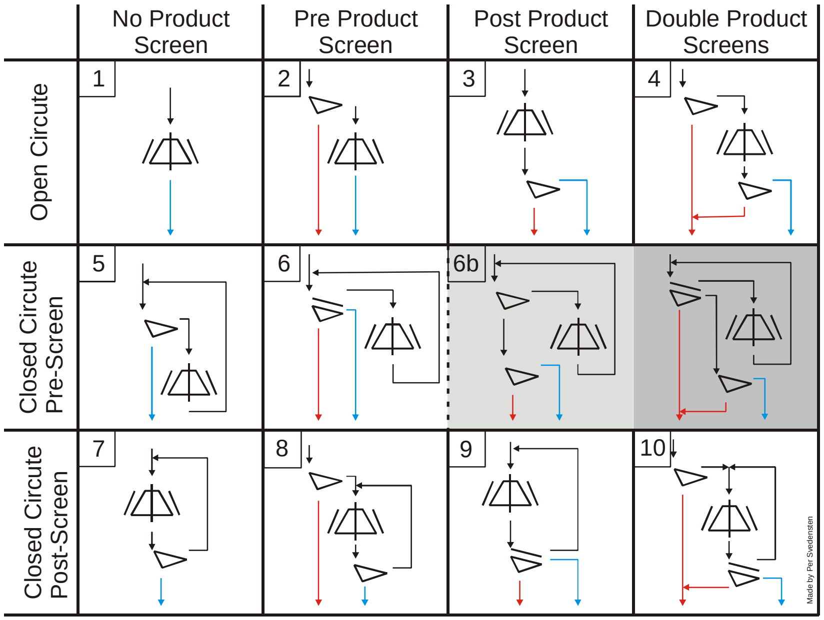
+ Limited size of crushers and screens
+ Material will have improved quality
- No Top size control

+ Smaller sized crusher can be used
-/+ Some quality improvment in all material
+ Top size control

+ Material will have improved quality
+ Top size control
- Bigger sized crusher is needed

Processes

Selecting and Combing Circuits



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-/+ Some quality improvment in all material
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+ Material will have improved quality
+ Top size control
- Bigger sized crusher is needed

- Only one product

- By-pass material will not improve in quality

+Improved quality in all material

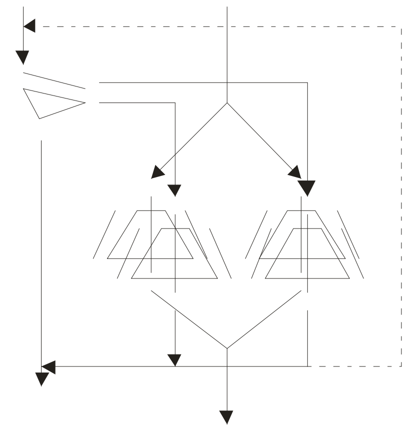
- Cost for screens
- By-pass material will not improve in quality

Note: Quality is defined as strenght and average shape

Processes

Special Circuits

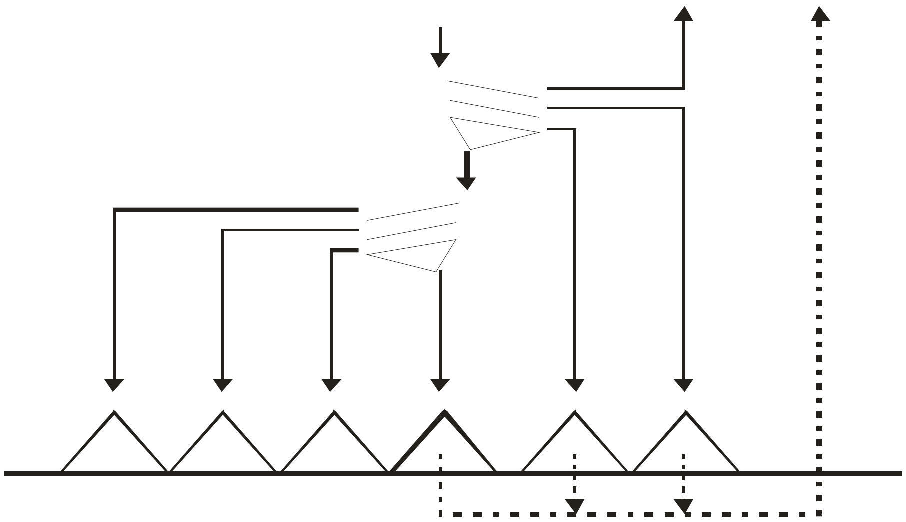
- Selection screen
  - Combining two crusher in one stage.
  - Increases flexibility and makes process adjustment easier.
- Parallel Crushers
  - Flexibility in capacity
  - Run at different settings to get a wide curve
  - Better shaped material in a wide part of the product.



Processes

Screening Stages

Final screening in order to make several products
Consider possibilities for re-crushing products



Processes

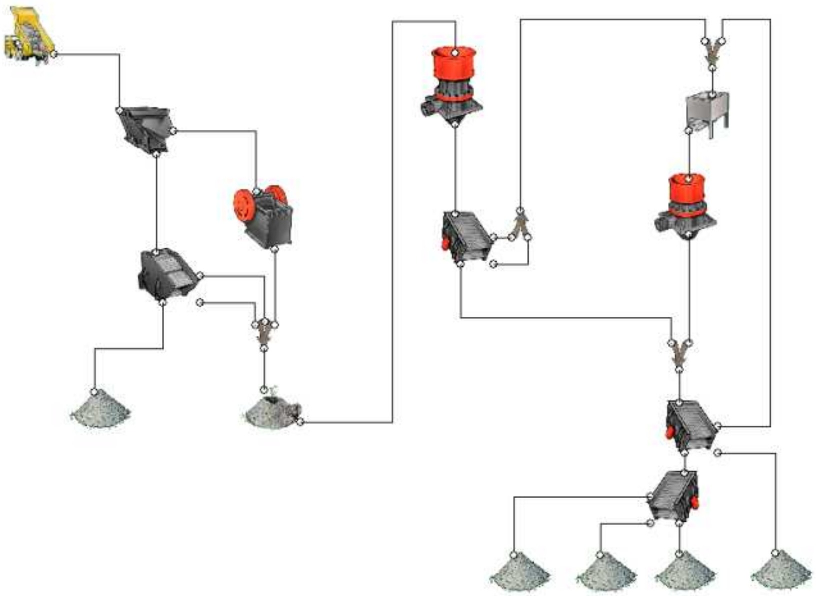
Summary and Conclusions

- Equipment performance is the starting point for process performance.
  - Selecting the right equipment for the right task
- Processes and plants can be configured in many ways
  - Understanding the pros and cons of processes and how to combine processes is important.
- Different types of circuits
  - Open/Closed
  - Product Screen / Process Screen
  - Screening before / after crusher

Crushing plant optimization using TCO

Objective of project

- To optimize the crushing plant using computer optimization
- Use sampling to calibrate the computer model in order to increase model accuracy
- Optimize with the goal to maximize gross profit



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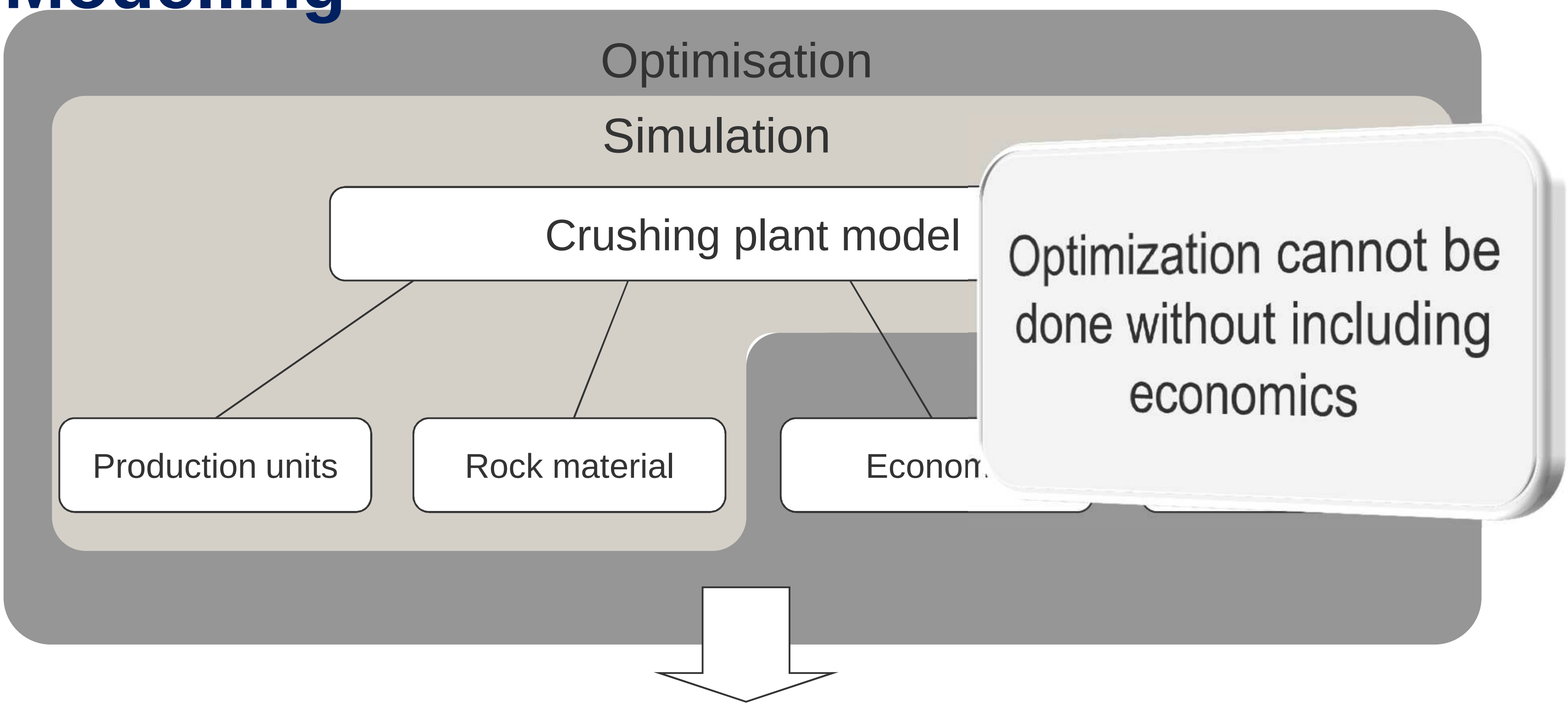
Modelling



Yield the most profitable production strategy and meet the market demand

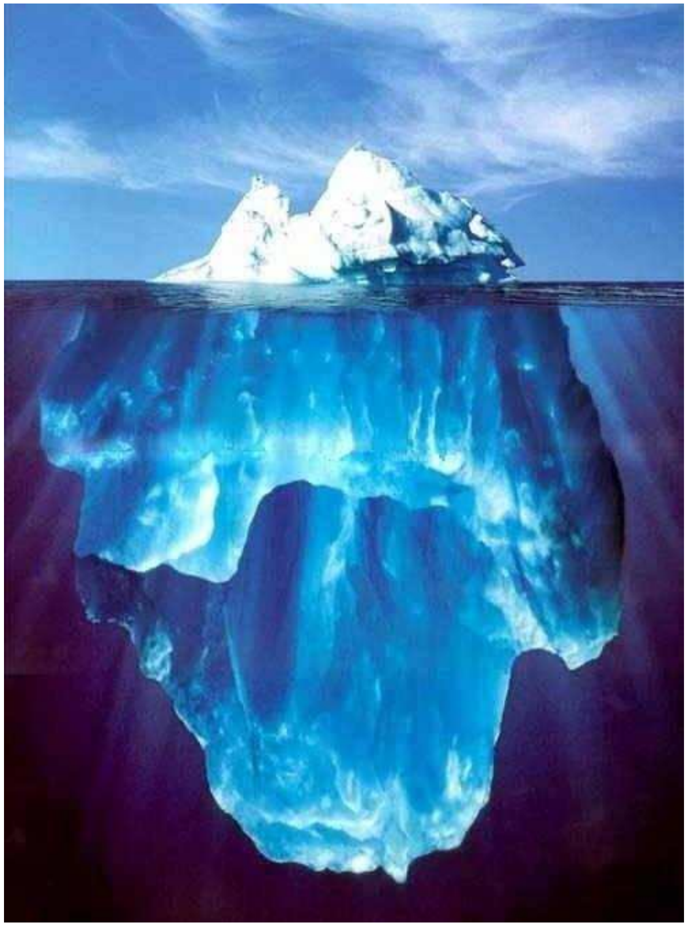
Total Cost of Ownership

- A method to estimate the life cycle cost of equipment.
- NOT for deciding to invest!
- One method to calculate and compare cost for products or processes
- Purpose
  - Mean production cost per ton
  - Compare and evaluate different equipment solutions
  - Crushing Plant Optimization
  - Total analysis of quarry operation, combine with other processes

Total Cost of Ownership

Relations between costs

- Some costs are more visual then others
- Often other costs and performance figures will have a bigger impact on the ownership cost and earnings. Investment cost is just the top of the iceberg.
- TCO will bring light on the entire Iceberg, not just the normally visible top.



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Total Cost of Ownership

- Includes equipment performance
- Divided into: Ownership and operating costs.
  - Ownership typically fixed costs
  - Operating cost typically variable
- Even more powerful when used on systems of equipment.
  - Crushing and Screening Plant
  - Load and haul systems
- Considers Availability and Utilization

Included in the TCO calculation

Area of interest

- Aimed at the crushing and screening process
- Vehicles needed for plant operation is in the boarder area for the calculation
- Most difficult to handle is how the plant is operated.
  - Maintenance policy – Repairs


Included in the TCO calculation

Area of interest

- It is important to establish the correct level of details when estimating costs
- To detailed:
  - Enormous amount of work
  - The extra work will give little benefit
  - Small changes or uncertainties will ruin the work
- Not detailed enough:
  - Changes in production will not affect the costs. Optimization and other analysis are not possible.

Cost Calculation

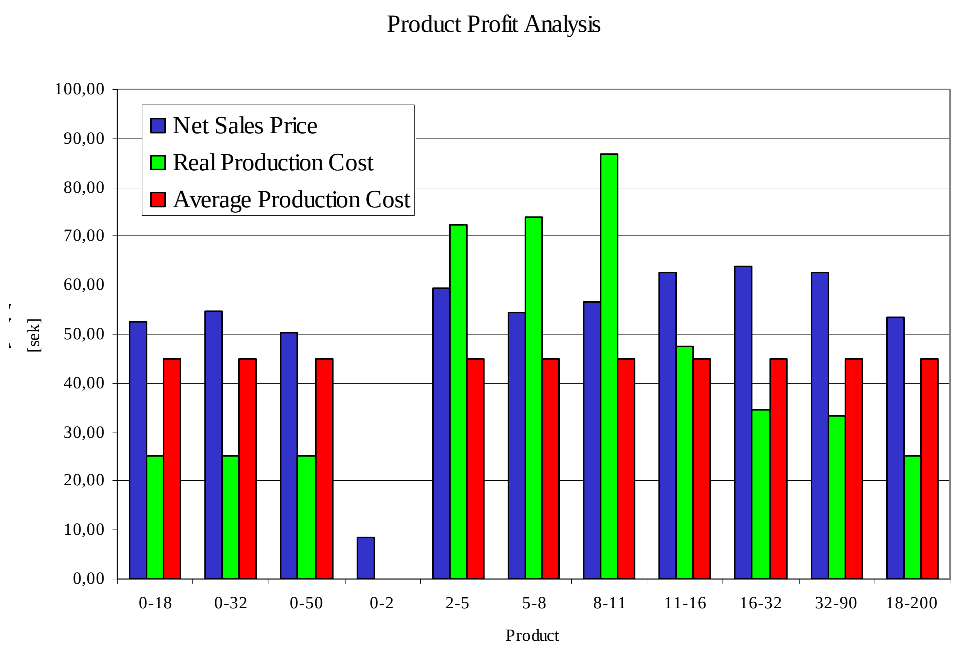
The Difference between getting it right and wrong

Using ‘Real’

The production cost

Using Average Cost

The production cost is summed up and divided equally



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TCO and Gross Profit

- Included in cost the calculation
  - Raw material
  - Depreciation
  - Interest
  - Energy cost
  - Wear parts replacement
  - Service cost
  - By-product production
  - Personnel

- Income calculation
  - Sellable products
  - Product demand

- Other factors included that effects the gross profit
  - Availability
  - Utilization

TCO and Gross Profit

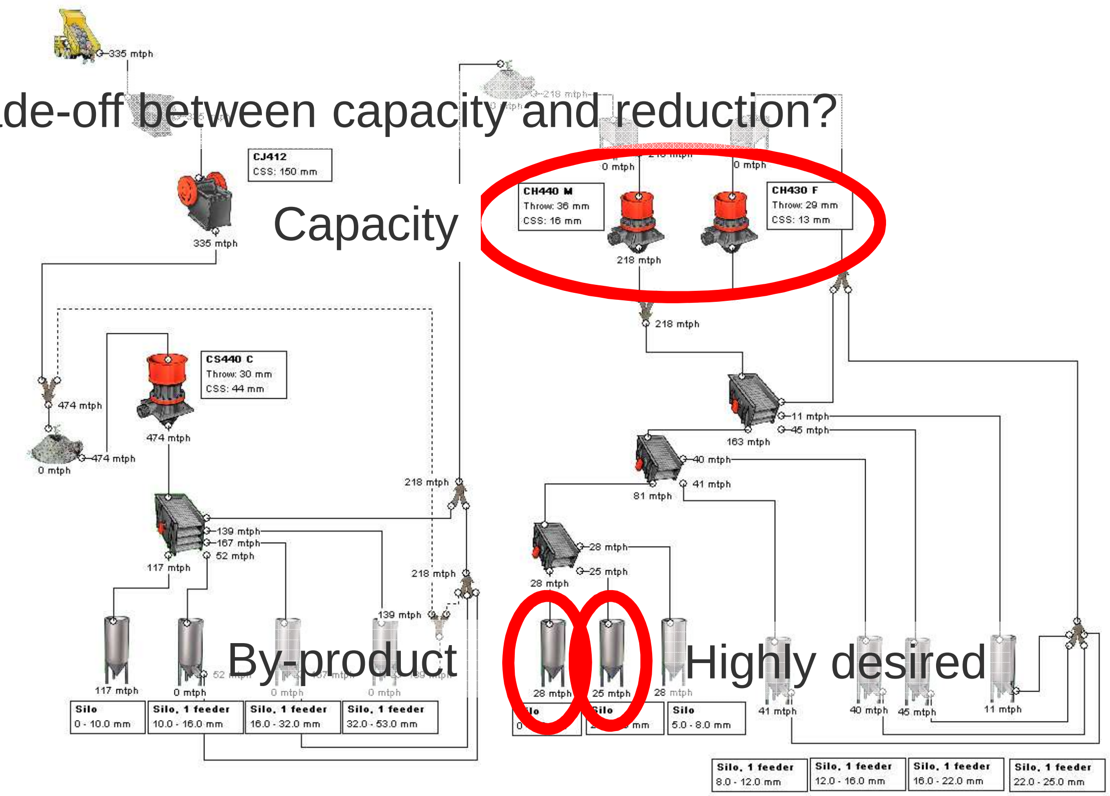
Does in look difficult?

- Some parts are difficult
- Strategy: Do your best, make estimations and guesses, and you will be close to the actual cost!

Crushing plant optimization using TCO

Plant Challenges

What is the best trade-off between capacity and reduction?



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Crushing plant optimization using TCO

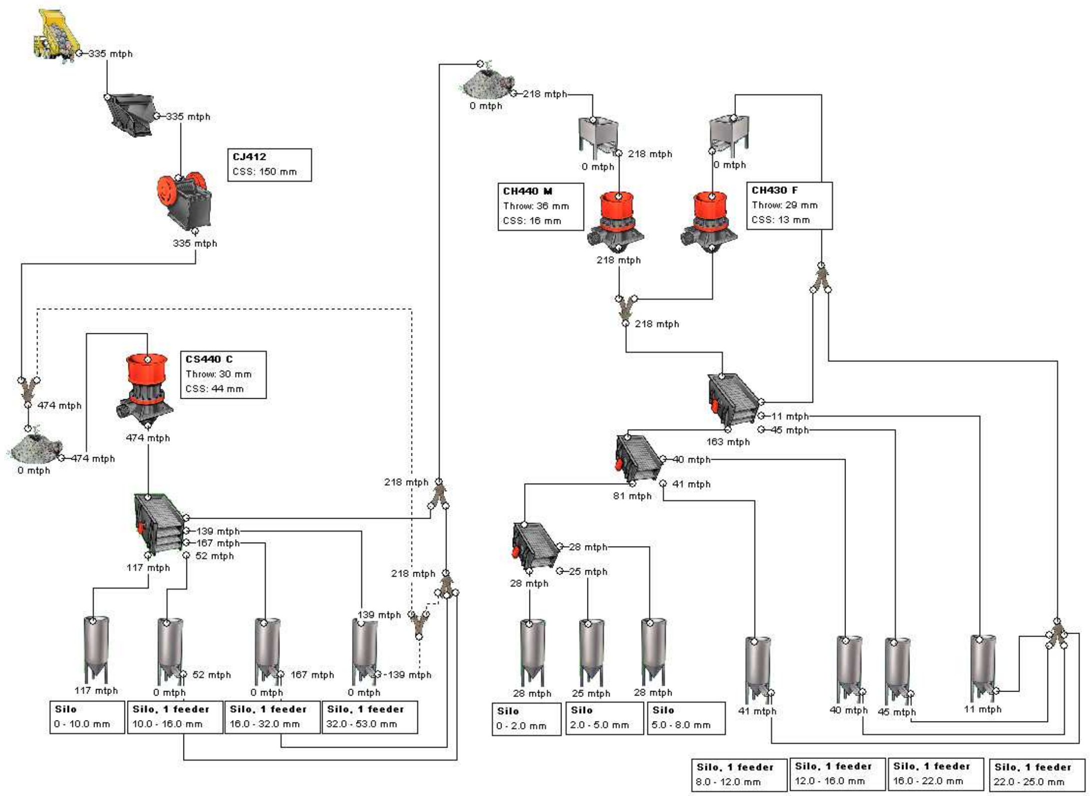
Test plant

In normal production following CSS are utilized:

Secondary crusher	CSS 44 mm
Tertiary crusher	CSS 16 mm
Quaternary crusher	CSS 13 mm

Products:

- 0-2 mm
- 2-5 mm
- 5-8 mm
- 8-11 mm
- 11-16 mm
- 16-22 mm



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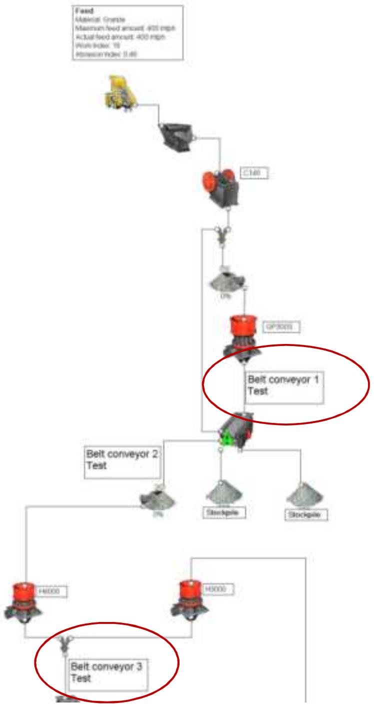
Crushing plant optimization using TCO

Test plan

Objectives for the first test session:

- Measure particle size distribution to calibrate the model
- CSS at original settings



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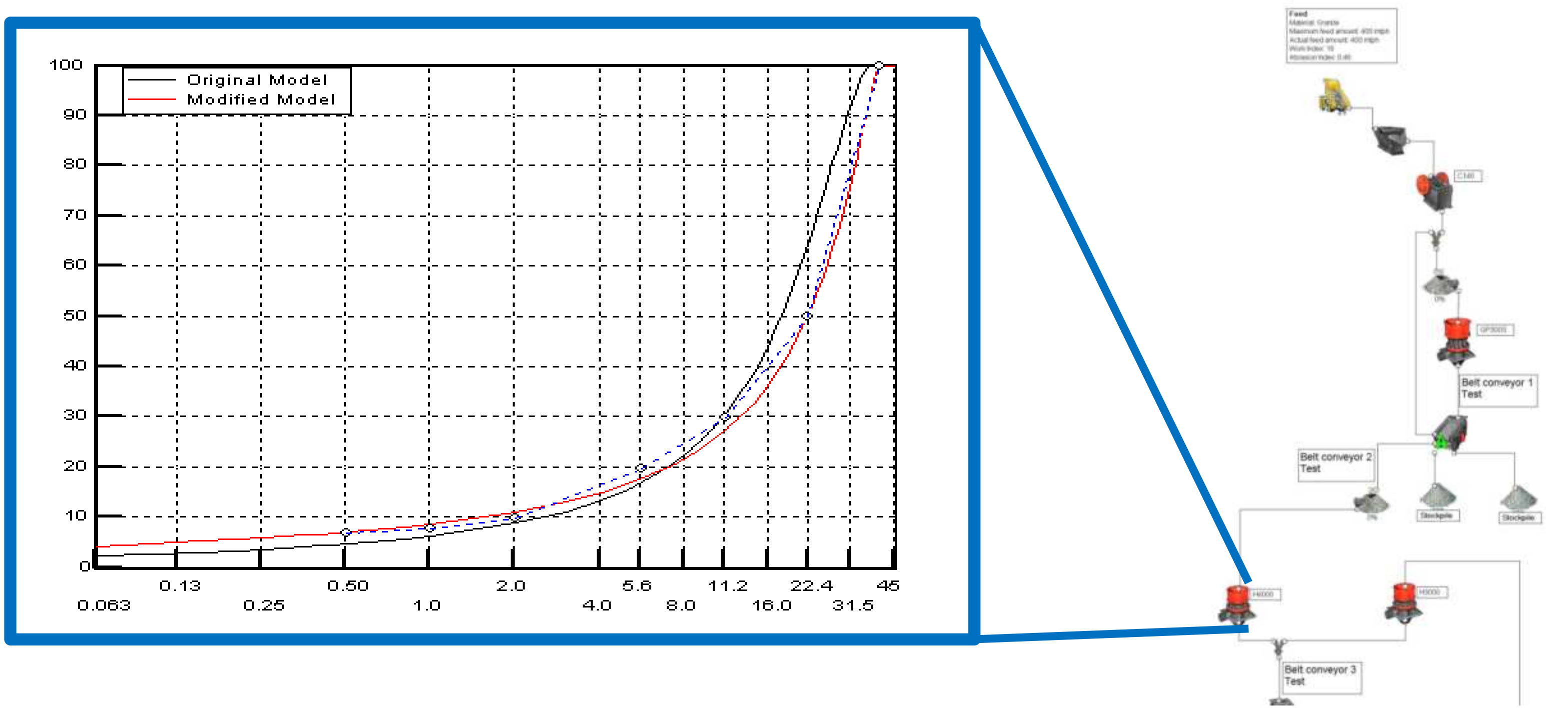
Crushing plant optimization using TCO

Model Calibration



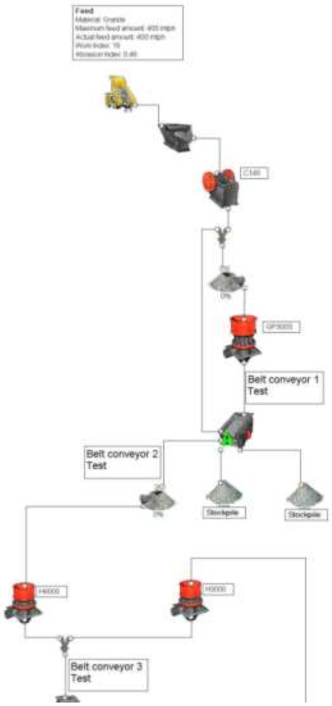
Crushing plant optimization using TCO

Running the TCO optimization module

The computer tool automatically finds the best solution using an optimization algorithm

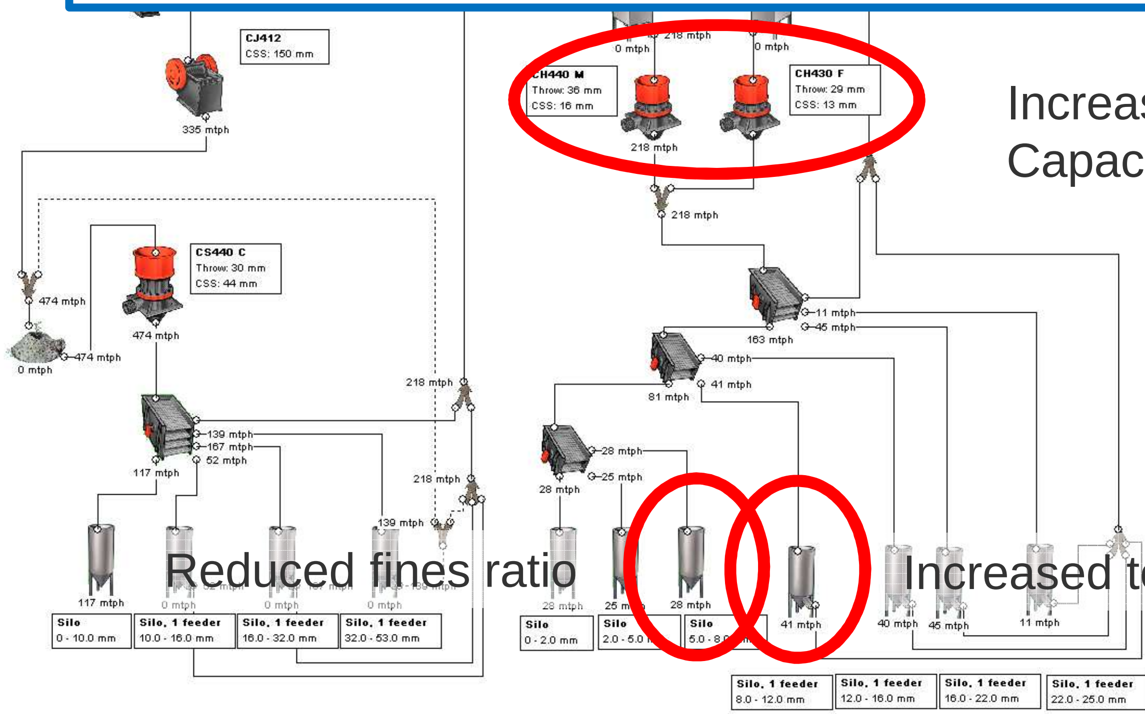
The solution that yields the best profit:

- Secondary crusher CSS 50 mm (44)
- Tertiary crusher CSS 20 mm (16)
- Quaternary crusher CSS 14 mm (13)



Crushing plant optimization using TCO

Result: +11 % in Calculated Gross Profit



Increased Capacity

Reduced fines ratio

Increased total production

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Crushing plant optimization using TCO

- Optimization must be a combination of technical and economic analysis
- Computer optimization can improve productivity
- Model calibration increases accuracy
- Minimizing cost does not necessarily maximize profit
- Combined performance of different machines should be considered. Solves the trade-off between capacity and reduction


Questions?

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