Crushing
Optimizing the Process

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ACADEMY

Improving Processes. Instilling Expertise.

DYNO
Dyno Nobel

SANDVIK

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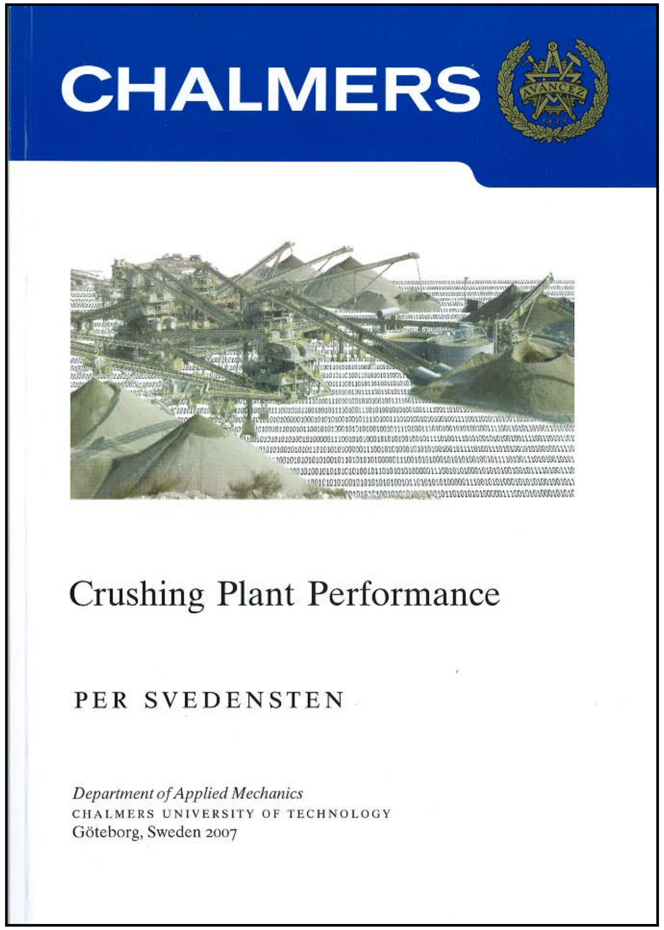
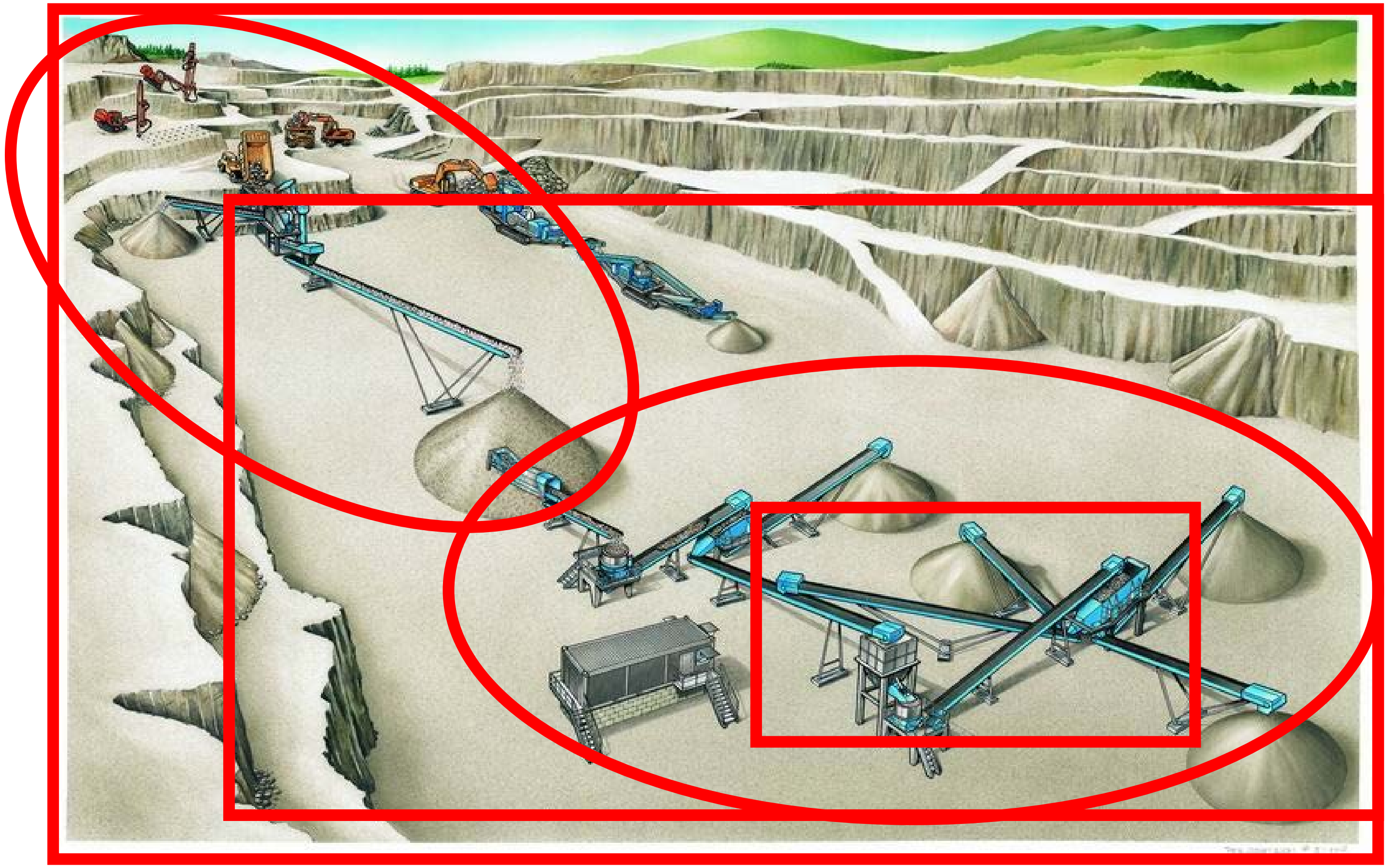
Optimizing the Process

- 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



Crushing Plant Optimization

- Point of interest
  - Crushing stage
  - Crushing plant
  - Quarry Process
- Today:
  - Optimize the feed
  - Optimize the process



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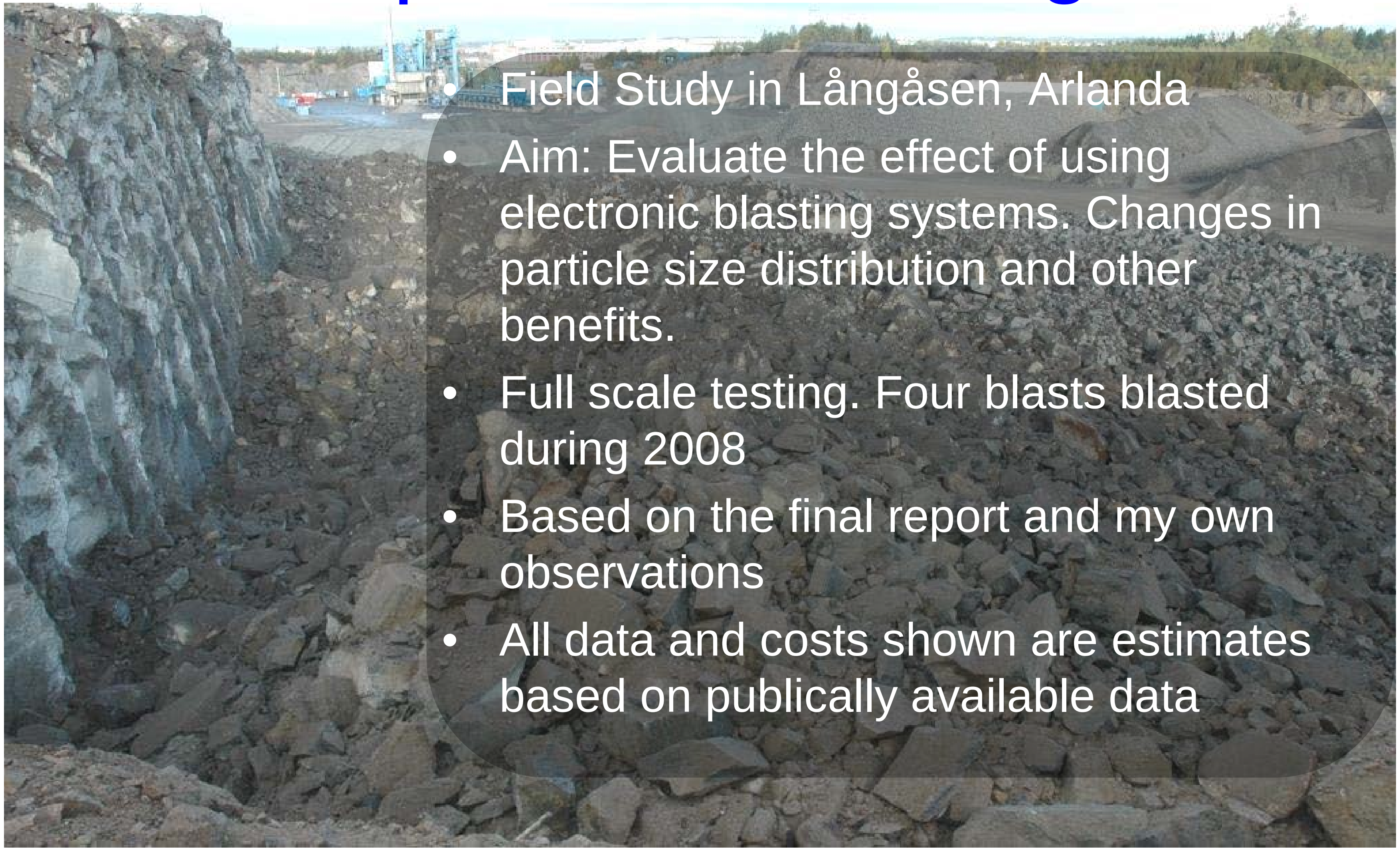
MinBaS II
Optimized blasting



- 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

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The Quarry
Långåsen, Arlanda

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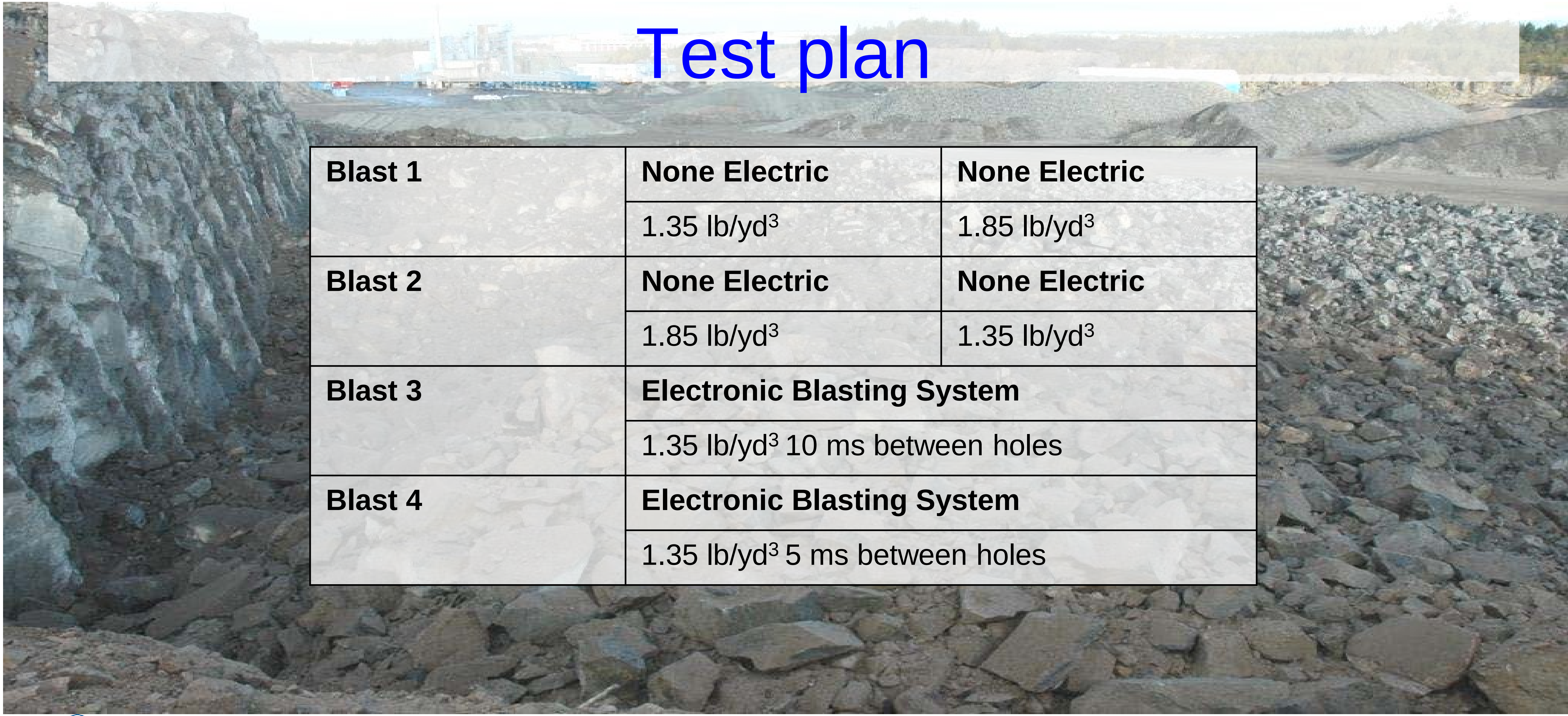
Blasted Material
Test plan



Blast 1	**None Electric**	**None Electric**
	1.35 lb/yd^3	1.85 lb/yd^3
Blast 2	**None Electric**	**None Electric**
	1.85 lb/yd^3	1.35 lb/yd^3
Blast 3	**Electronic Blasting System**	
	1.35 lb/yd^3 10 ms between holes	
Blast 4	**Electronic Blasting System**	
	1.35 lb/yd^3 5 ms between holes	

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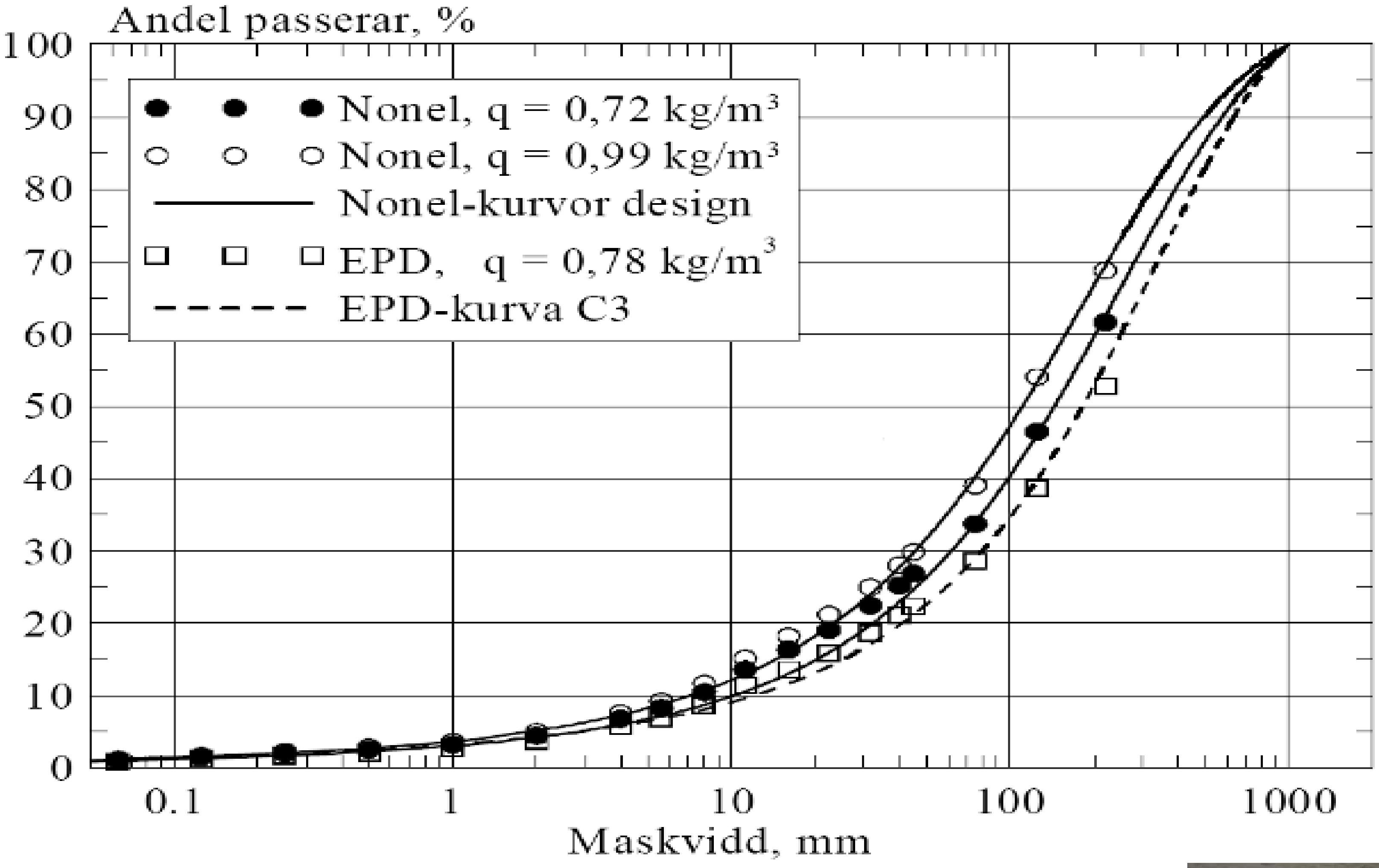
Blasting result

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	0.90	1.23	0.97
Added cost for detonators	0,00	0,00	0.30
Bolder Management	0.30	0.15	0.22
Sum	1.20	1.38	1.49

*Estimates based on publicly available data

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Loading and Hauling
Conditions and Measurments

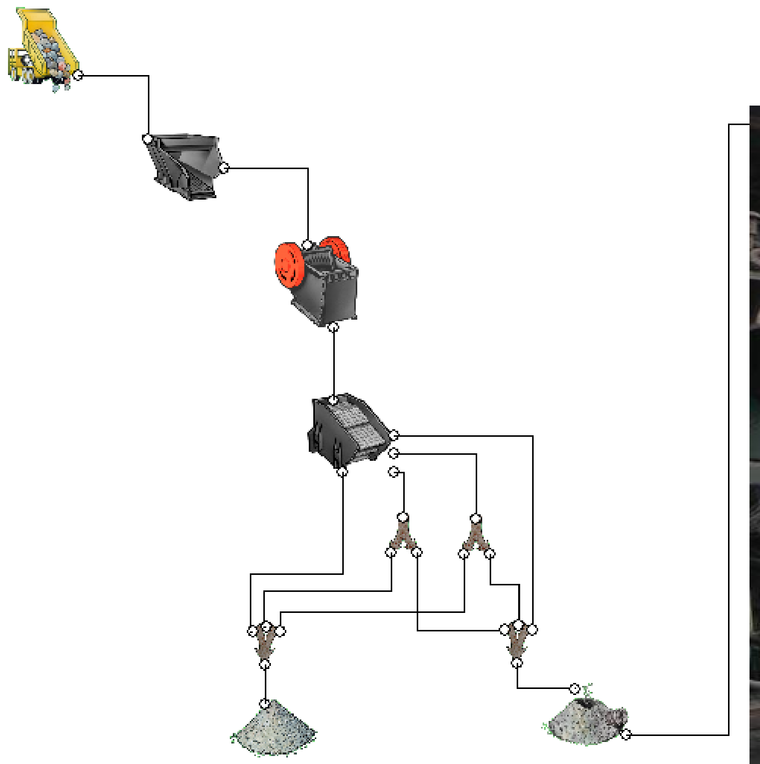
- Loading and Hauling to primary crusher
  - Wheel loader carries the material from the muck pile to the crusher
- Conducted studies
  - Measurment of wheel loaded loading times
  - Measurment of loaded material [tph]
  - Manual timing during several days

Loading and Hauling
Cost analysis

	Nonel norm. q	Nonel high q	EPD norm. q
Contractor [$/h*]	448	448	448
Loading Capasity [tph]	298	316	313
Cost [$/ton]	1.50	1.42	1.43
Sum incl Drilling and Blasting [$/ton]	1.20+1.50= =2.70	1.38+1.42= =2.80	1.49+1.43= =2.92

*Estimates based on publicly available data

Crushing and Screening
Plant Setup and Conditions for the Study



0-3.5''
(0-90 mm)

+3.5''
(+90 mm)

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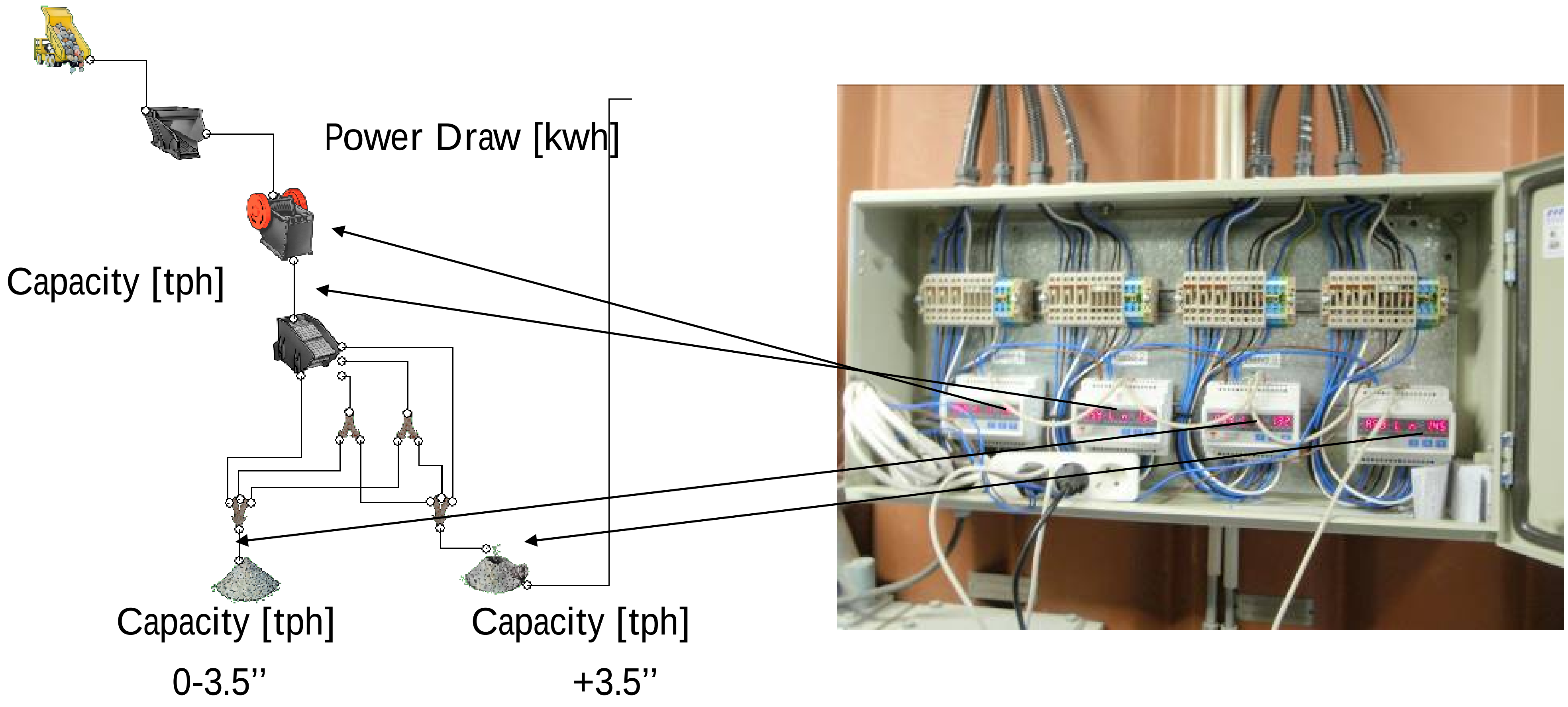
Crushing and Screening Performed Measurements



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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 (0.30 $/kWh)*	0.09	0.07	0.10
Fixed Cost [$/h] [$/ton]	746 2.41	746 2.29	746 2.28
Cost [$/ton]	2.50	2.36	2.38
Sum incl D&B och L&H [$/ton]	1.20+1.50+2.50= = 5.20	1.38+1.42+2.36= = 5.16	1.49+1.43+2.38= = 5.30

*Estimates based on publicly available data

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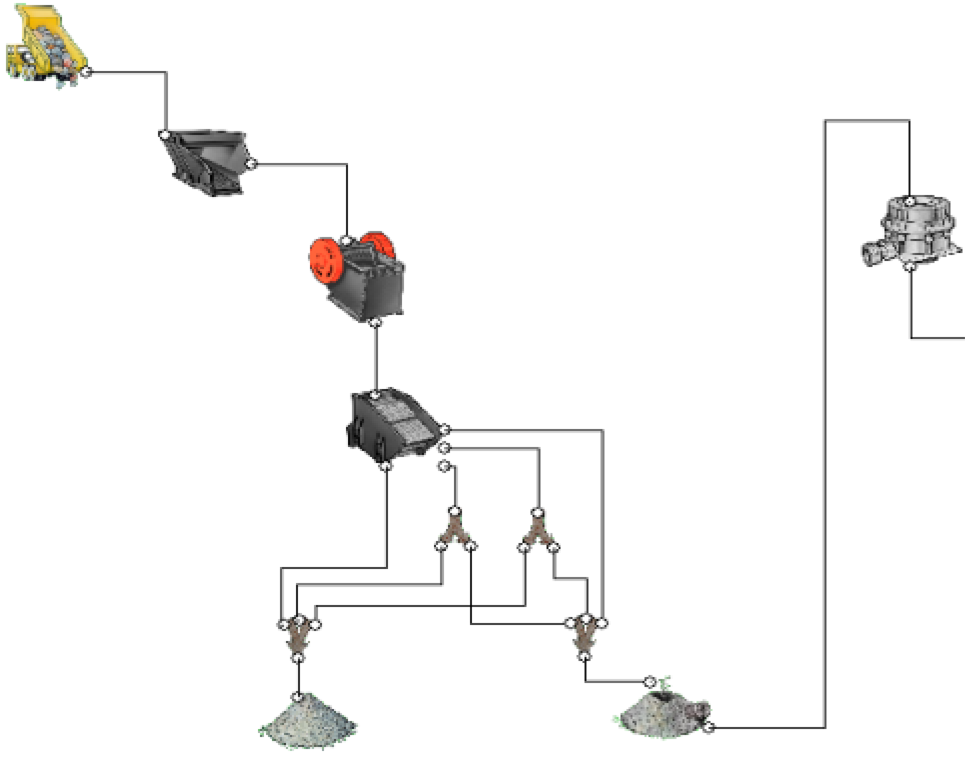
Production
Total cost $/h

	Nonel norm. q	Nonel high q	EPD norm. q
Production rate [tph]	298	316	313
Cost [$/h]	1600	1676	1723



Distribution between 0-3.5'' and +3.5'' is partly controlled by the blasting result

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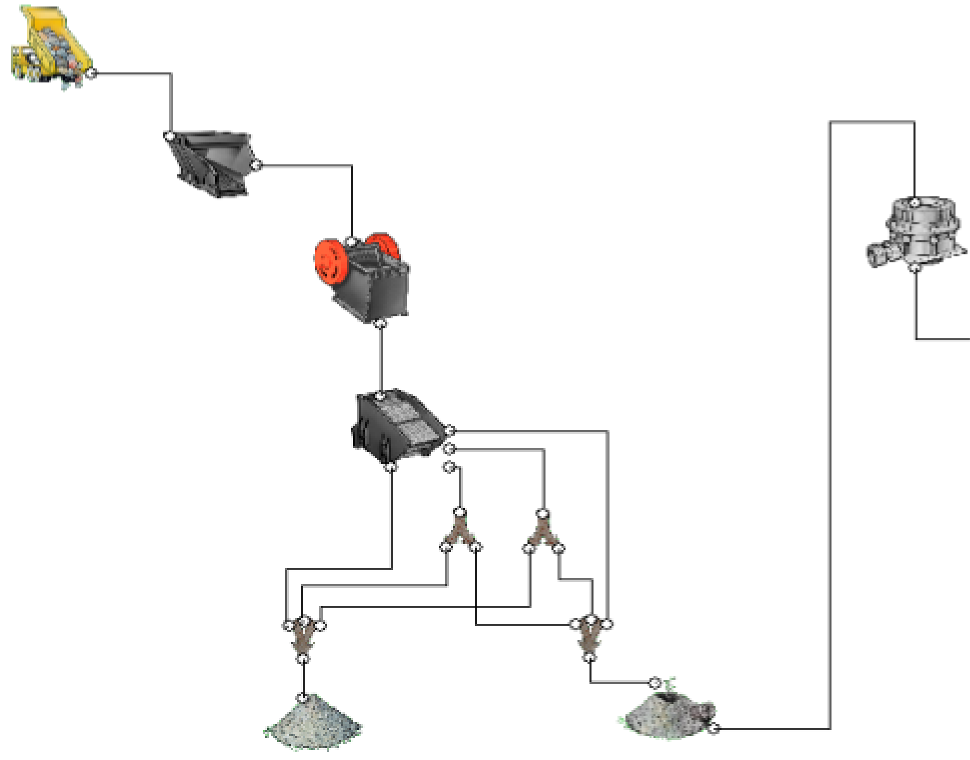
Procution
Product Price

Fraction [mm]	Price [$/ton]	Crushing stage	Ave. Price [$/ton]
0-90	11.94	1 (Prim.)	11.94
0-4	19.25	3-4	21.19
4-8	20.75		
8-11	23.73		
11-16	22.53		
16-32	20.15		



0-3.5''
11.94 $/ton

+3.5''
21.19 $/ton

*Estimates based on publicly available data

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Production Revenue sek/h

	Nonel normalt q	Nonel high q	EPD normalt q
Production [tph]	298	316	313
Production 0-3.5” [tph]	186	206	189
Price 0-3.5” $/ton*	11.94	11.94	11.94
Production +3.5” [tph]	112	110	124
Ave. Price +3.5” $/ton*	21.19	21.19	21.19
Revenue $/h	4595	4791	4885

*Estimates based on publicly available data

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Production
Cost and Revenue*

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

Distribution between 0-3.5'' and +3.5'' is partly controlled by the blasting result

*Based on publicly available data

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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.

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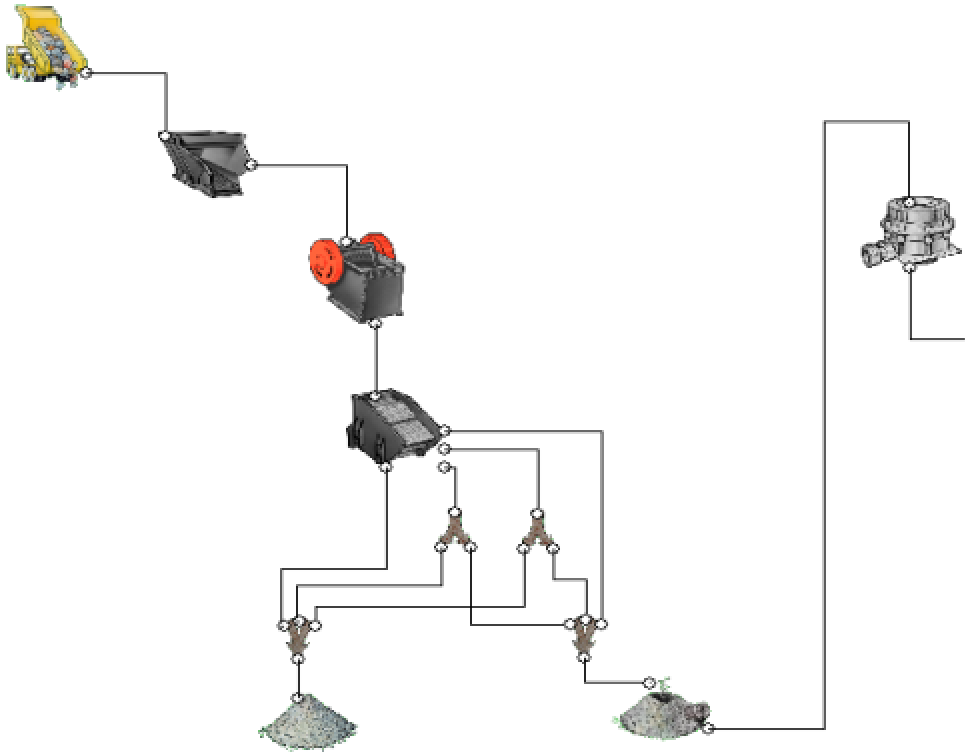
Conclusions – Guidance for previous processes

- Feed to the primary crusher matters more then just boulders
- The effect of different feed gradations (blast results) are difficult to detect without measuring actively.
- Communicate effects upwards in the process



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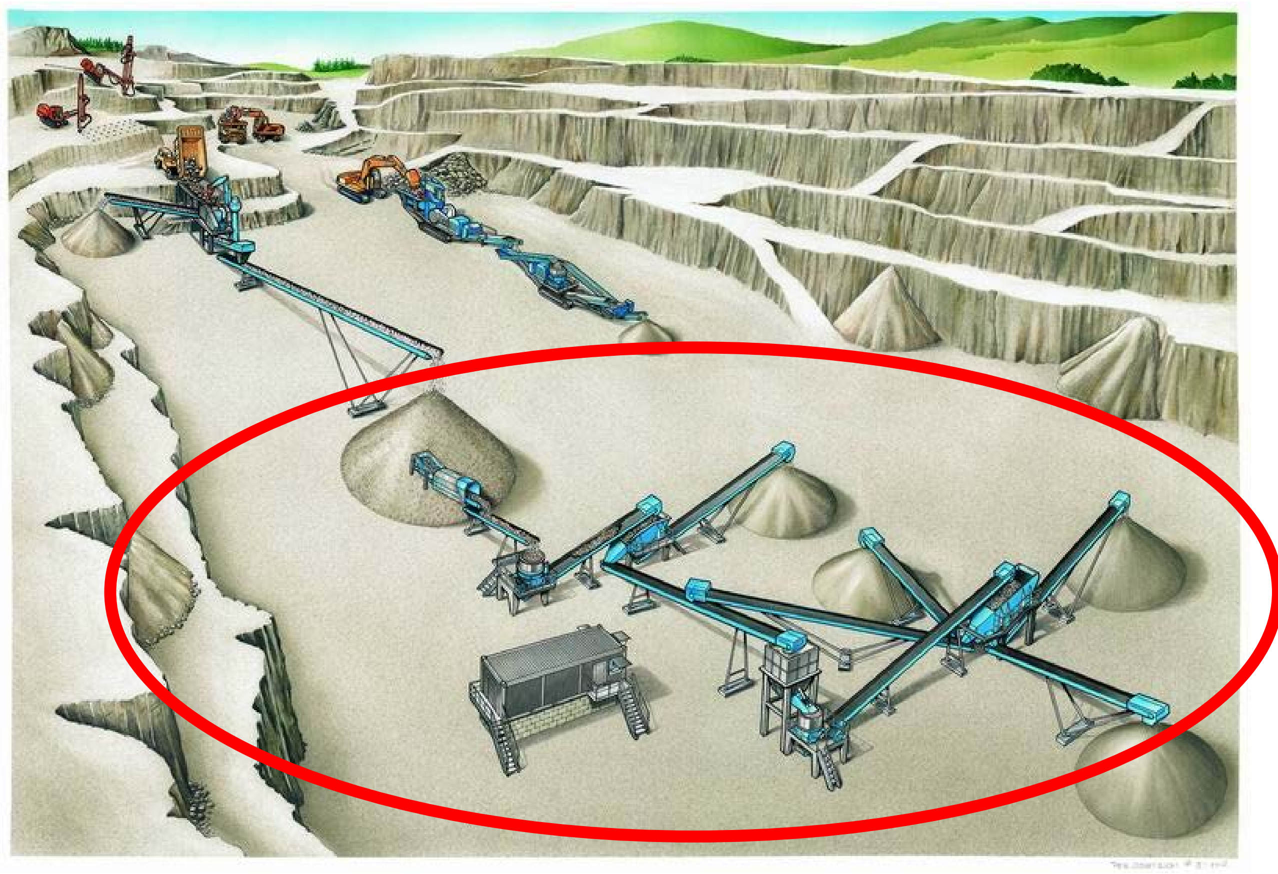
What about Optimizing the Crushing and Screening Process?

- 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?



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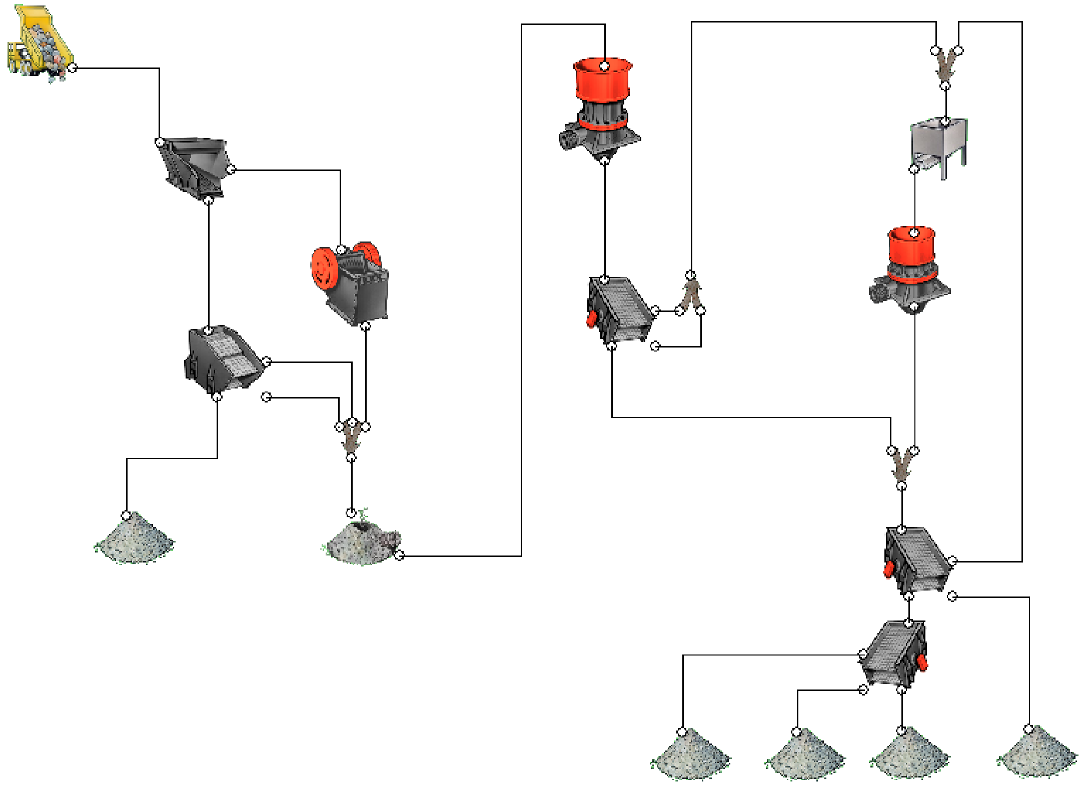
Crushing plant optimization using TCO
Objective of project

- 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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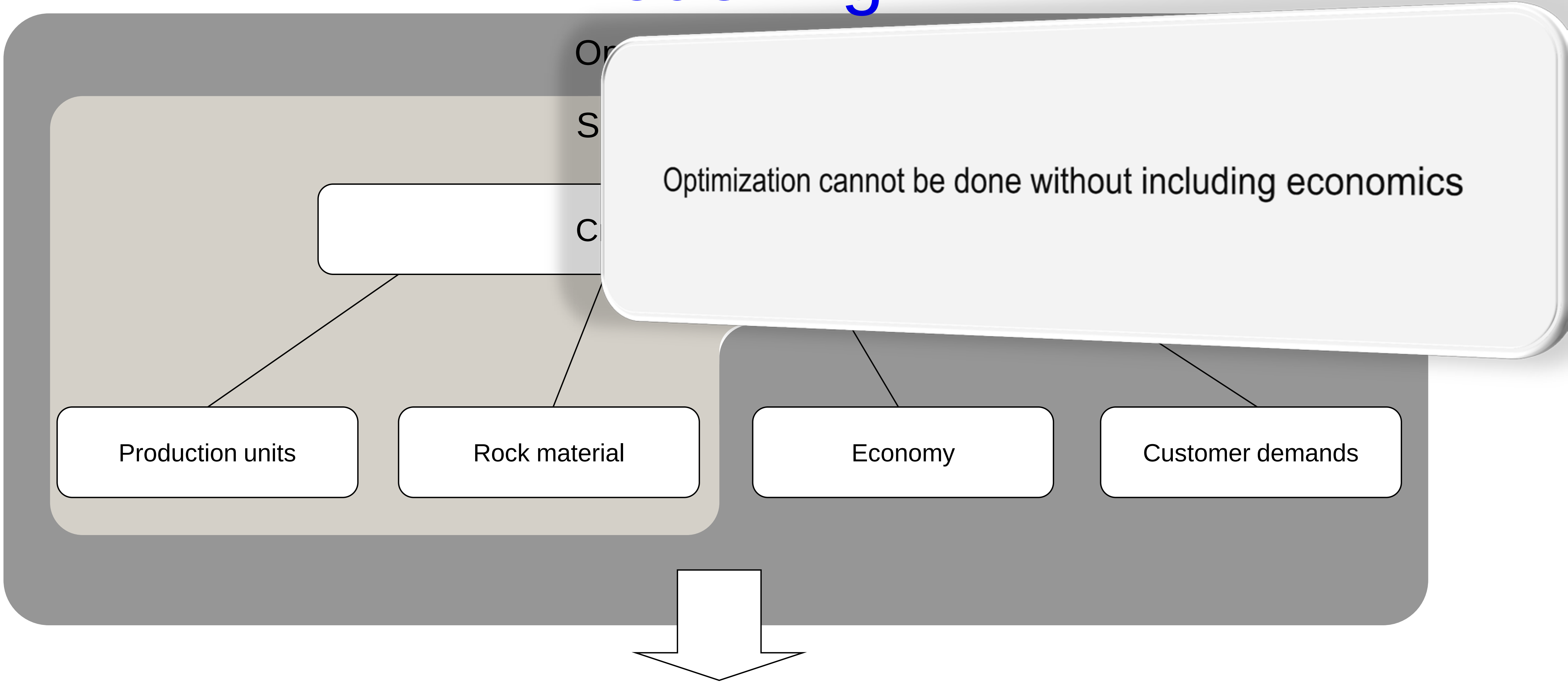
Modelling



Yield the most profitable production strategy and meet the market demand

Crushing plant optimization using TCO Calculation approach

- 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

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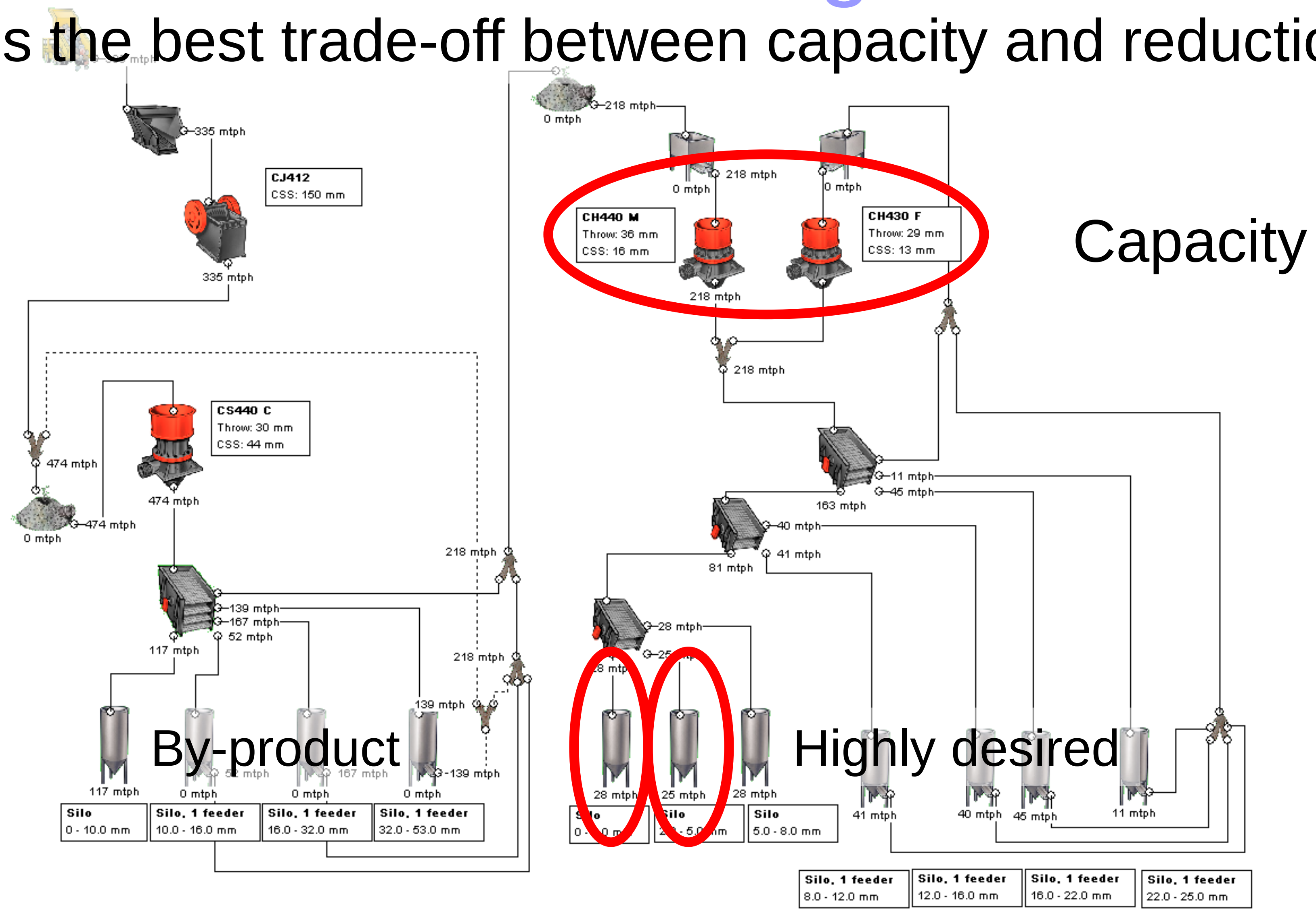
Crushing plant optimization using TCO

Plant Challenges

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



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Crushing plant optimization using TCO

Test plant

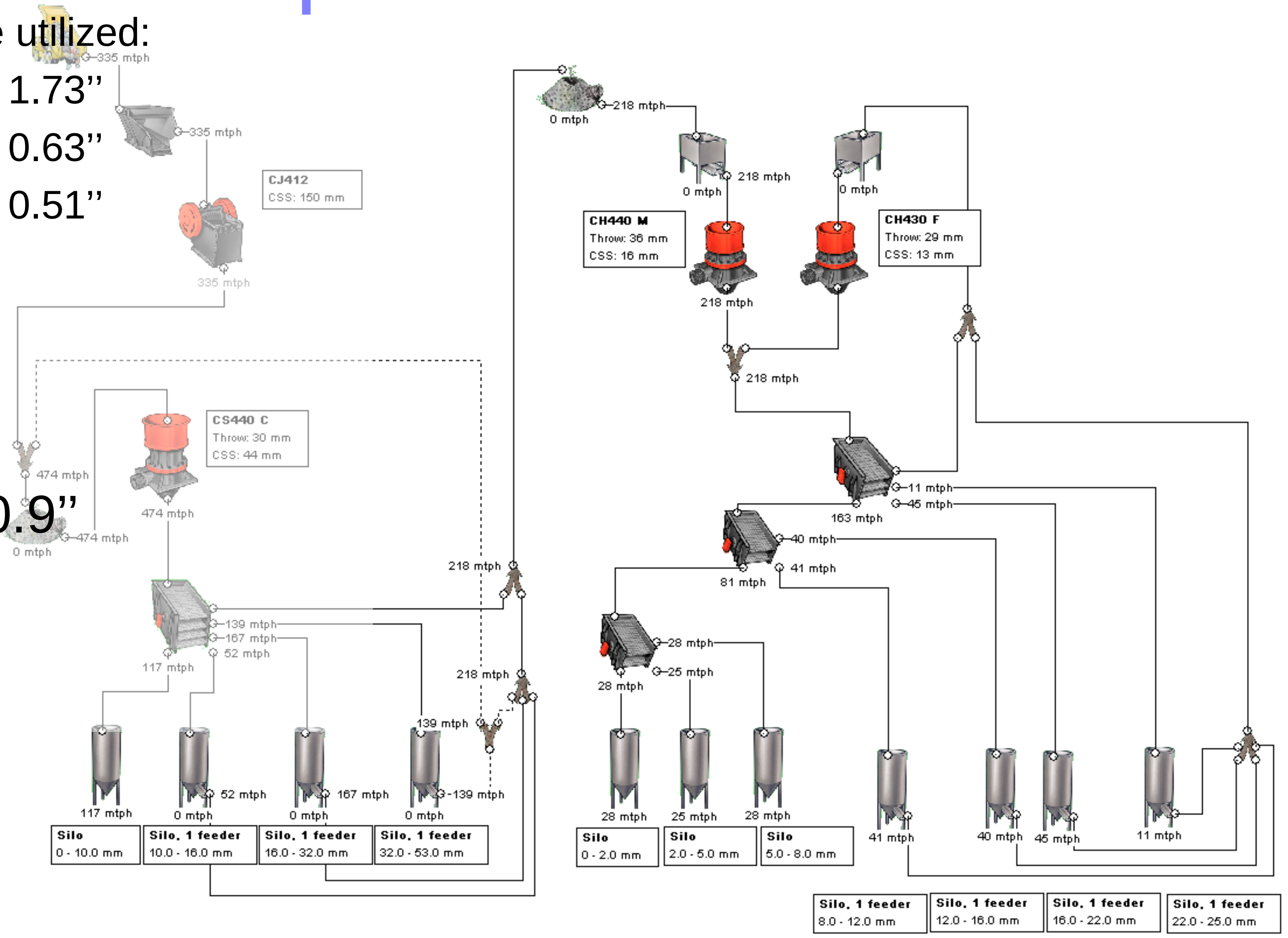
In normal production following CSS are utilized:

Secondary crusher	–	CSS 44 mm 1.73''
Tertiary crusher	–	CSS 16 mm 0.63''
Quaternary crusher	–	CSS 13 mm 0.51''

Products:

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

0-0.9''



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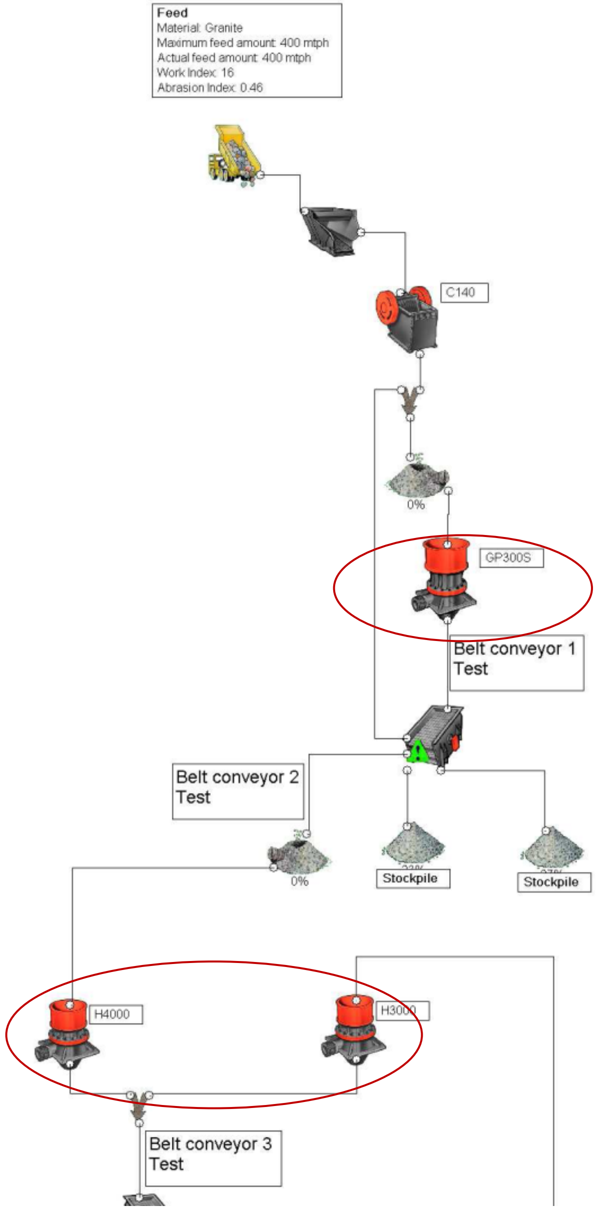
Crushing plant optimization using TCO
Test plan

Objectives for the first test session:

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



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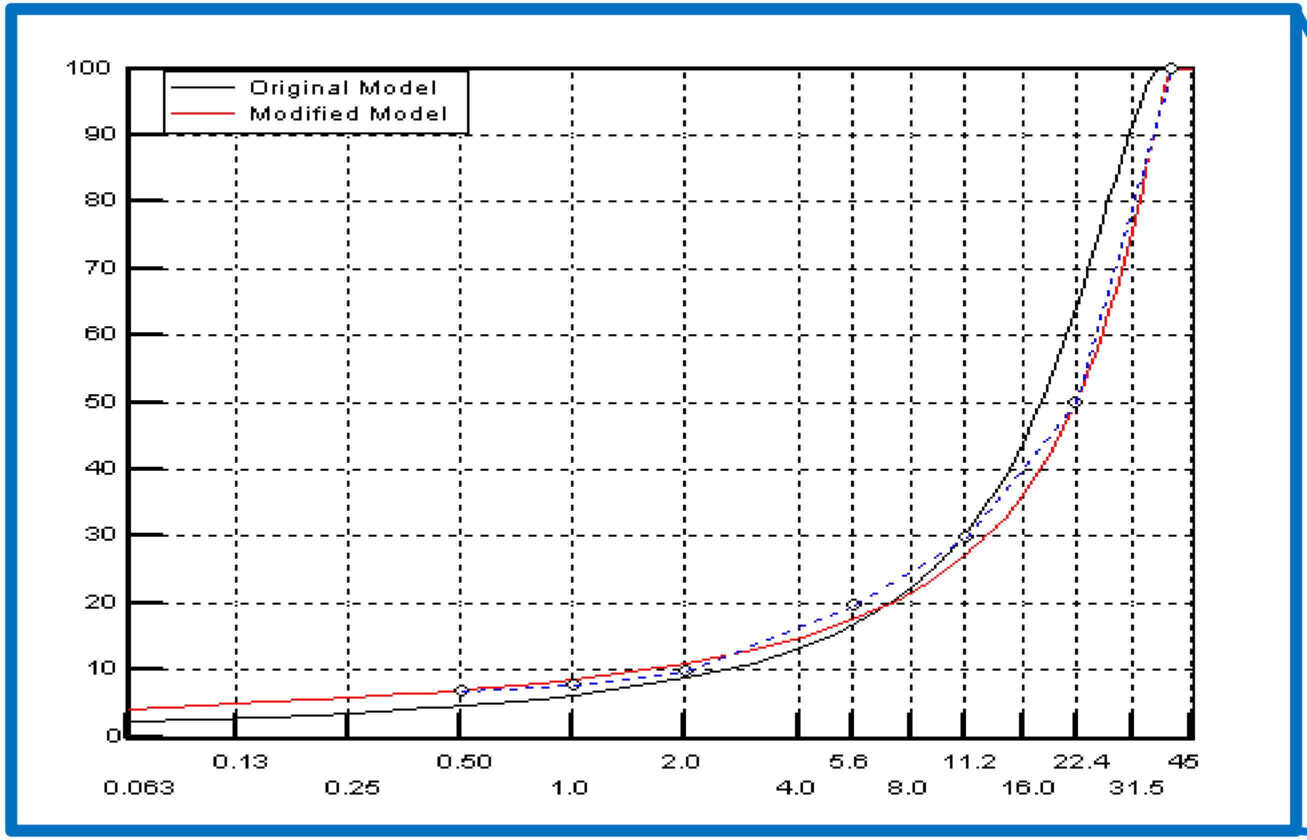
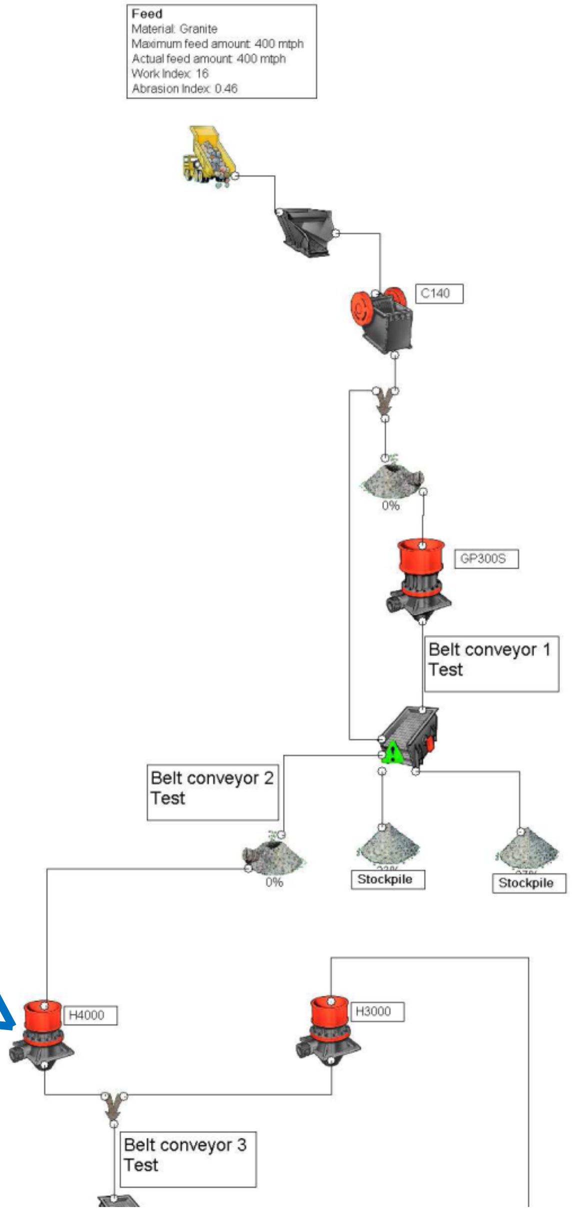
Crushing plant optimization using TCO Model Calibration





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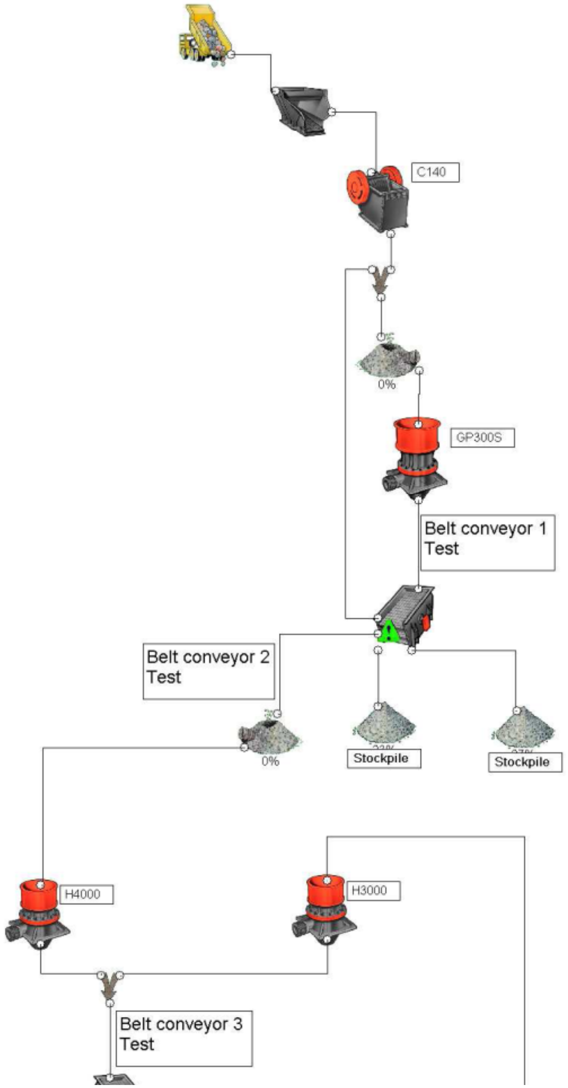
Crushing plant optimization using TCO
Running the TCO optimization module

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), 1.96’’ (1.73’’)
- Tertiary crusher – CSS 20 mm (16) 0.78’’ (0.63’’)
- Quaternary crusher – CSS 14 mm (13) 0.55’’ (0.51’’)



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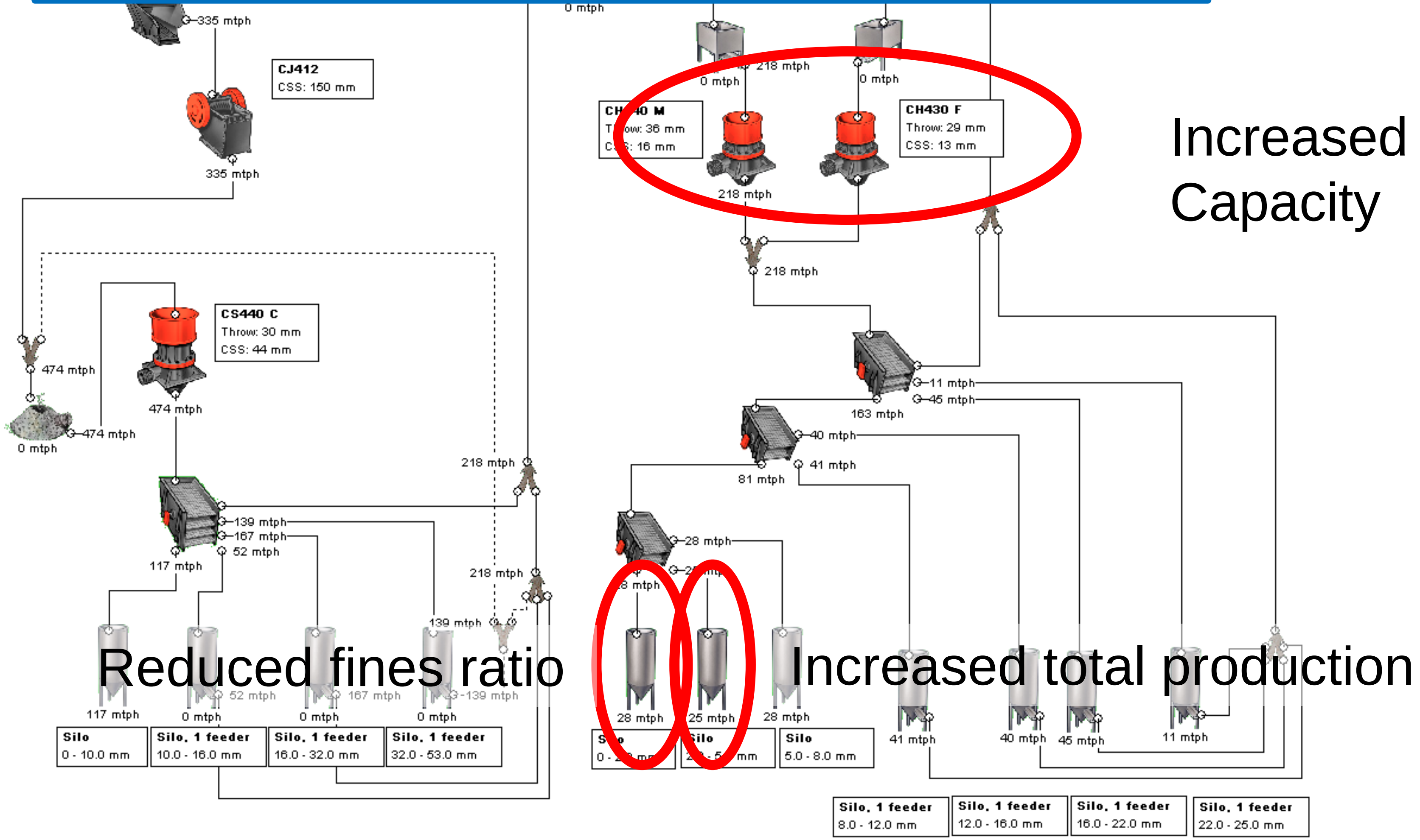
Crushing plant optimization using TCO Results

Result: +11 % in Calculated Gross Profit



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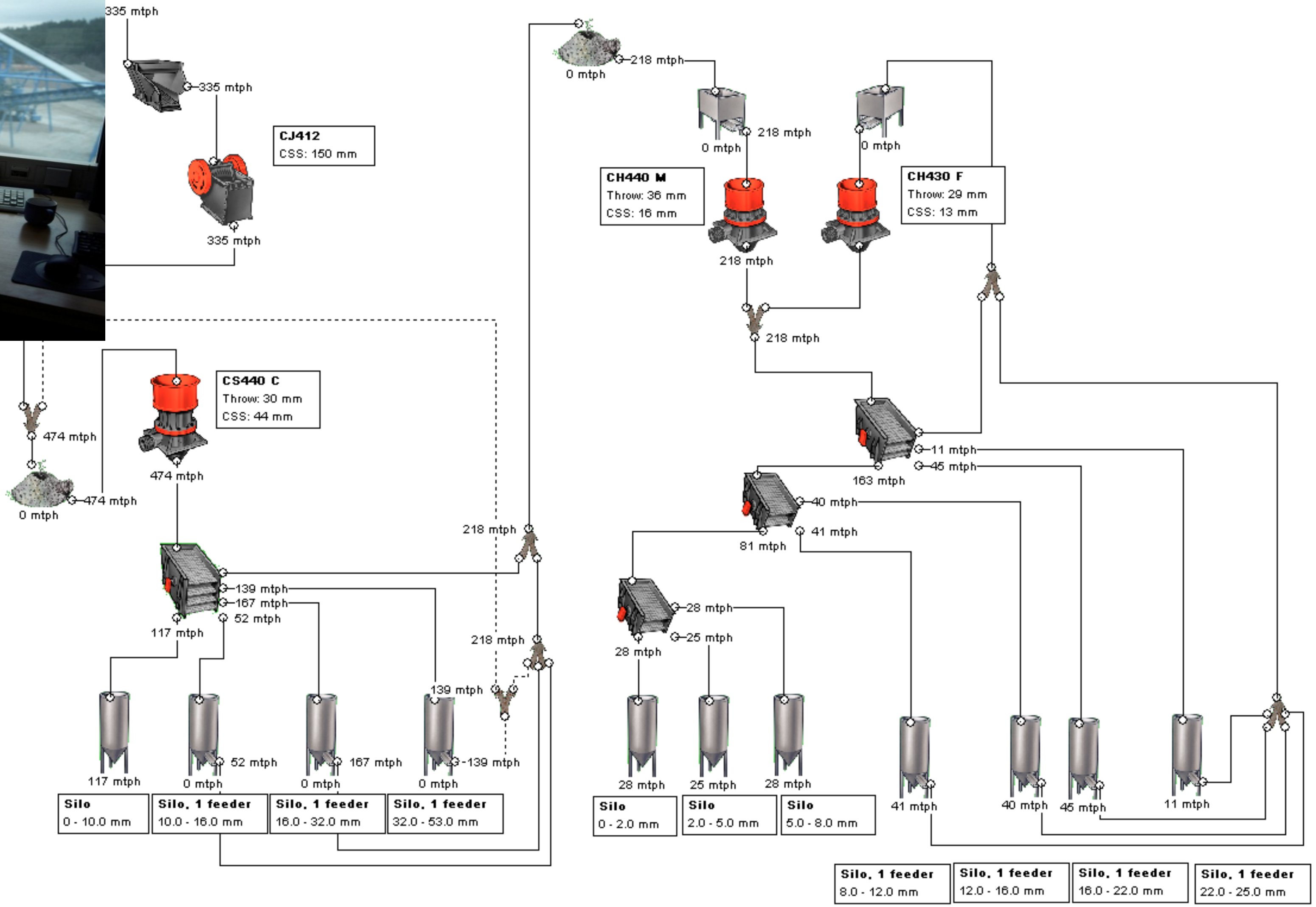
Crushing plant optimization using TCO
How can it be done?



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Crushing plant optimization using TCO Conclusion

- 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

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