Crushing
- Optimizing the Process

Per Svedensten

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Improving Processes. Instilling Expertise.

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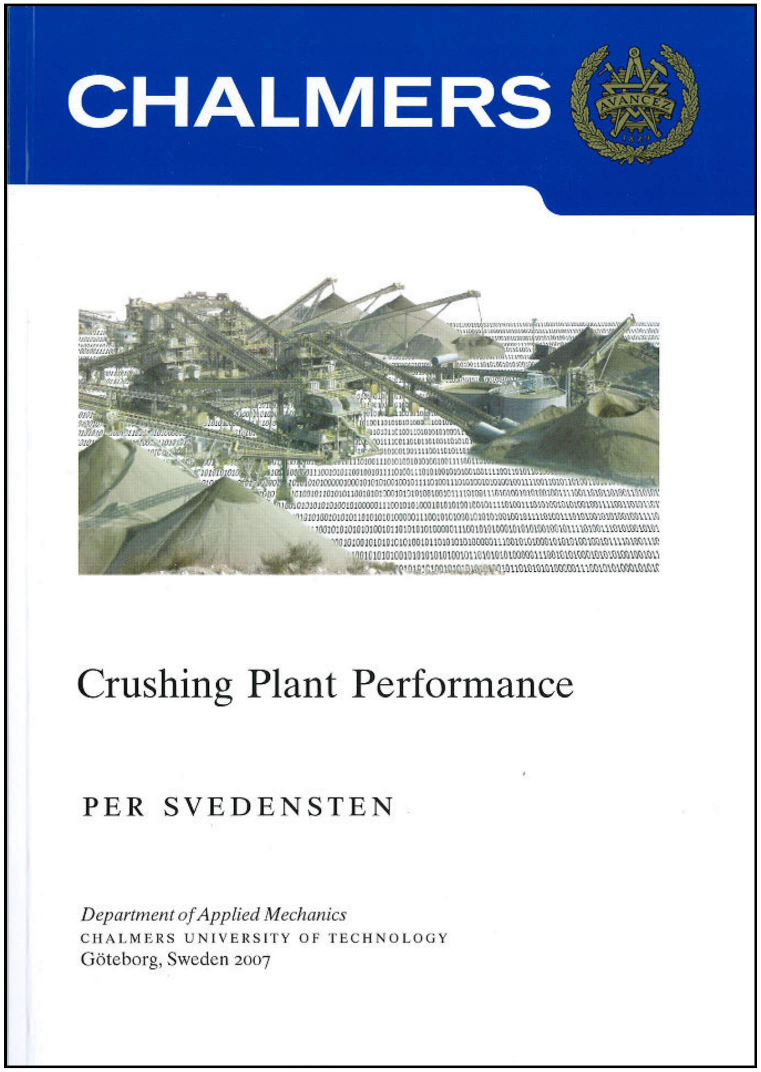
Optimizing the Process

- **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**



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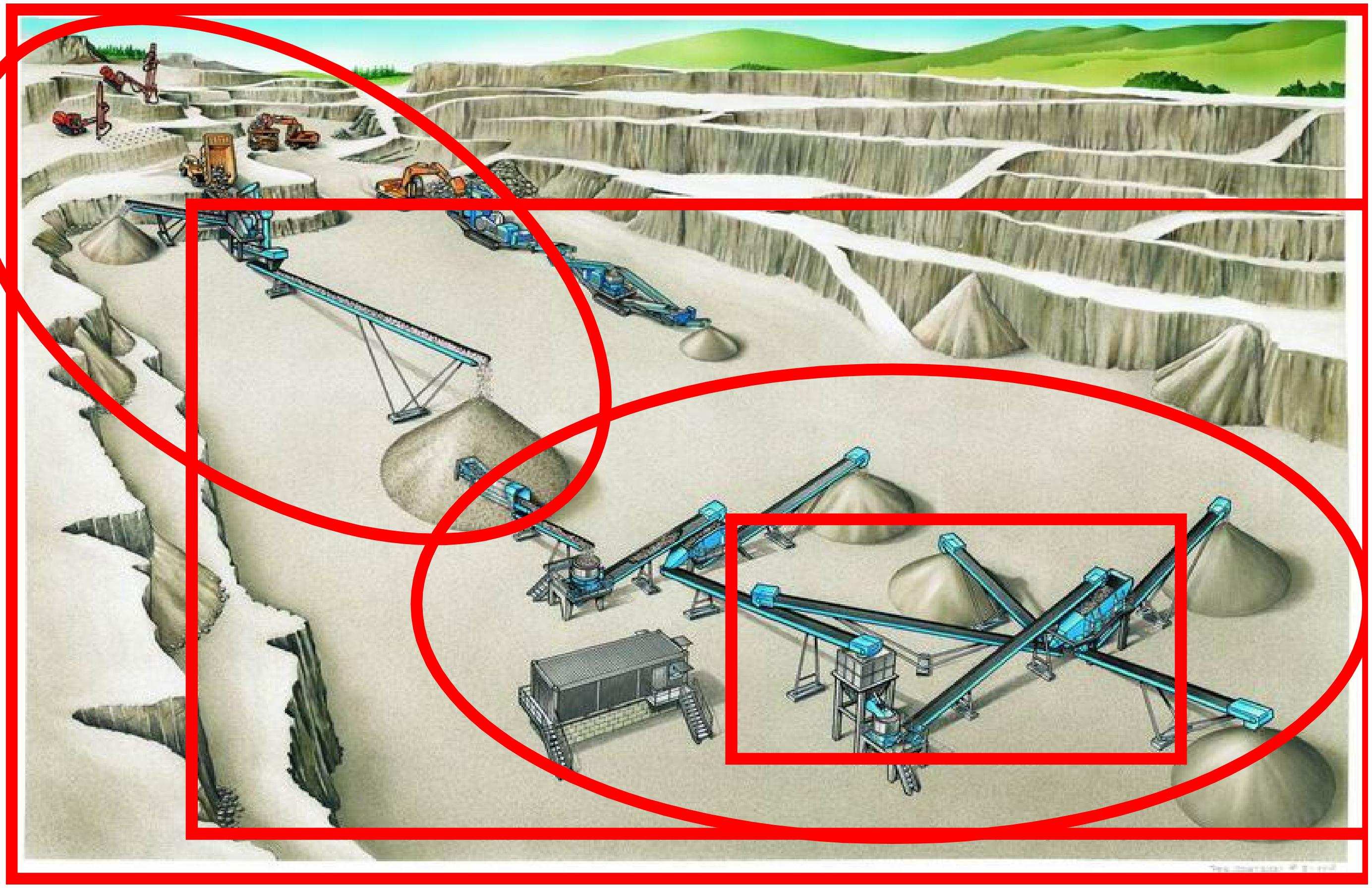
Crushing Plant Optimization

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



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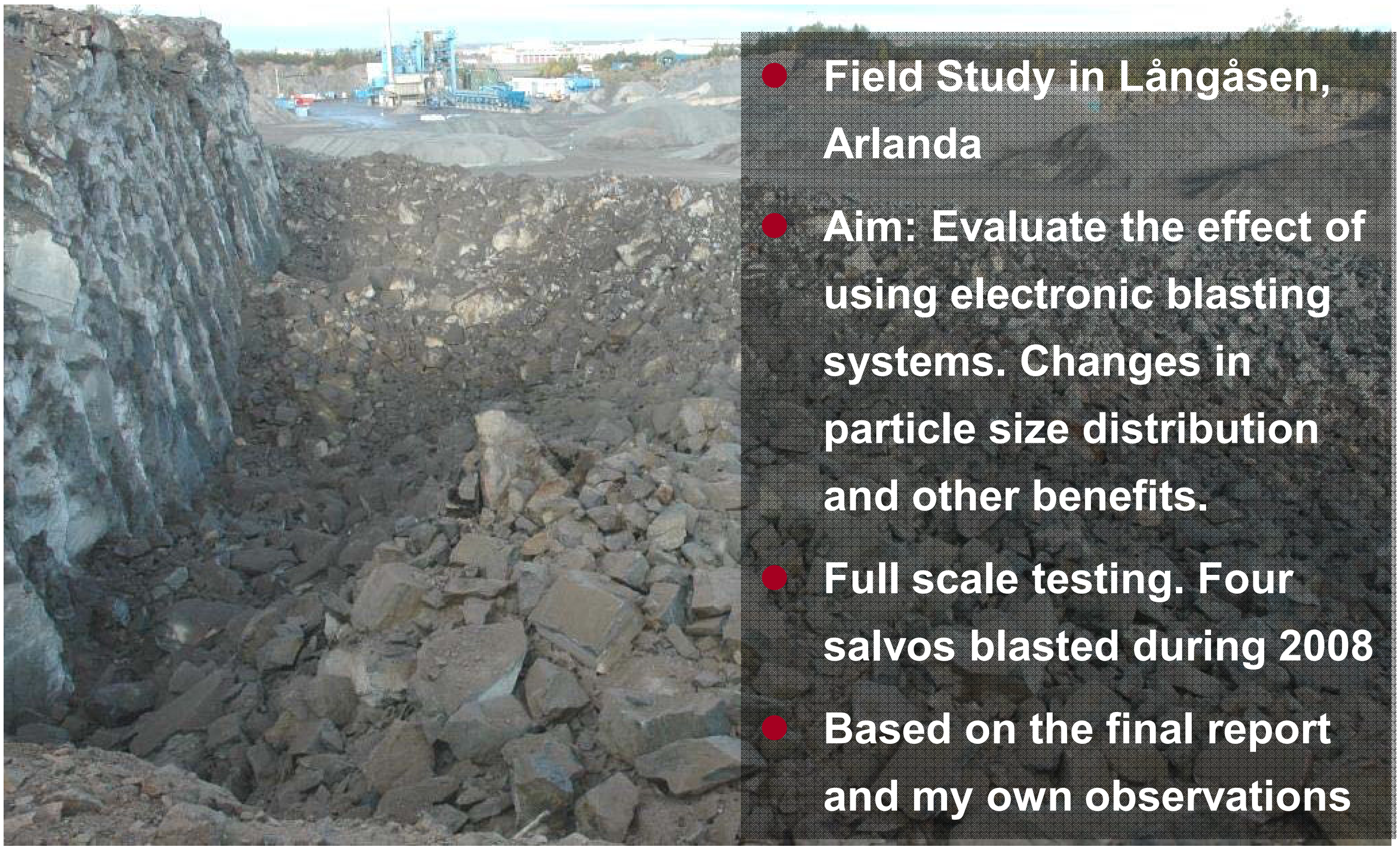
MinBaS II
Project: Optimized blasting



- 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 salvos blasted during 2008
- Based on the final report and my own observations

The Study

- Drilling and Blasting
- Loading and Hauling
- Crushing and Screening Plant
- Comparisons between the cost and earnings for the different alternatives.
- Conclusions and recommendations

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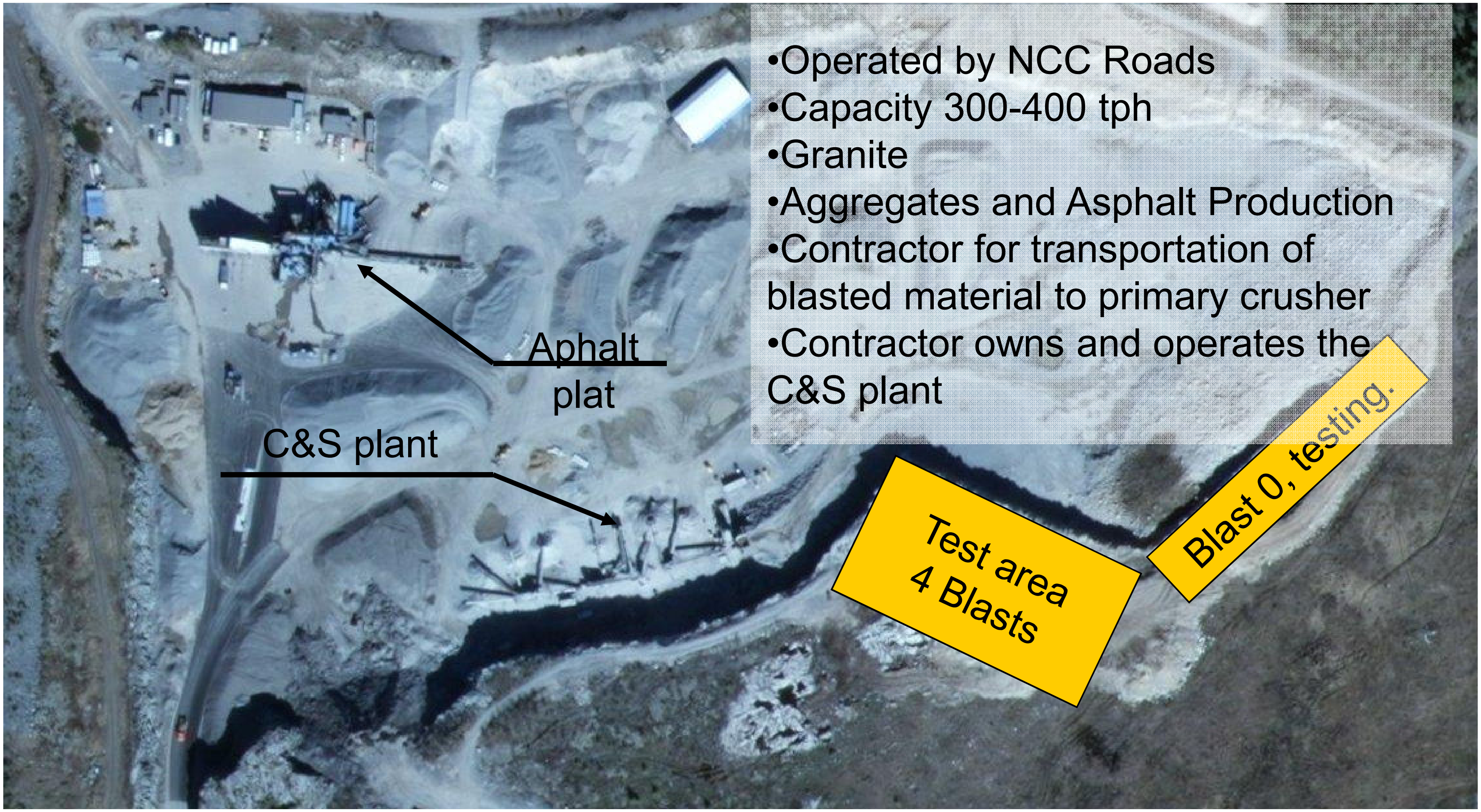
The Quarry
Långåsen, Arlanda



- Operated by NCC Roads
- Capacity 300-400 tph
- Granite
- Aggregates and Asphalt Production
- Contractor for transportation of blasted material to primary crusher
- Contractor owns and operates the C&S plant

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Blasting
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	

The blasting was divided into 11 subparts which were analyzed separately

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Blasted Material

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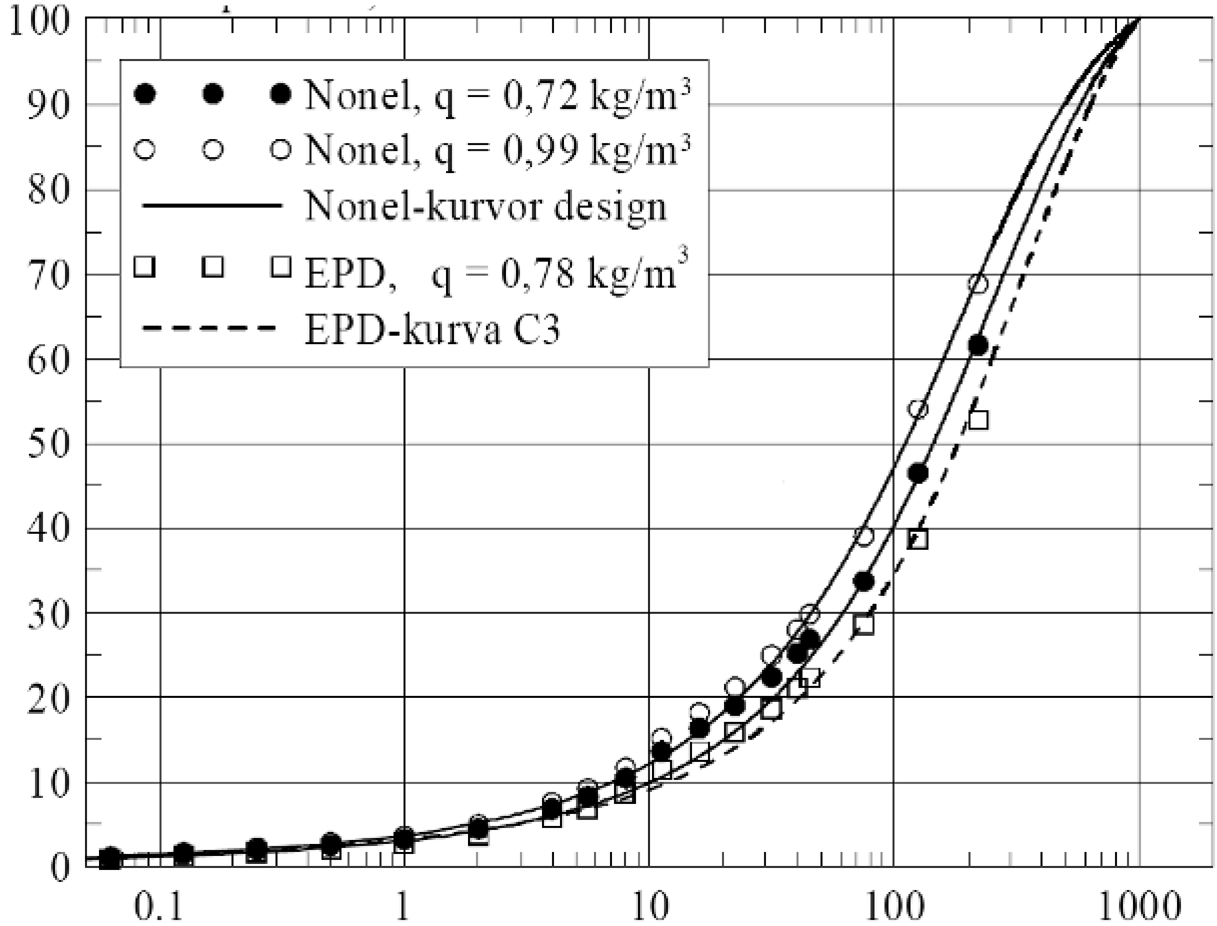
Blasting result
Measuring the Particle Size Distribution

Percent Passing



Particle Size Distribution (milimeters)

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Blasting Result
Cost* Analysis

	None el. norm PF [$/ton]	None el. high PF [$/ton]	EPD norm. PF [$/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**

*All costs are estimates based on publicly available data

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Loading and Hauling Conditions and Measurements

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

Loading and Hauling Cost* analysis

	None el. norm. PF	None el. high PF	EPD norm. PF
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**

*All costs are estimates based on publicly available data

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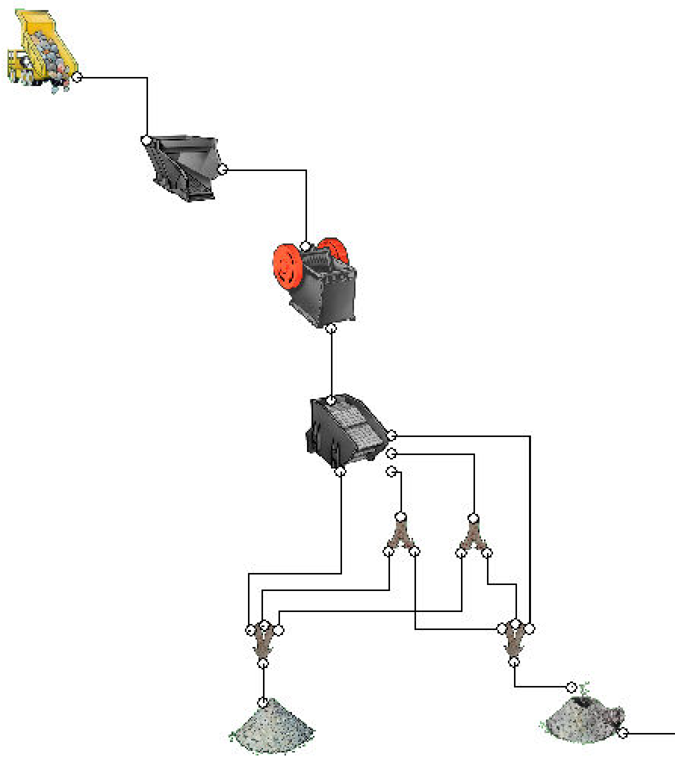
Crushing and Screening
Plant Setup and Conditions for the Study



0-90 mm   +90 mm

0 to 3-1/2"   + 3-1/2"

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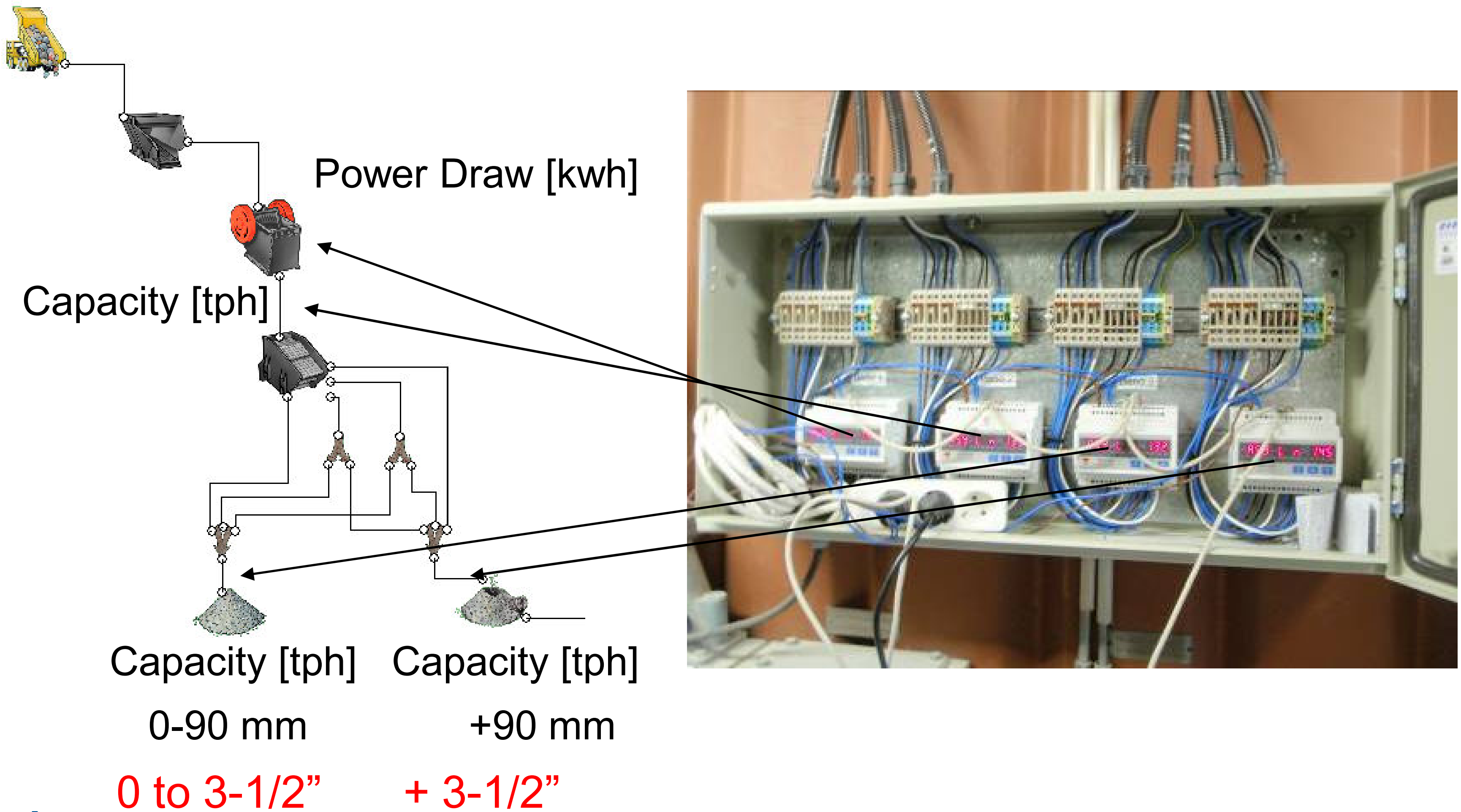
Crushing and Screening Performed Measurements



Crushing and Screening Cost* analysis

	None el. norm. PF	None el. high PF	EPD norm. PF
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**

*All costs are estimates and are publicly available

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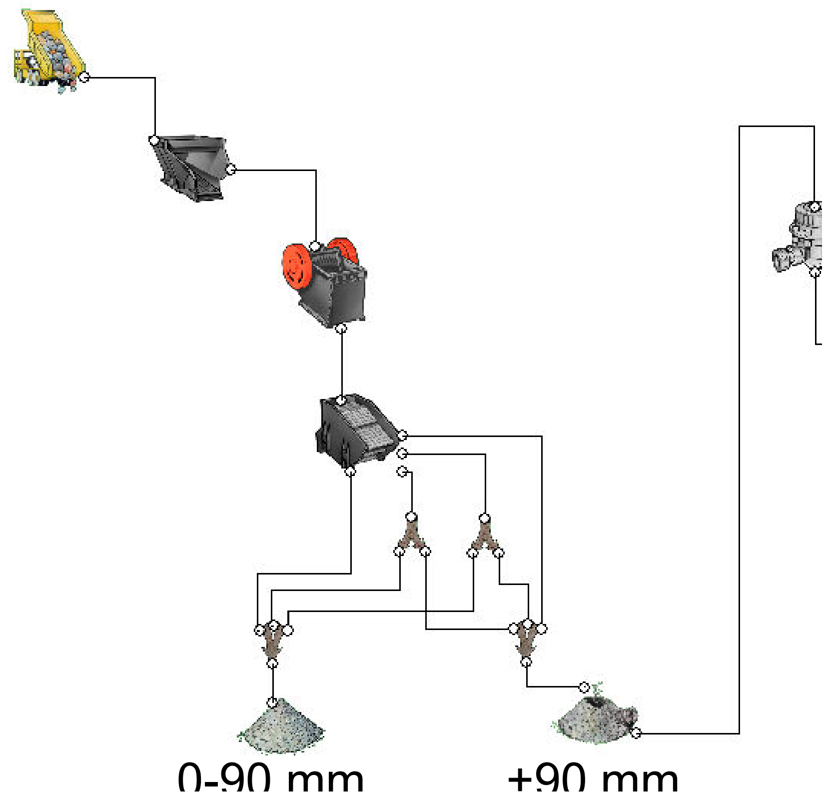
Production
Total cost sek/h

	None el. norm. PF	None el. high PF	EPD norm. PF
Production rate [tph]	298	316	313
Production rate 0-90 mm [tph]	186	206	189
Cost 0-90 mm [$/ton]	5.20	5.16	5.30
Production rate +90 mm [tph]	112	110	124
Cost +90 [$/ton] (+2.24 $/ton)	7.44	7.40	7.54
Cost [$/h]	1600	1676	1723



0 to 3-1/2"   + 3-1/2"

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

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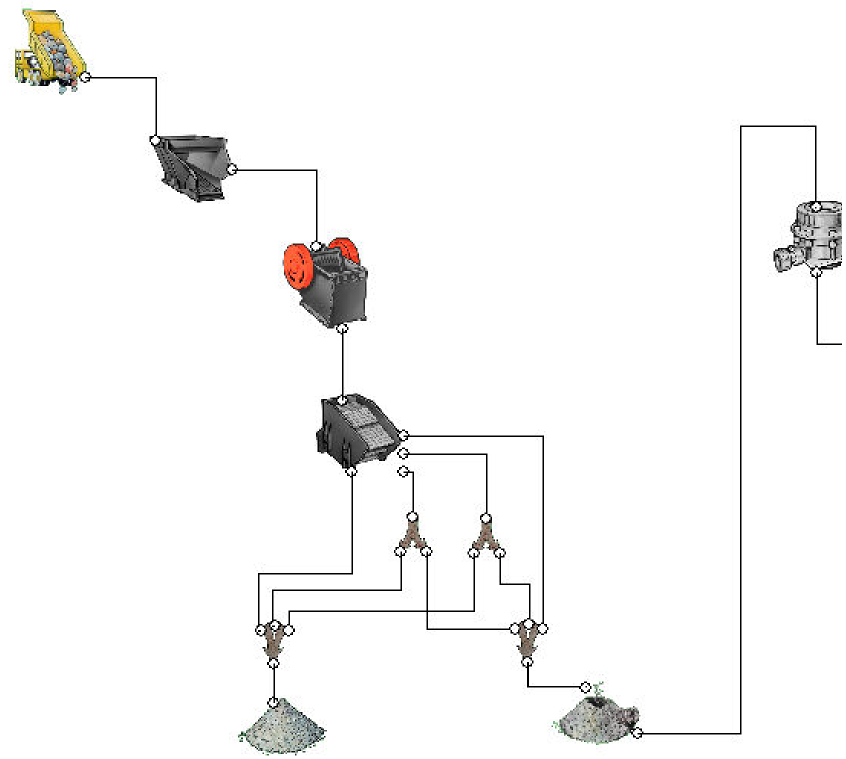
Procution
Product Price*

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		



0-90 mm +90 mm
11.94 $/ton 21.19 $/ton
0 to 3-1/2” + 3-1/2”

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*All prices are estimates based on publicly available information

Production
Revenue $/hour

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

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Summary of Cost and Revenue

	Nonel norm. PF	Nonel high PF	EPD norm. PF
Revenue [$/h]	4595	4791	4885
Production Cost. [$/h]	1600	1676	1723
"Gross Profit" [$/h]	2995	3115	3162
Difference Nonel norm q [$/h] [$/ton]	- -	120 0.38	167 0.53

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Take home message:

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.

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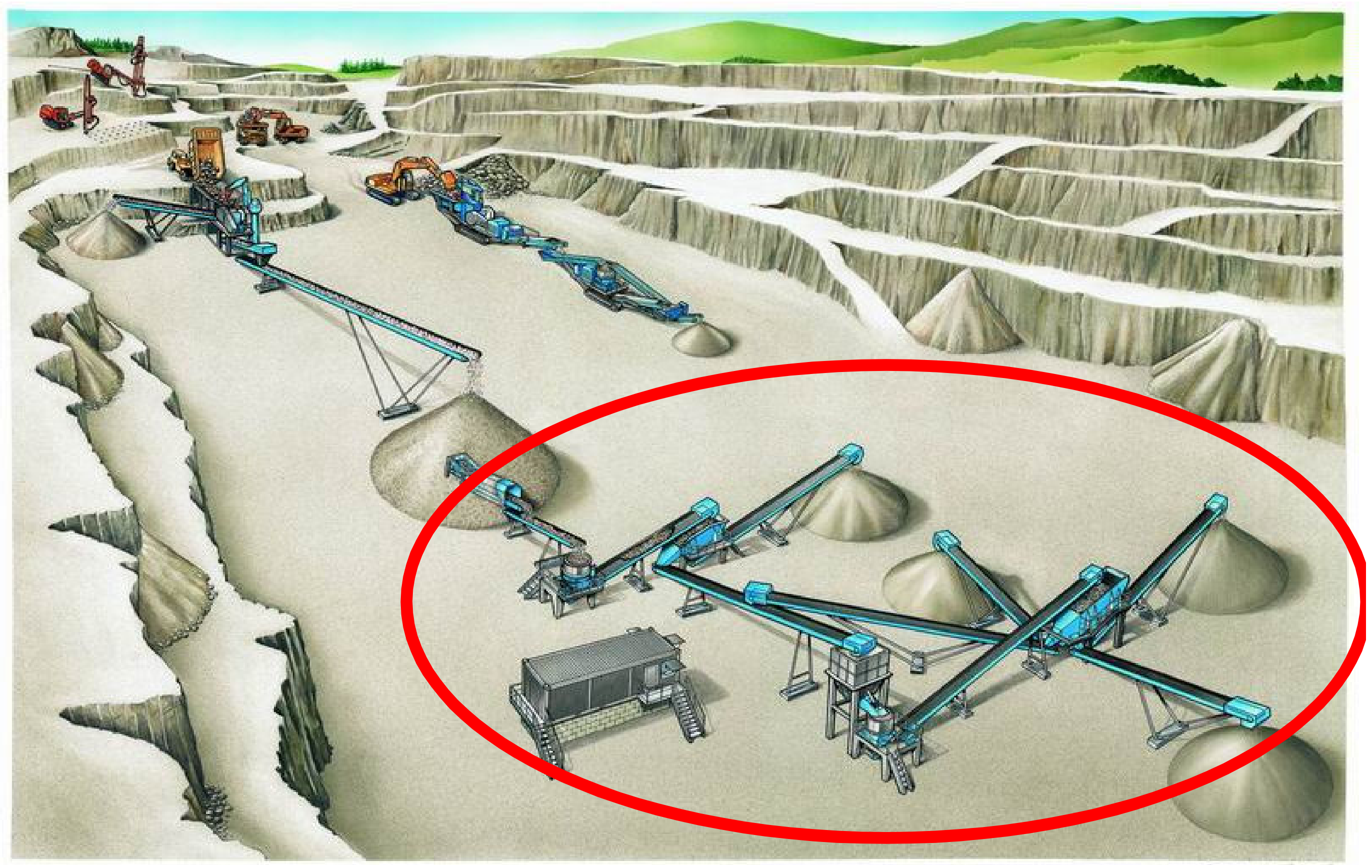
What about Optimizing the Crushing and Screening Process?

- 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?
  - ✓ Product quality



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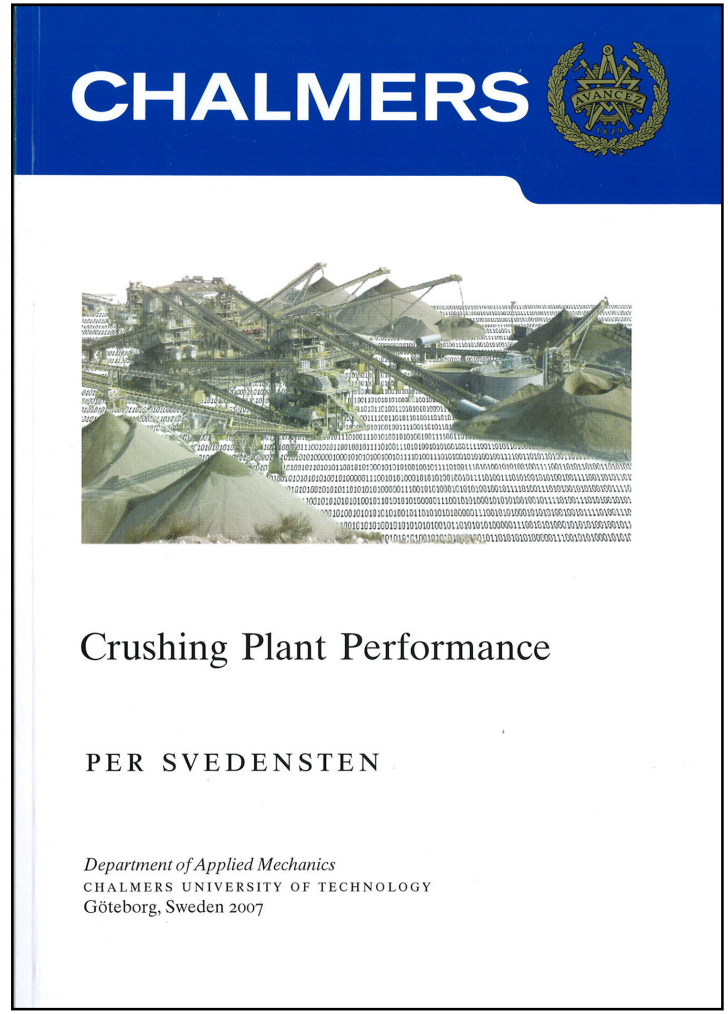
Crushing Plant Optimization

- **Methods to study and evaluate crushing plant performance**
- **Different methods to optimize crushing plants**
- **Theories on crushing plant operation**
- **Ph.D project Design and Operation of Crushing Plants**



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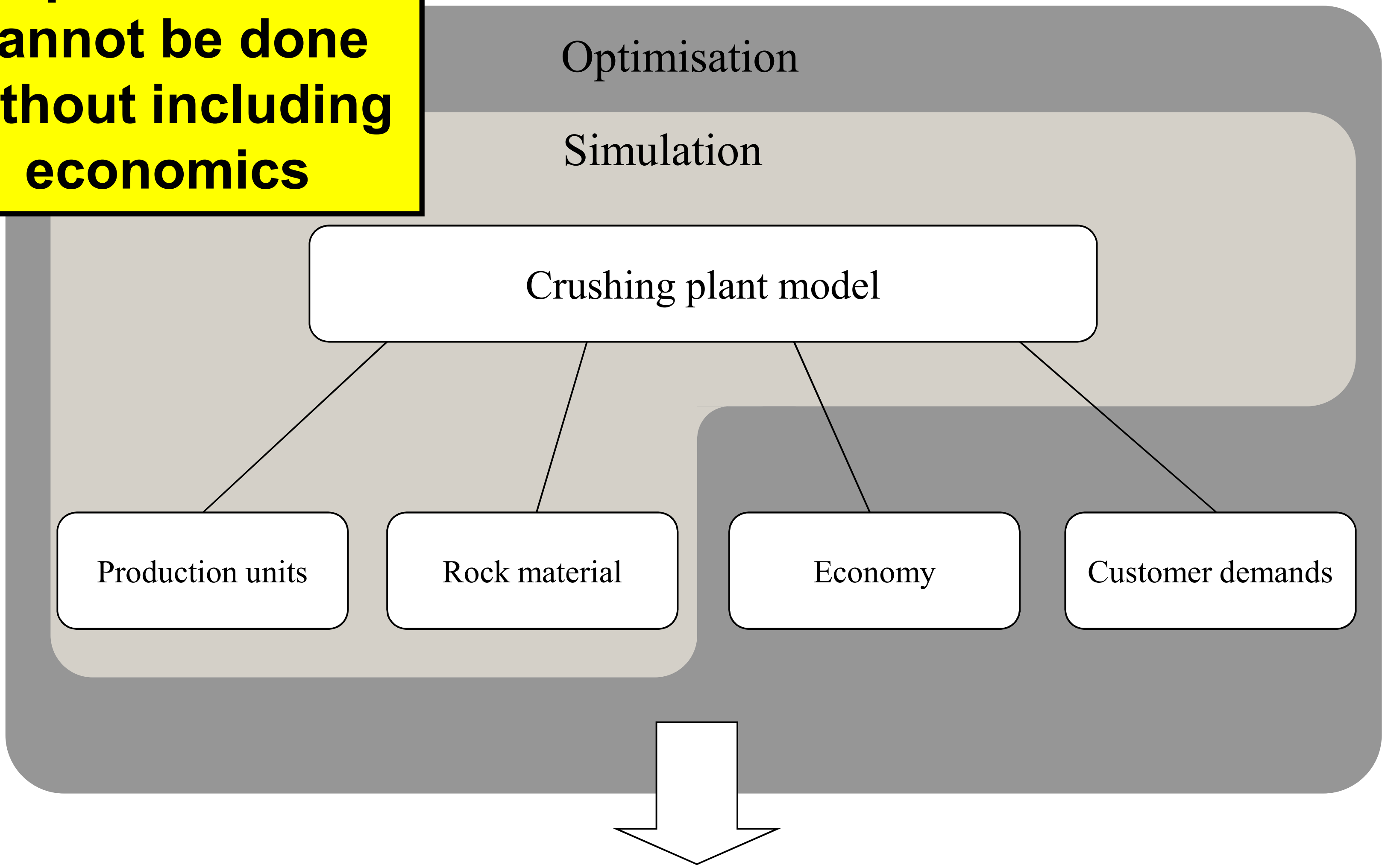
Take home message:

Optimization cannot be done without including economics

Modelling



Yield the most profitable production strategy and meet the market demand

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Computer based optimization

- Used for systems containing several interacting parameters.
- The goal is to find the best combination of parameter values in a simulation model.
- A cost function is used to evaluate different parameter combinations.
- The optimization routine aims to maximize or minimize the value of the cost function.
- In the crushing plant case: Maximize the gross profit.

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Total Cost of Ownership (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

- Goal for the optimization: Maximize the Gross Profit while producing products that fulfill the customer requirements.

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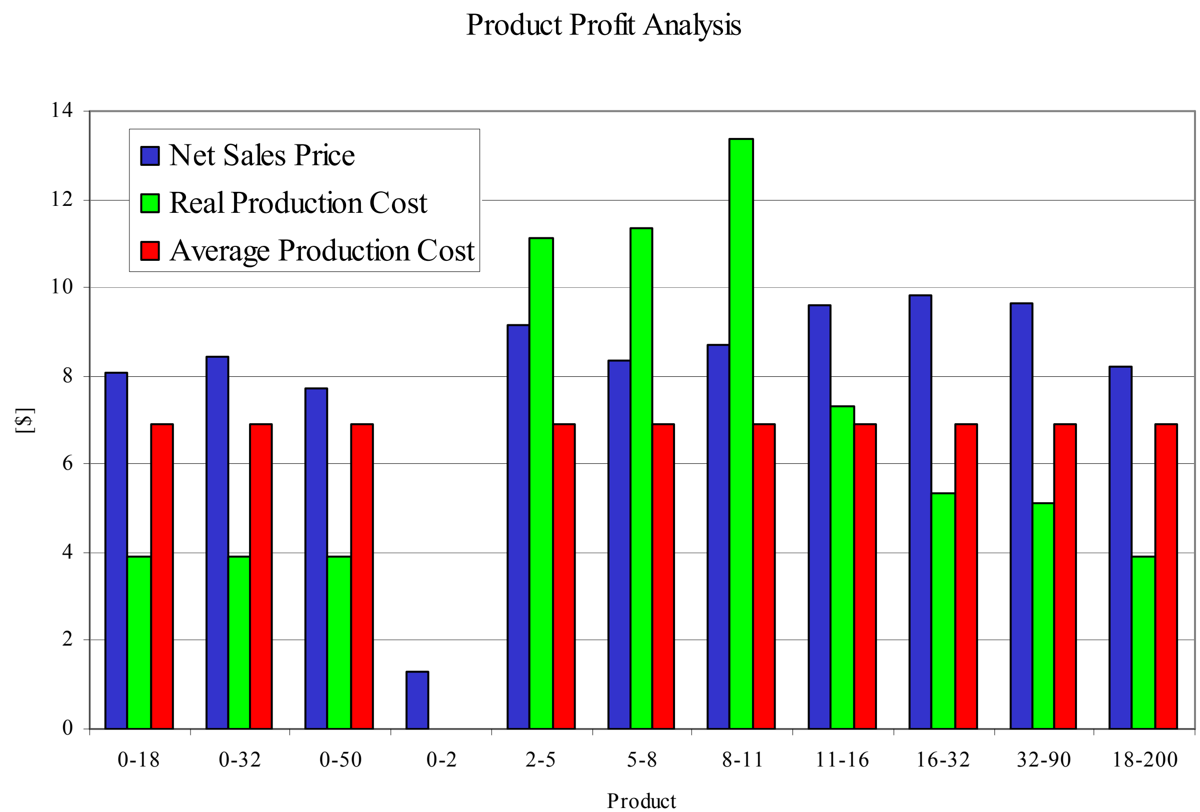
Cost* Calculation
The Difference between getting it right and wrong

Using "Real" cost*
true production cost

Using Average Cost*
The production cost is summed up and divided equally



Take home message:

Finding the right level of detail is important for the economic analysis

*All prices and costs are estimates and for illustrative purpose

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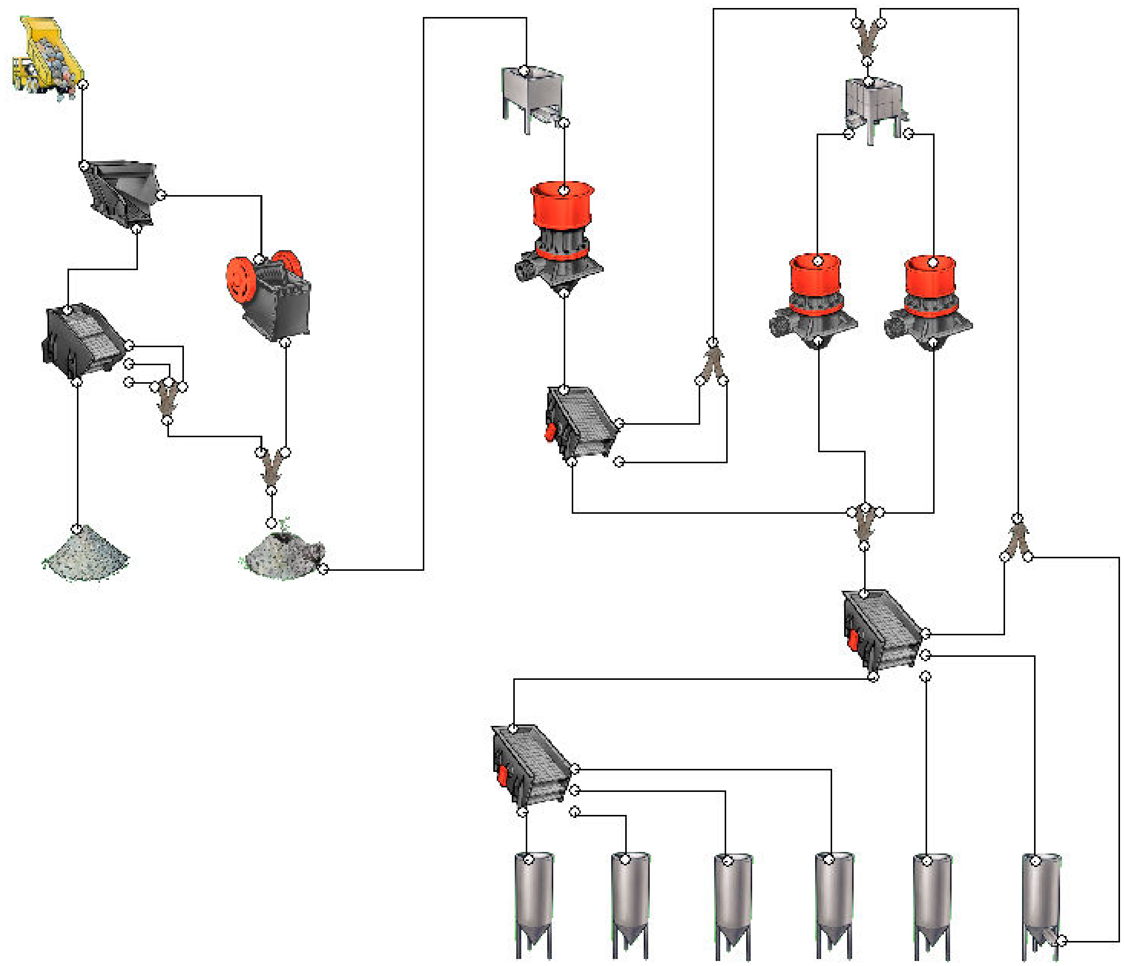
Computer Optimization
Example introduction

- Granite
- Blasted material
- 350 tph

- PlantDesigner® Expert Edition



Products

Optimization 2

Optimization 1

Product [mm]	Price* [$]	Shape Demand [FI]
0-30 Road base	14.70	-
2-4	19.70	-
4-8	21.30	<15
8-11	24.40	<15
11-16	23.10	<15
16-22	20.70	<15
0 – 2 (by-product)	-	-

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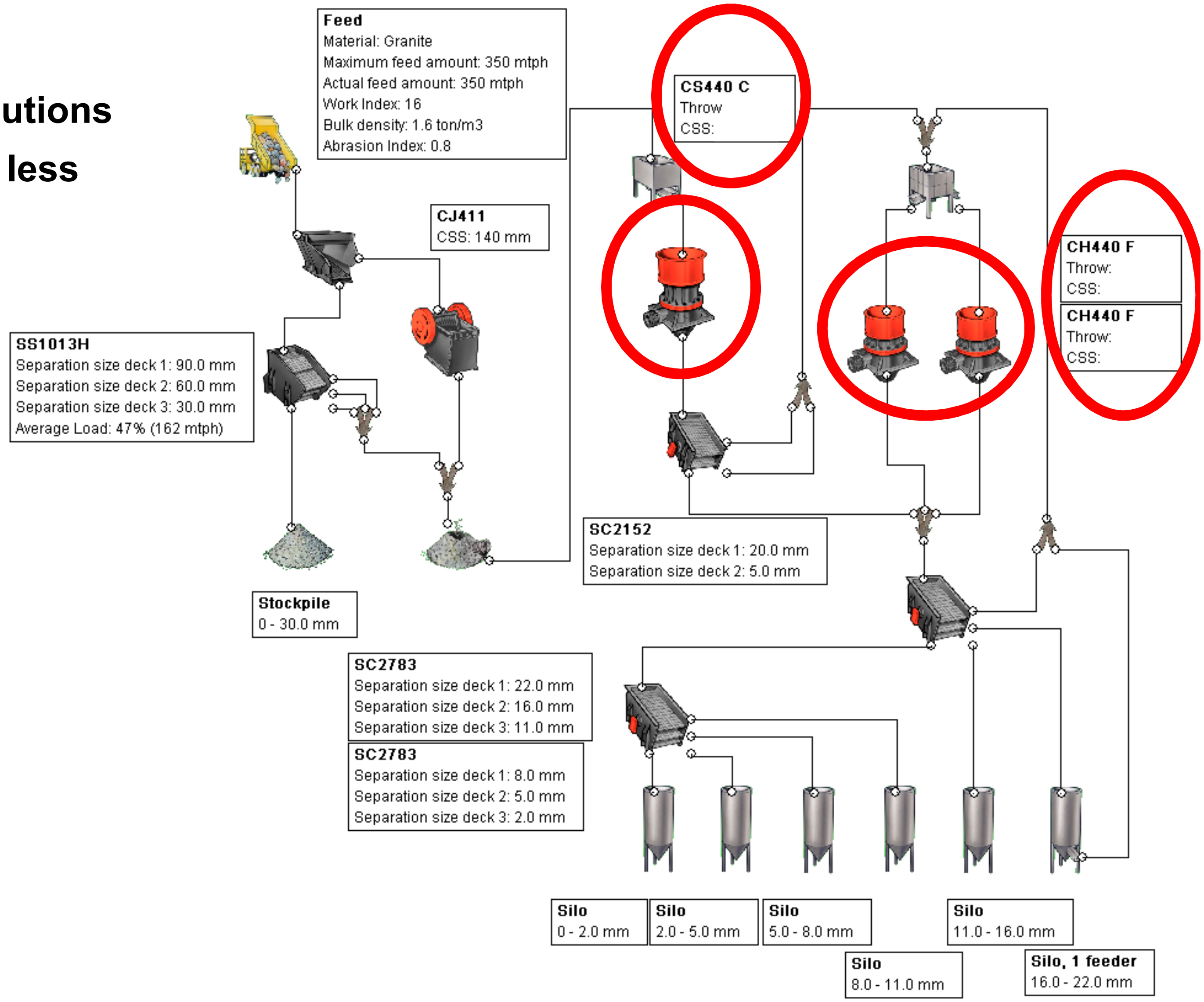
*All prices are estimates and only for illustrative purpose

Optimization 1
without particle shape demands

- **5.9 Million different solutions**
- **Solved by computer in less then 2 min.**



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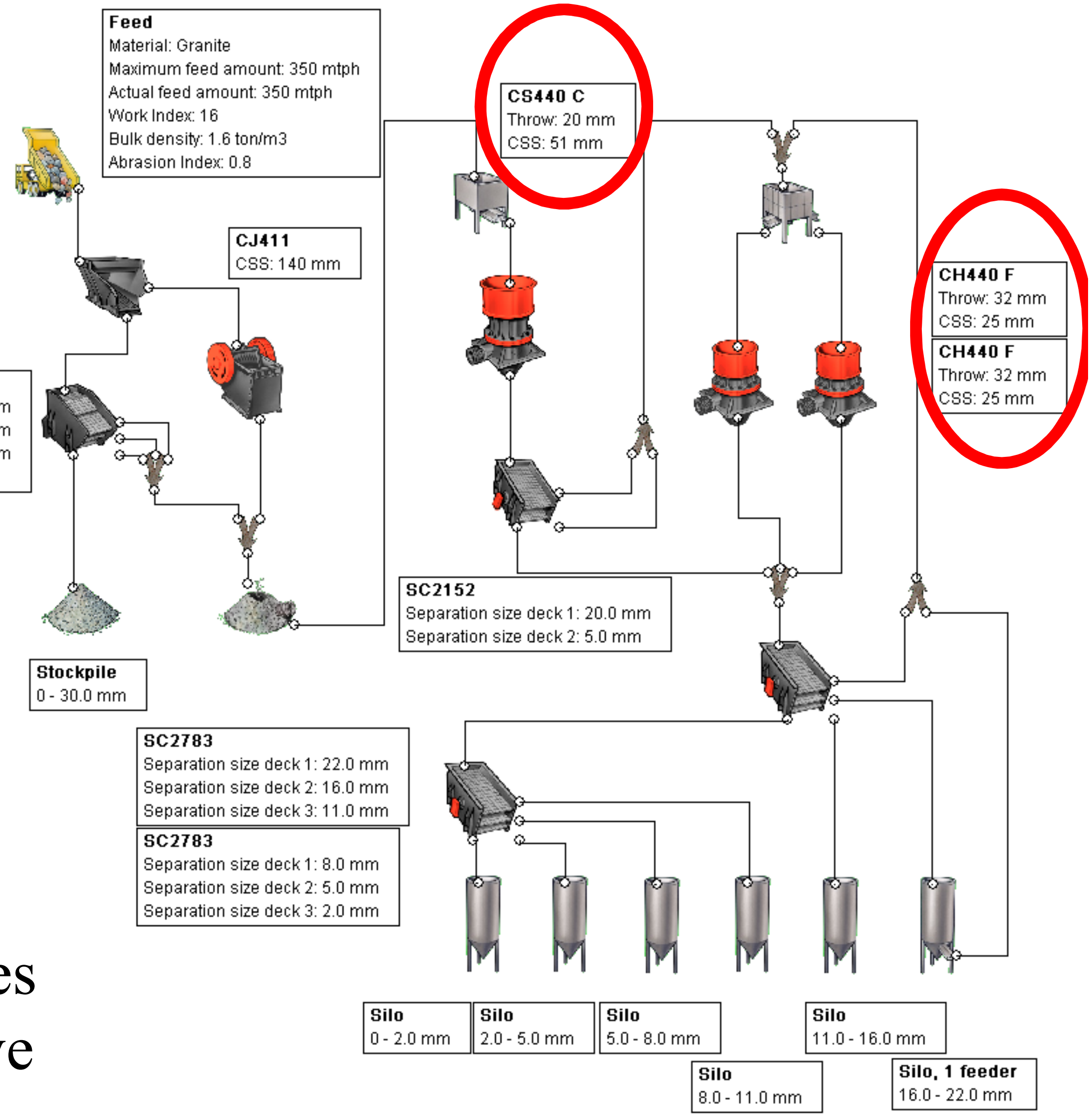
Optimization 1
without particle shape demands

- **After optimization**
- **Maximized Gross Profit**



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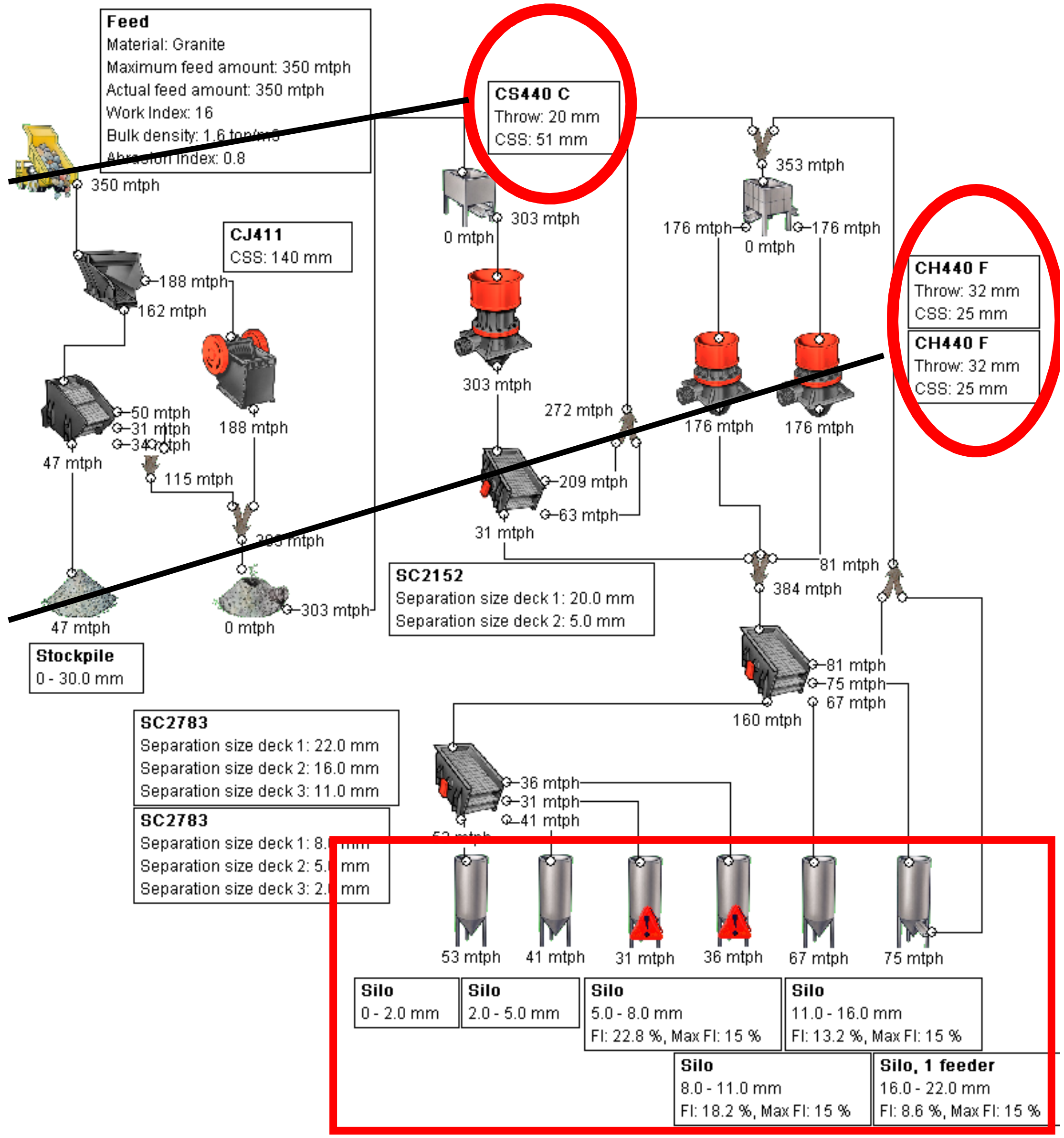
Optimization 2
<u>with</u> particle shape demands

Take home message:

Combined setting of equipement is important for process performance

CSS [mm]	25	13
CH440 F #2		
Throw [mm]	32	28
CSS [mm]	25	21



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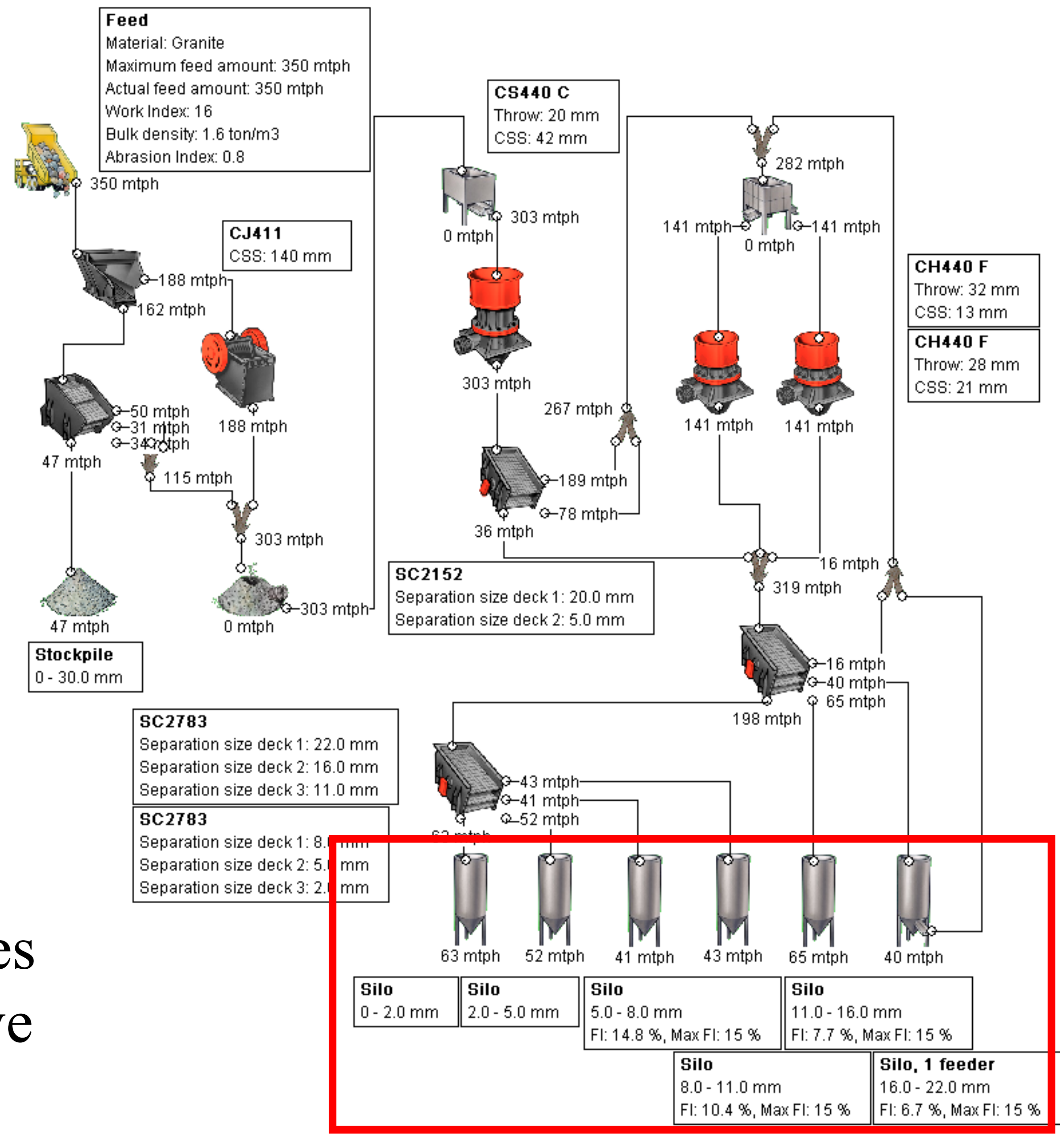
Optimization
Comparing results

Production Rate	Without Shape	With Shape
0-30 Road base	47 tph	47 tph
2-4	41 tph	52 tph
4-8	31 tph	41 tph
8-11	36 tph	43 tph
11-16	67 tph	65 tph
16-22	75 tph	40 tph
0 – 2 (by-product)	53 tph	63 tph



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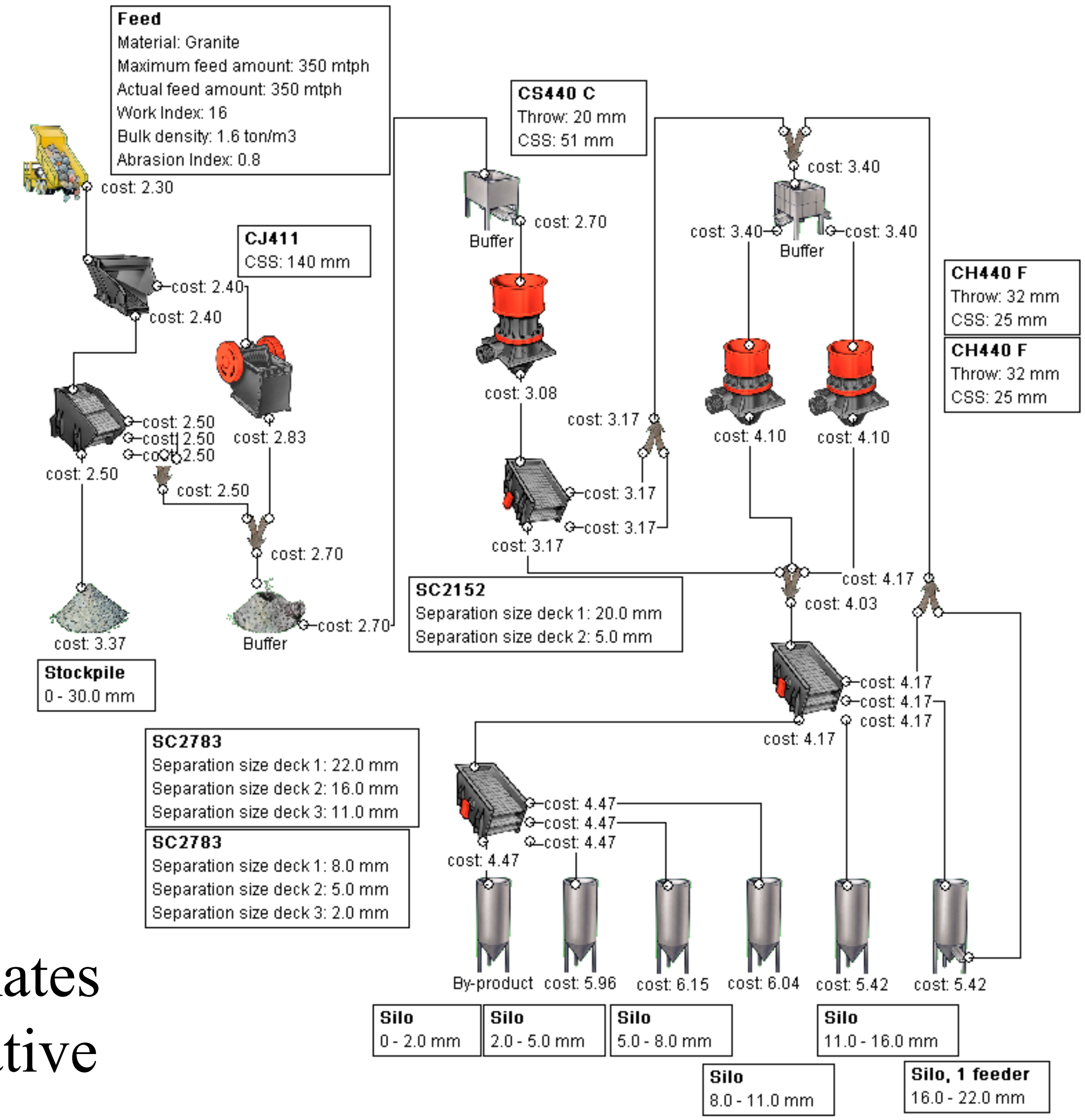
Optimization
Comparing results

	Without Shape	With Shape
TCO	$ 2 348 020	$ 2 352 136
"Gross Profit"	$ 4 484 309	$ 4 246 857



Take home message:

Quality is not free of charge

*All costs are estimates and only for illustrative purpose

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Conclusions

- Optimization must be a combination of technical and economic analysis
- Minimizing cost does not necessarily maximize profit
- Finding the right level of detail is important for the economic study
- Combined performance of different machines should be considered.

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