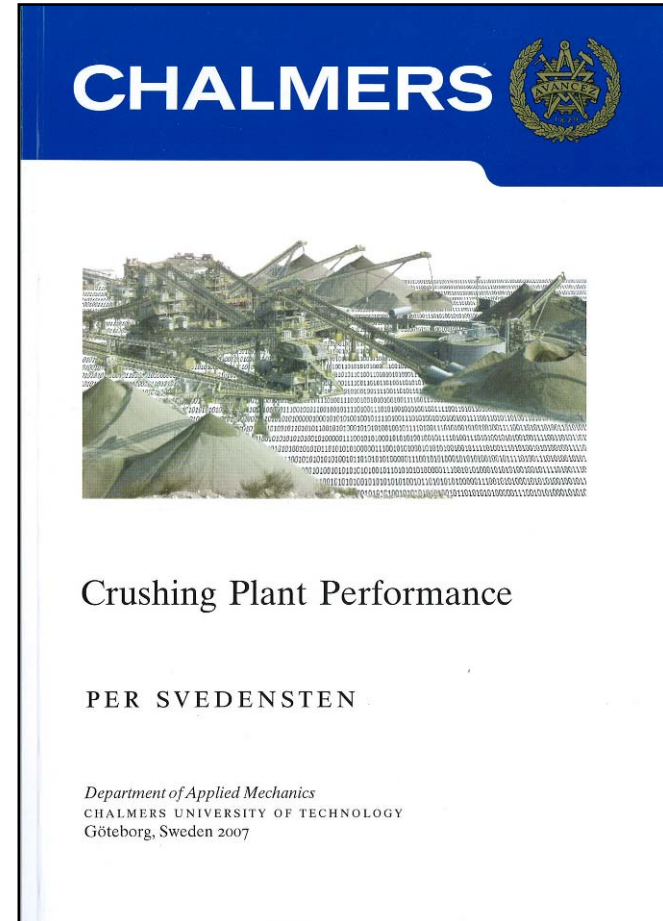# Optimizing the Process

## Per Svedensten

QUARRY ACADEMY

LIGHTEN UP!

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**

CHALMERS

Crushing Plant Performance

PER SVEDENSTEN

Department of Applied Mechanics
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2007

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Crushing Plant Optimization

- **Point of interest**
  - ✓ **Crushing stage**
  - ✓ **Crushing plant**
  - ✓ **Quarry Process**
- **Today:**
  - ✓ **Optimize the feed**
  - ✓ **Optimize the process**
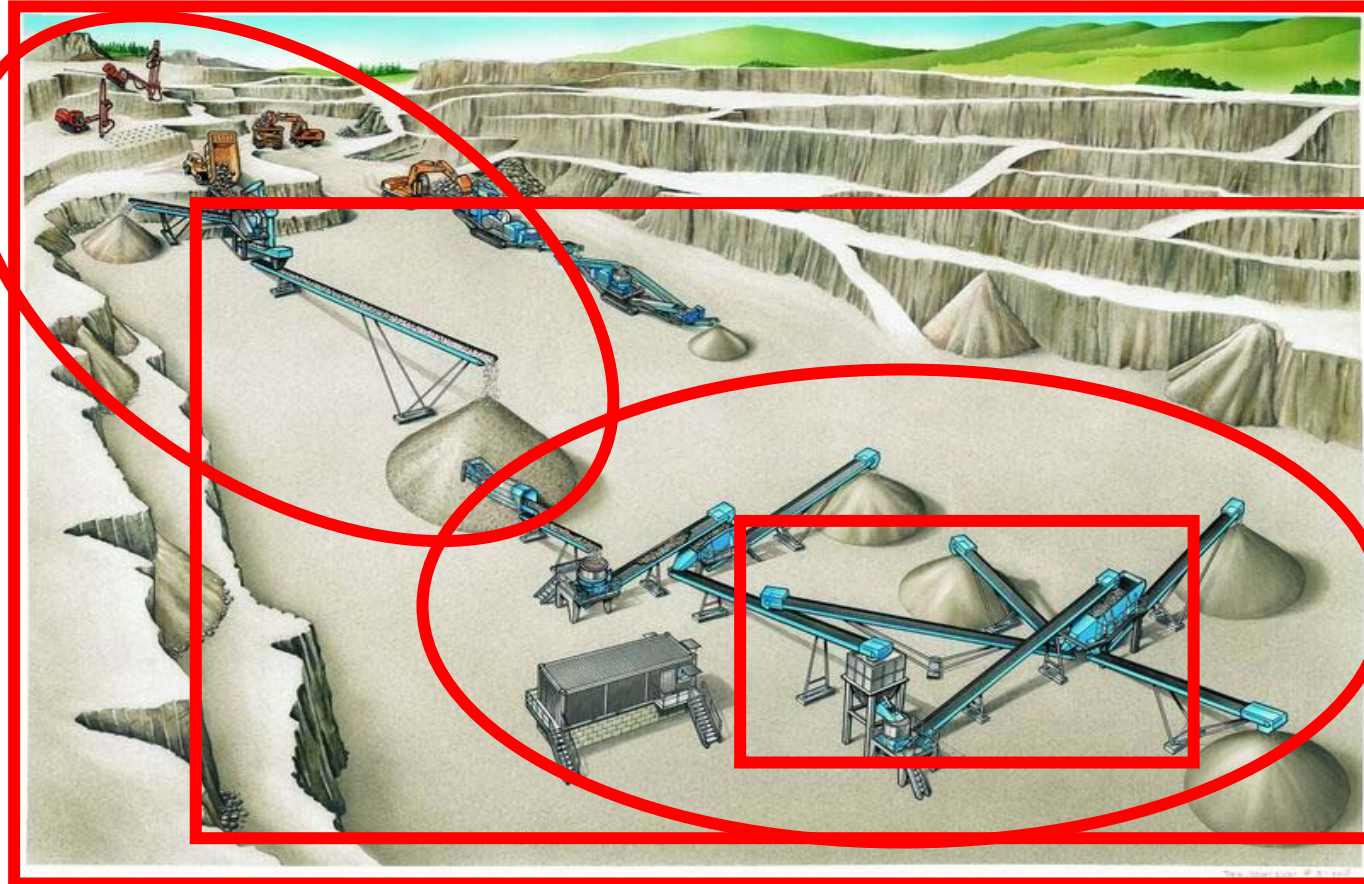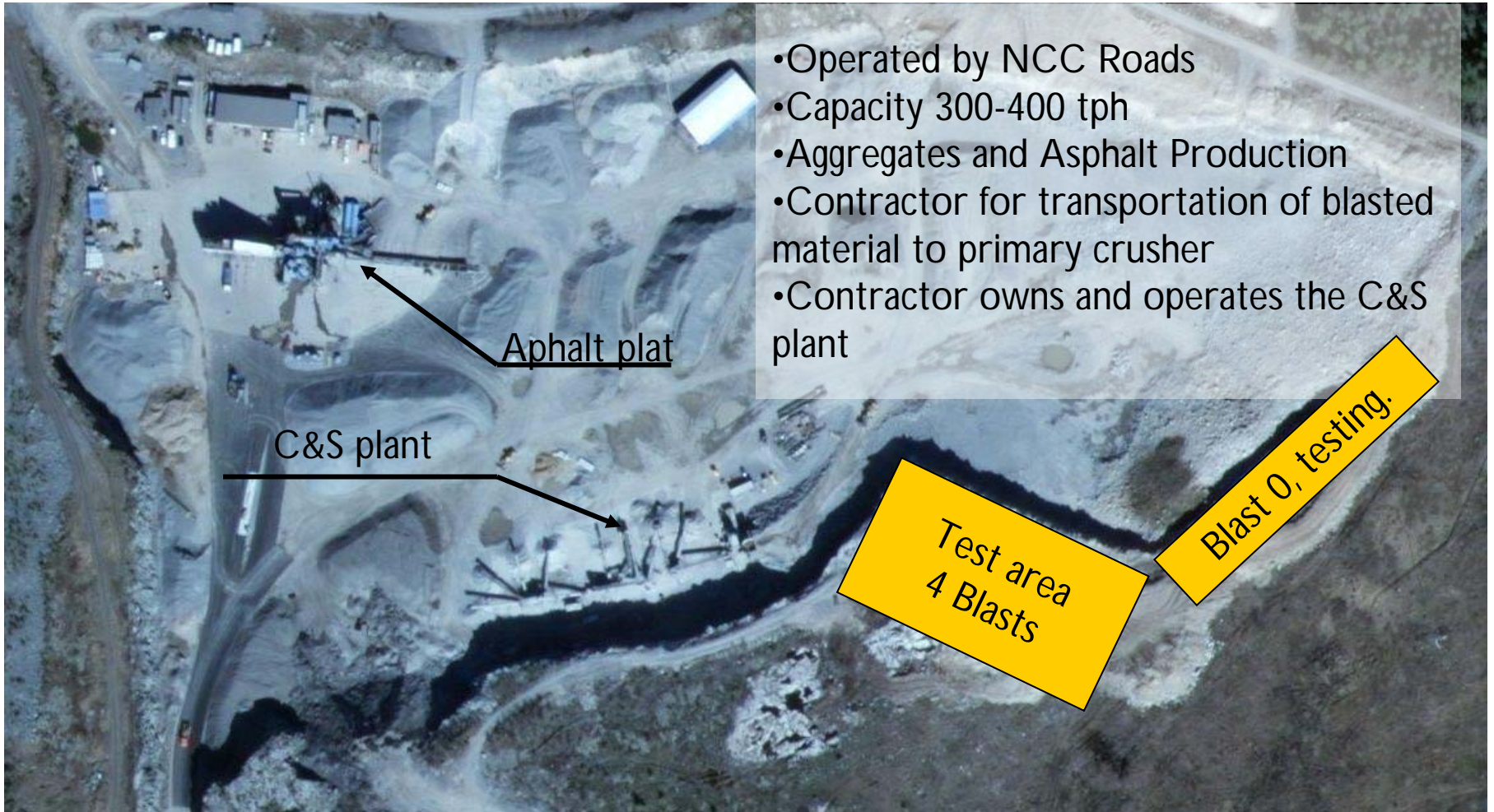
MinBaS II
Optimized blasting
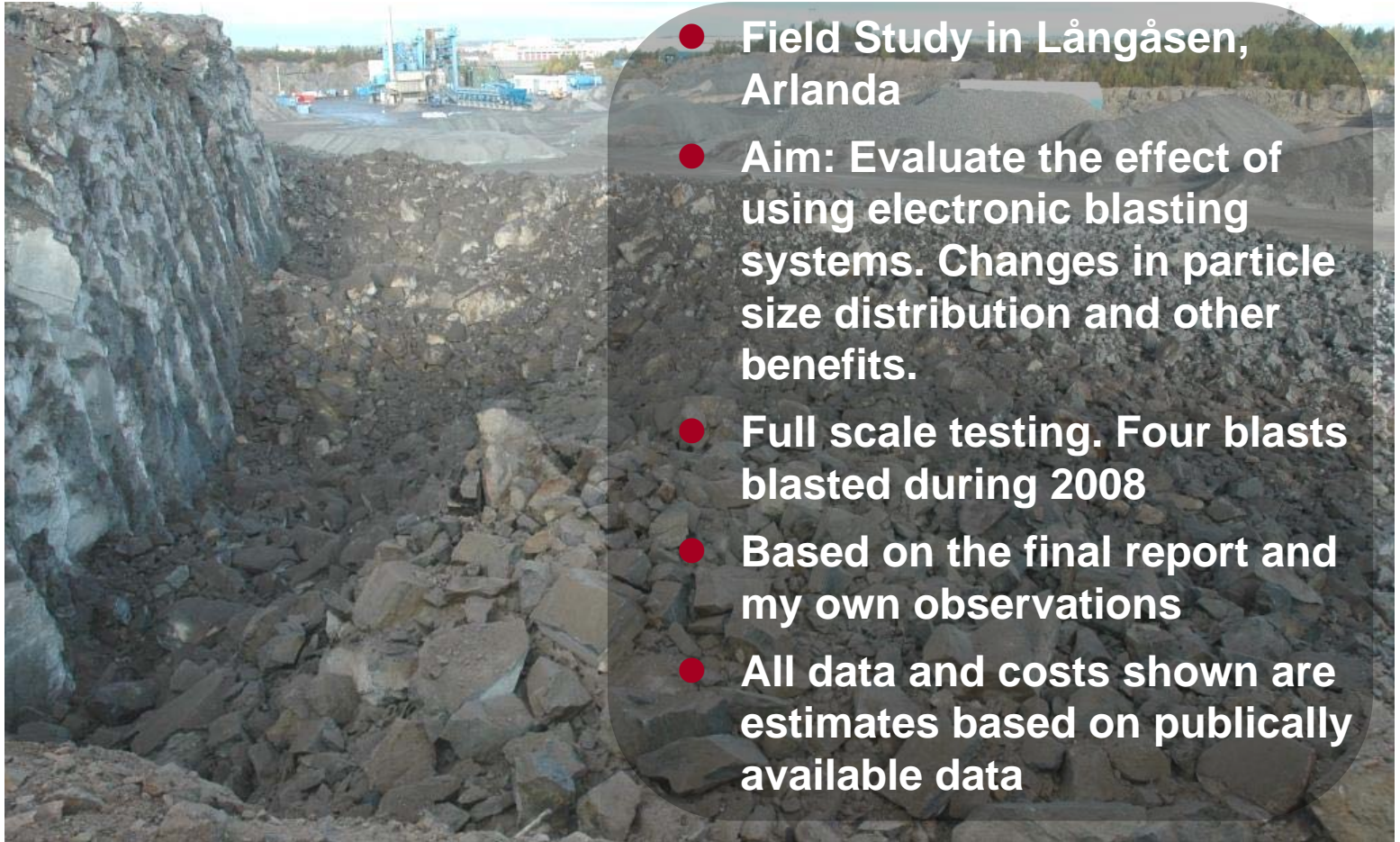
- Field Study in Långåsen, Arlanda

- 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

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

Aphalt plat

C&S plant

Test area
4 Blasts

Blast 0, testing.

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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	

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Blasting result
Measuring the Particle Size Distribution
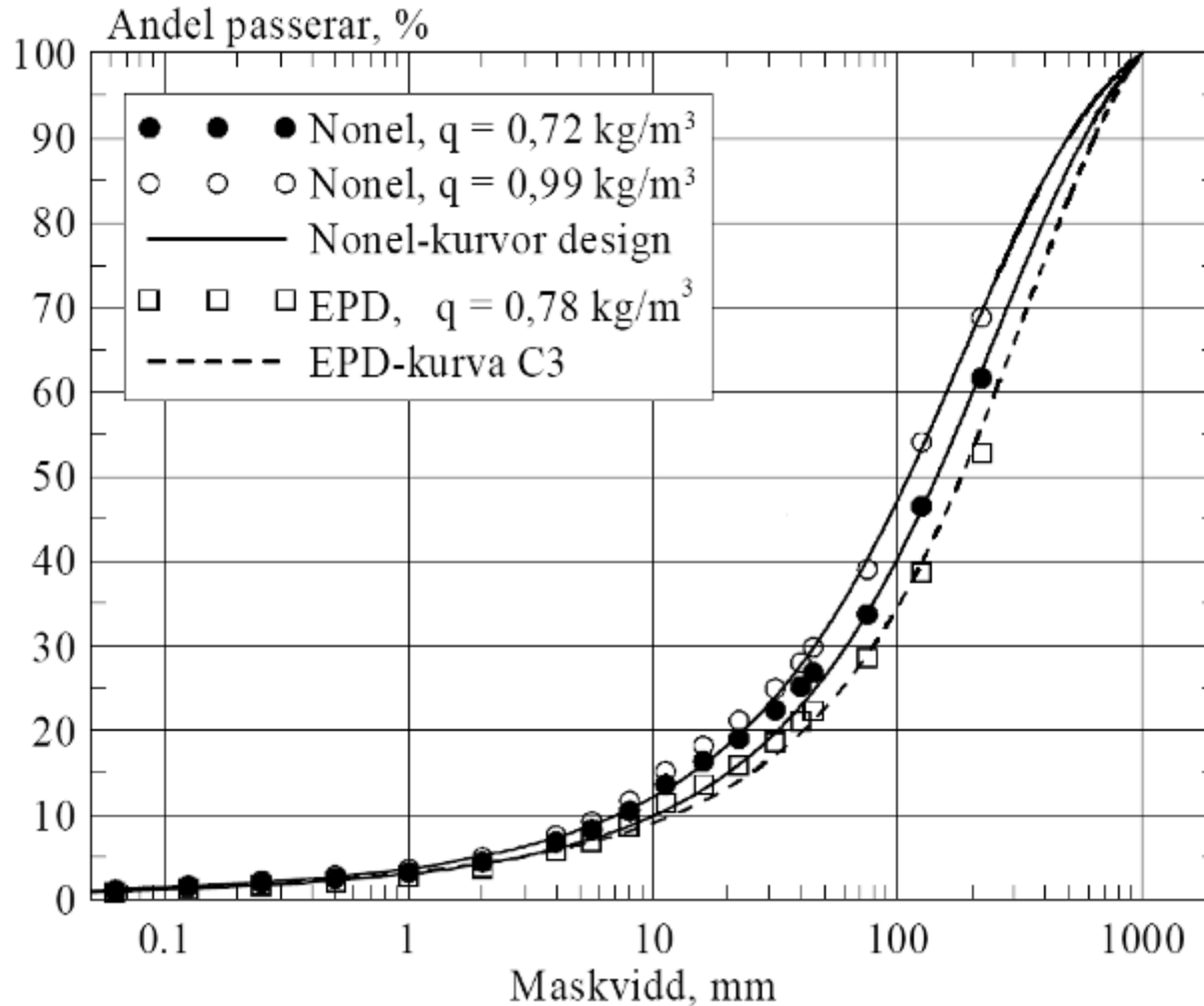
Blasting result
Cost analysis

	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**

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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



0-90 mm   +90 mm
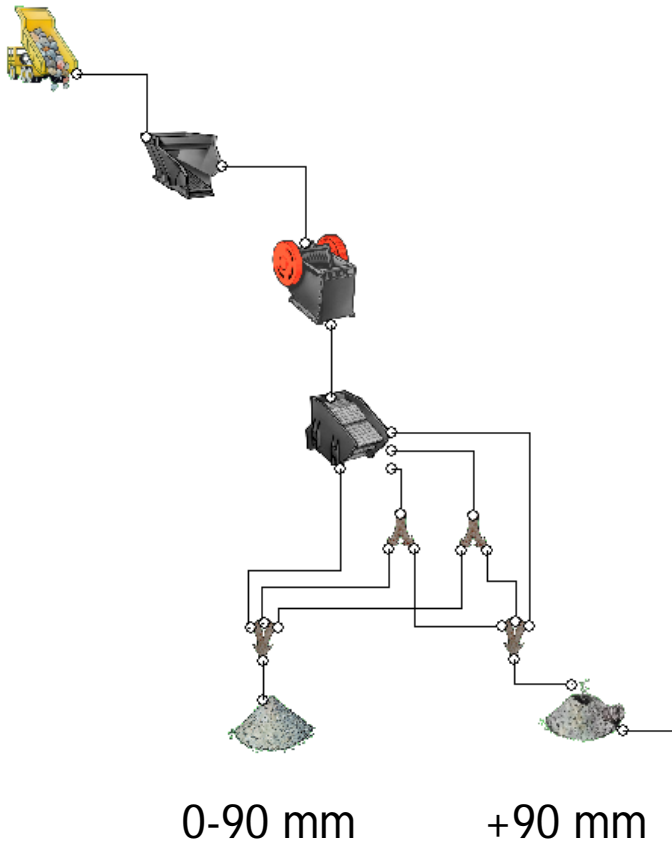
Crushing and Screening Performed Measurements

Power Draw [kwh]

Capacity [tph]

Capacity [tph]
0-90 mm

Capacity [tph]
+90 mm
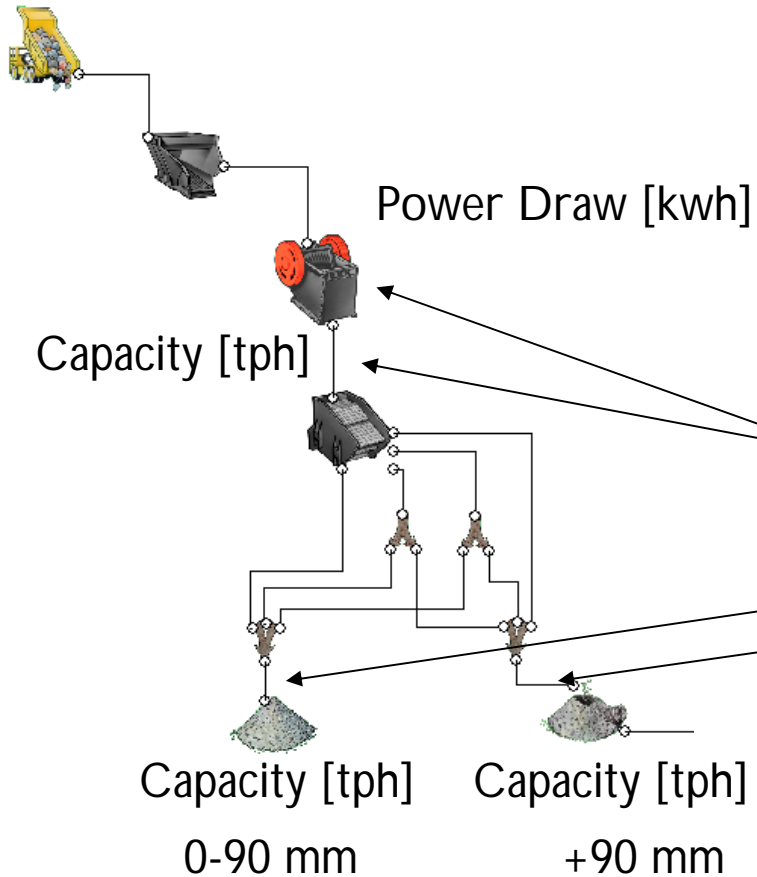
Crushing and Screening Cost analysis

	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

QUARRY ACADEMY

Production
Total cost $/h

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

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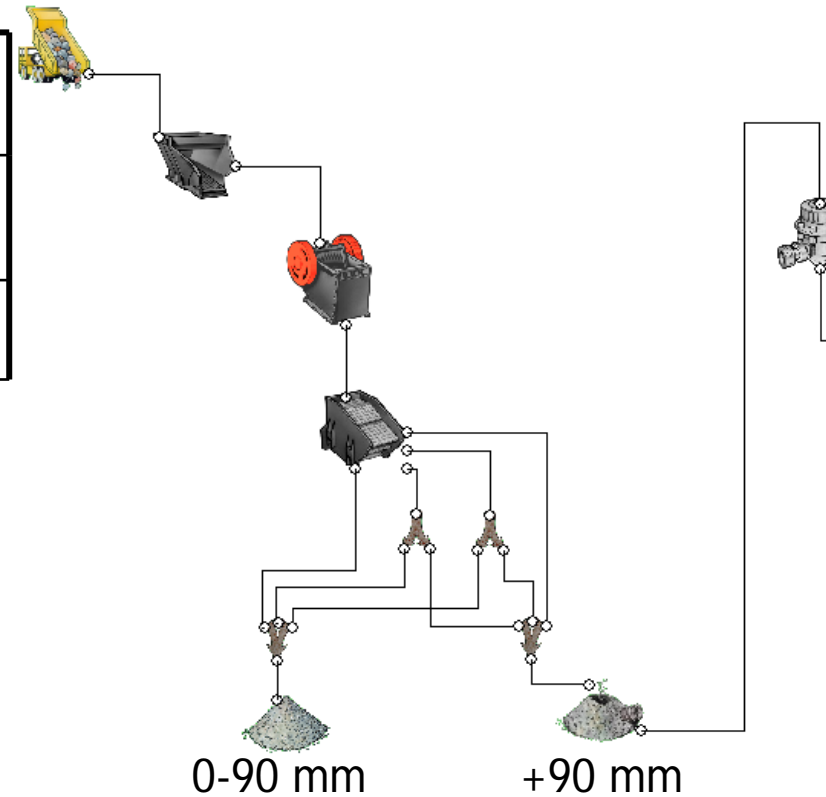
Distribution between 0-90 and +90 is
partly controlled by the blasting result

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
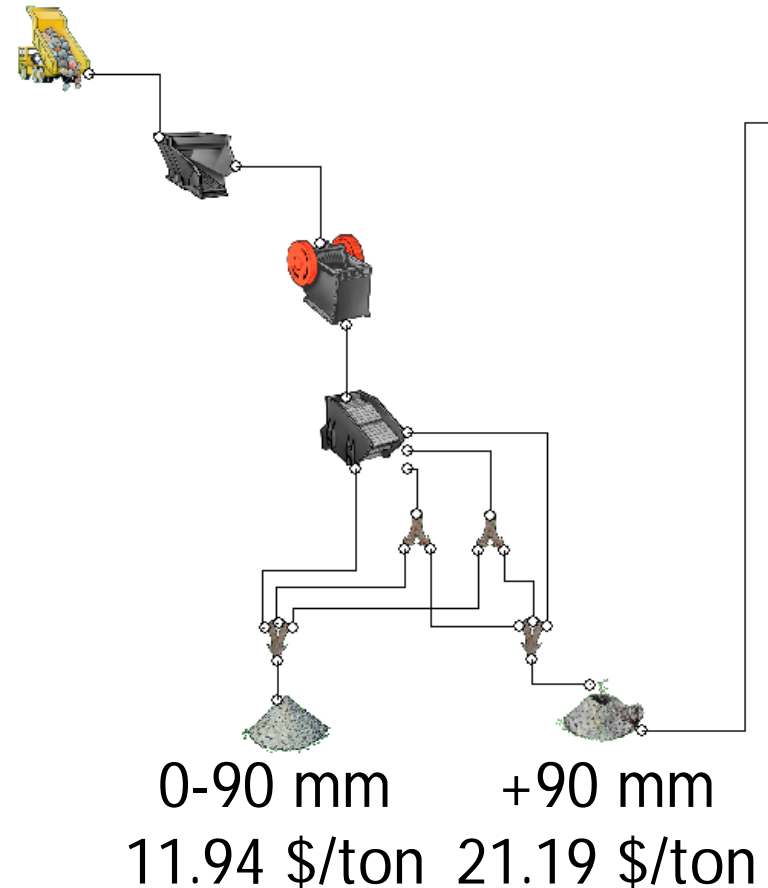
*Estimates based on publicly available data

Production
Revenue sek/h

	Nonel normalt q	Nonel high q	EPD normalt q
Produktion [tph]	298	316	313
Produktion 0-90 mm [tph]	186	206	189
Price 0-90 mm $/ton*	11.94	11.94	11.94
Produktion +90 mm [tph]	112	110	124
Ave. Price +90 mm $/ton*	21.19	21.19	21.19
Revenue $/h	4595	4791	4885

*Estimates based on publicly available data

QUARRY ACADEMY

Production
Cost and Revenue*

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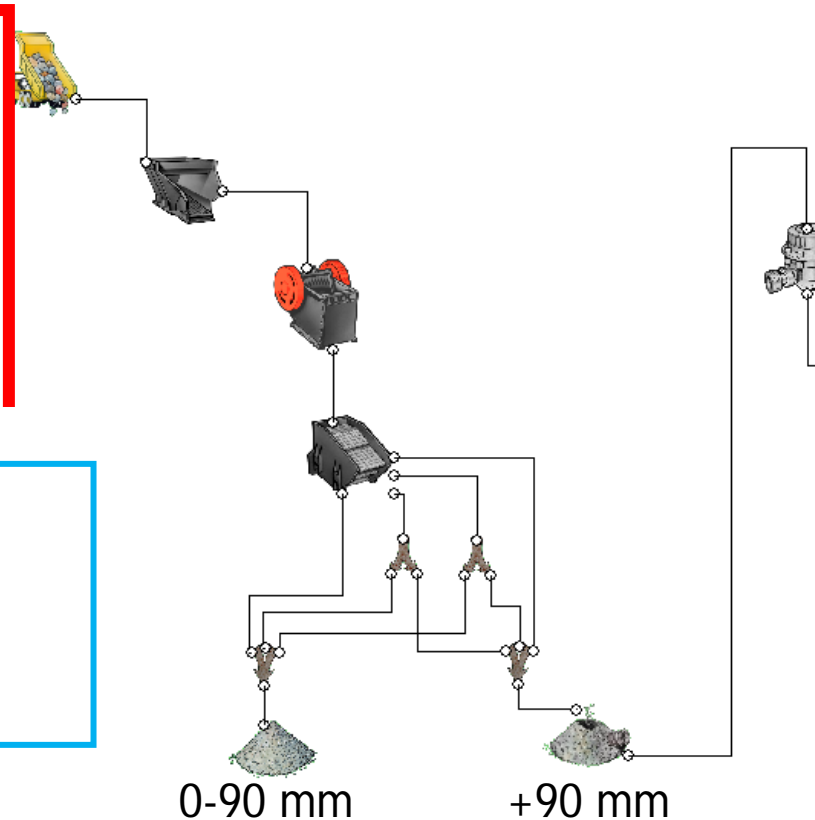
Take home message:

Minimizing cost does not necessarily maximize profit

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

*Based on publicly available data

QUARRY ACADEMY

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.**

# 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?**
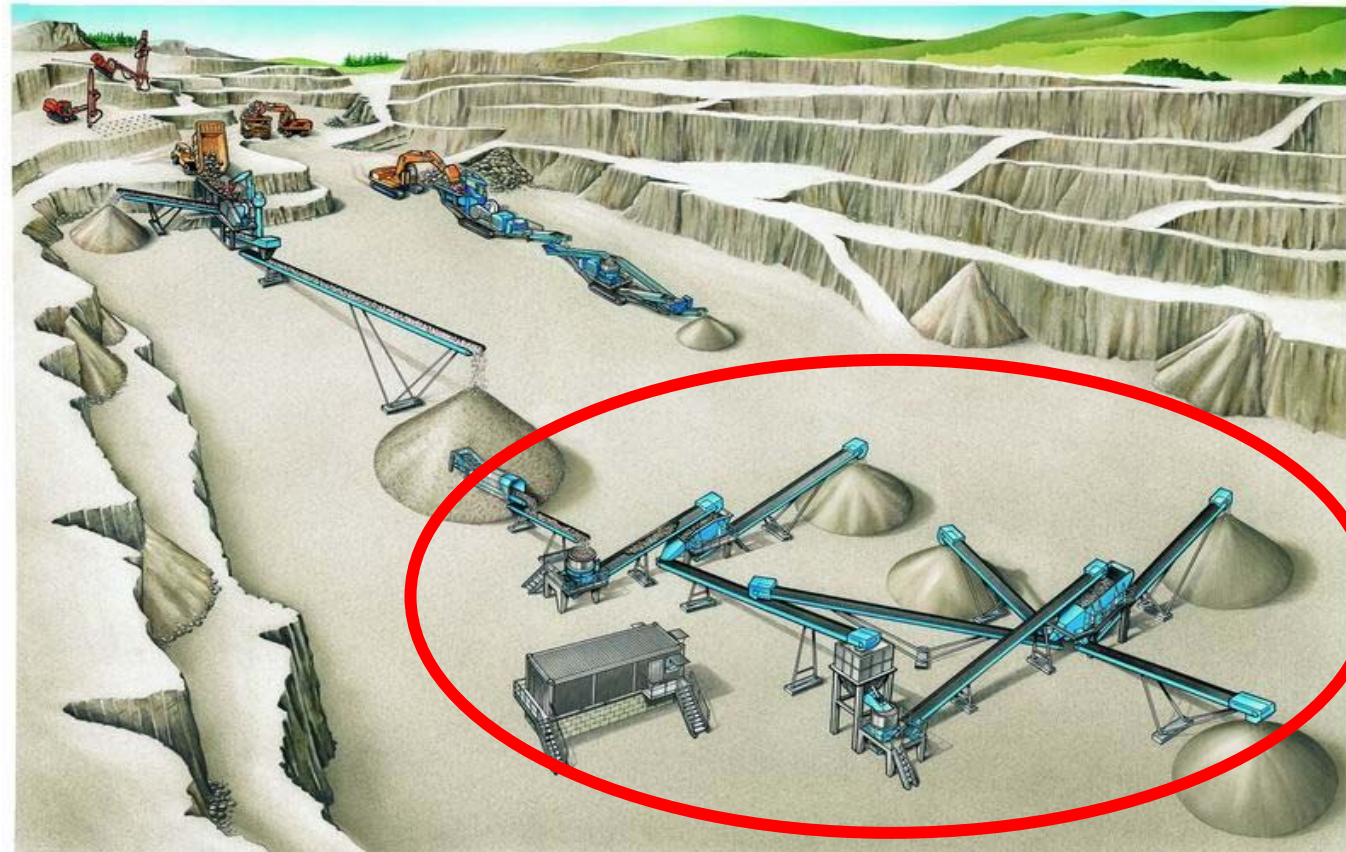
Crushing plant optimization using TCO
Objective of project

- **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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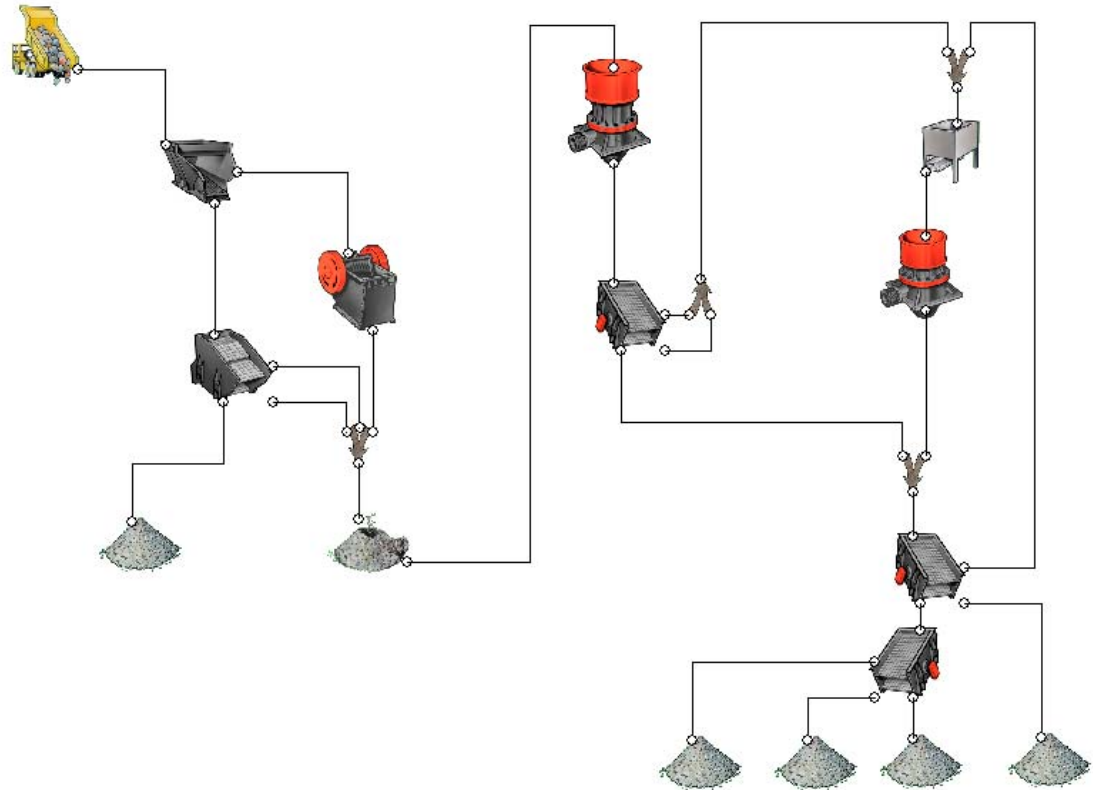
Modelling

Take home message:

Optimization cannot be done without including economics
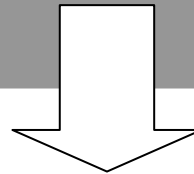
Optimisation

Simulation

Crushing plant model

Production units — Rock material — Economy — Customer demands

Yield the most profitable production strategy and meet the market demand

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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**

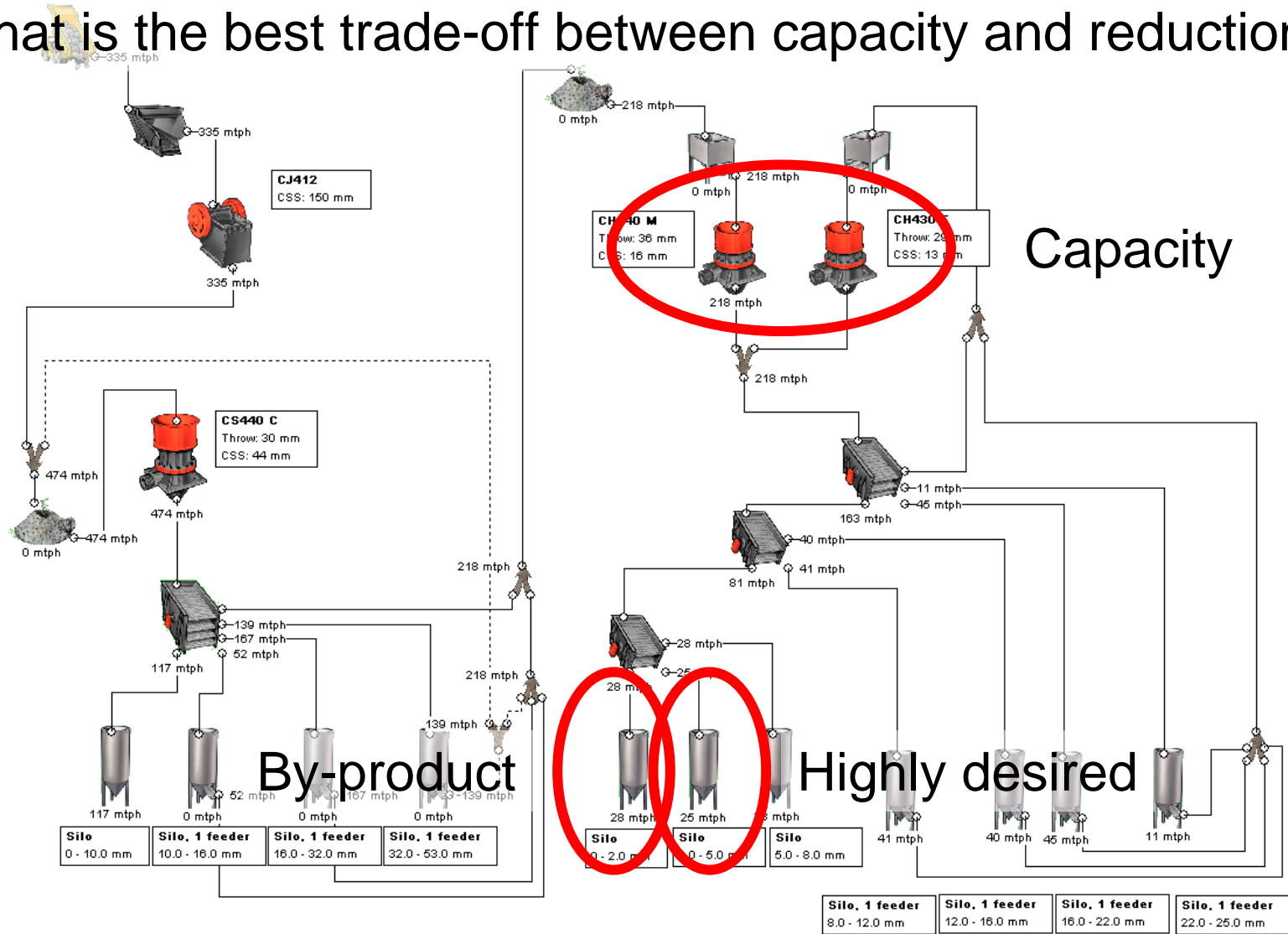- **Income calculation**
  - ✓ **Sellable products**
  - ✓ **Product demand**

- **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?

Capacity

By-product

Highly desired
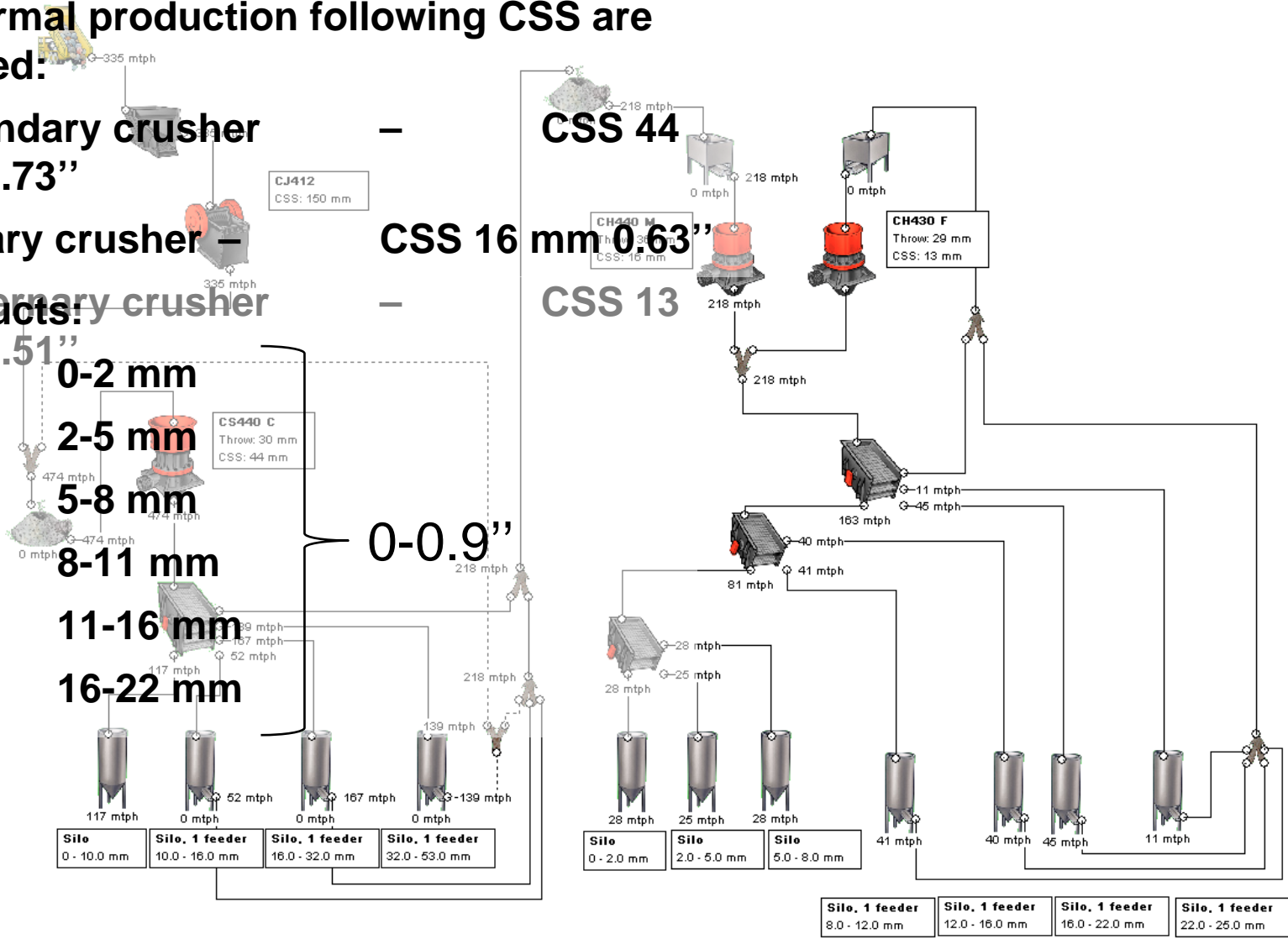
Crushing plant optimization using TCO
Test plant

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''

CJ412
CSS: 150 mm

CS440 C
Throw: 30 mm
CSS: 44 mm

CH440 M
Throw: 36 mm
CSS: 16 mm

CH430 F
Throw: 29 mm
CSS: 13 mm

335 mtph
218 mtph
474 mtph
218 mtph
163 mtph
81 mtph
139 mtph
28 mtph
25 mtph
11 mtph
45 mtph
40 mtph
41 mtph

Silo
0 - 10.0 mm

Silo, 1 feeder
10.0 - 16.0 mm

Silo, 1 feeder
16.0 - 32.0 mm

Silo, 1 feeder
32.0 - 53.0 mm

Silo
0 - 2.0 mm

Silo
2.0 - 5.0 mm

Silo
5.0 - 8.0 mm

Silo, 1 feeder
8.0 - 12.0 mm

Silo, 1 feeder
12.0 - 16.0 mm

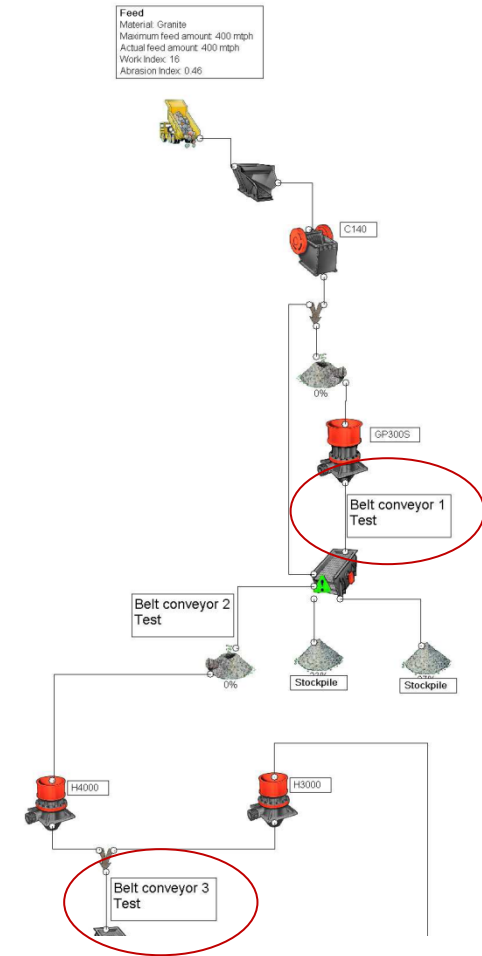Silo, 1 feeder
16.0 - 22.0 mm

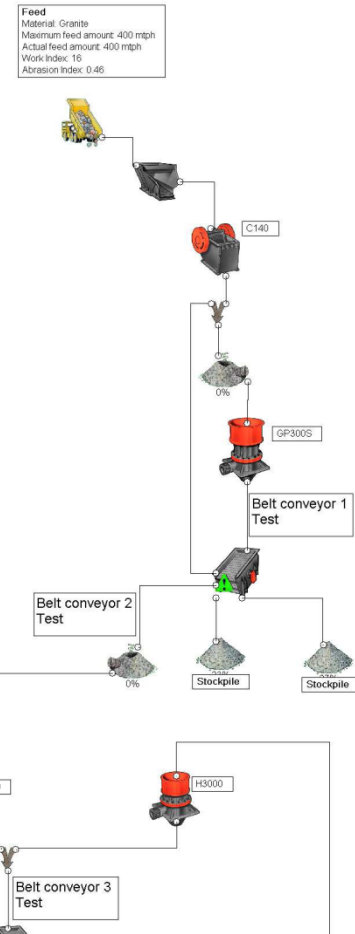Silo, 1 feeder
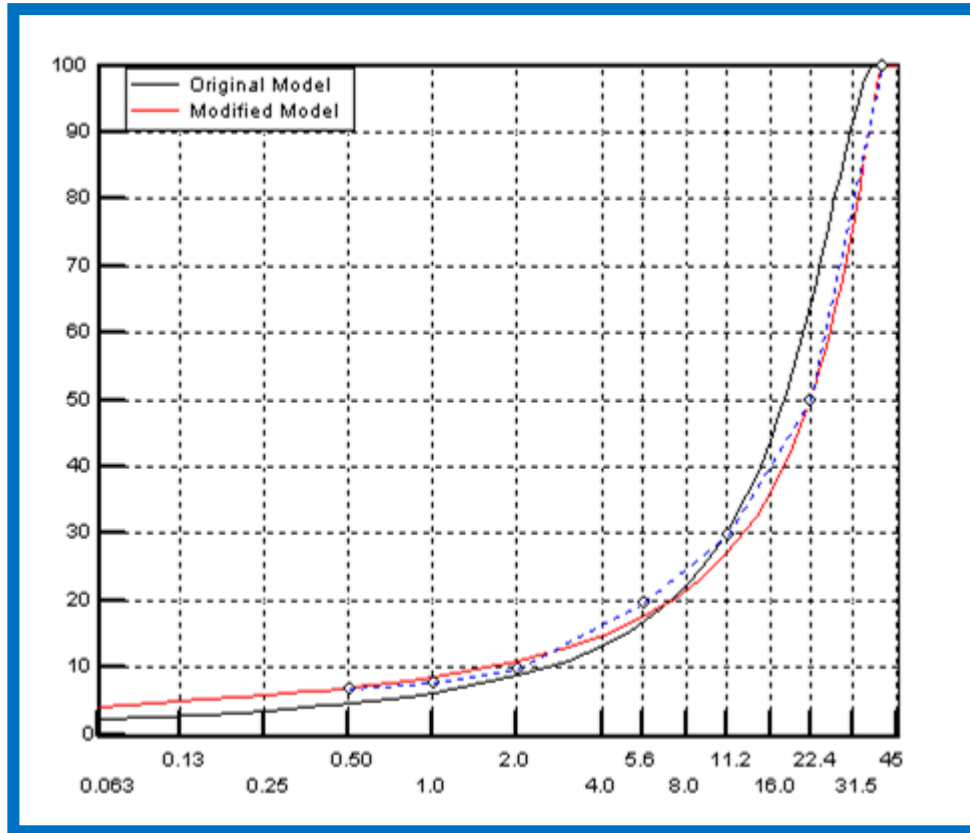22.0 - 25.0 mm

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Crushing plant optimization using TCO Test plan

Objectives for the first test session:

- Measure particle size distribution to calibrate t simulation model

- CSS at original settings

Feed
Material: Granite
Maximum feed amount: 400 mtph
Actual feed amount: 400 mtph
Work Index: 16
Abrasion Index: 0.46

C140

0%

GP300S

Belt conveyor 1
Test

Belt conveyor 2
Test

0%

Stockpile

Stockpile

H4000

H3000

Belt conveyor 3
Test

QUARRY
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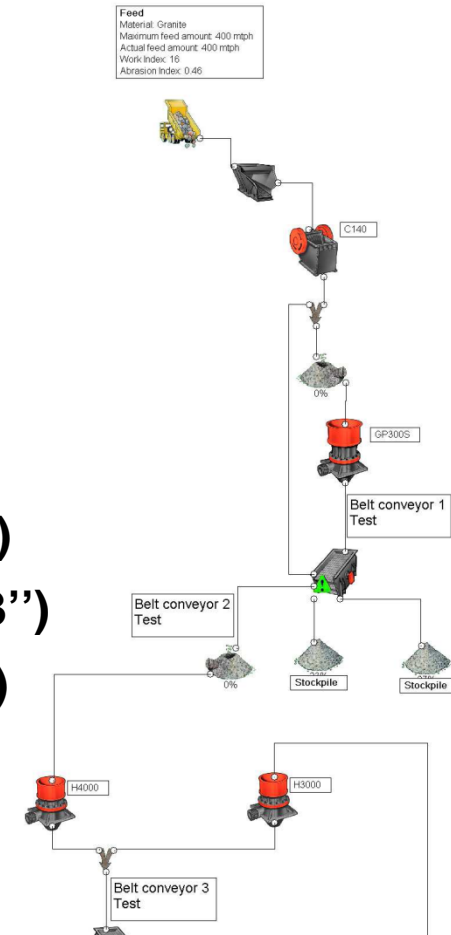# Crushing plant optimization using TCO Model Calibration

Crushing plant optimization using TCO
Running the TCO optimization module

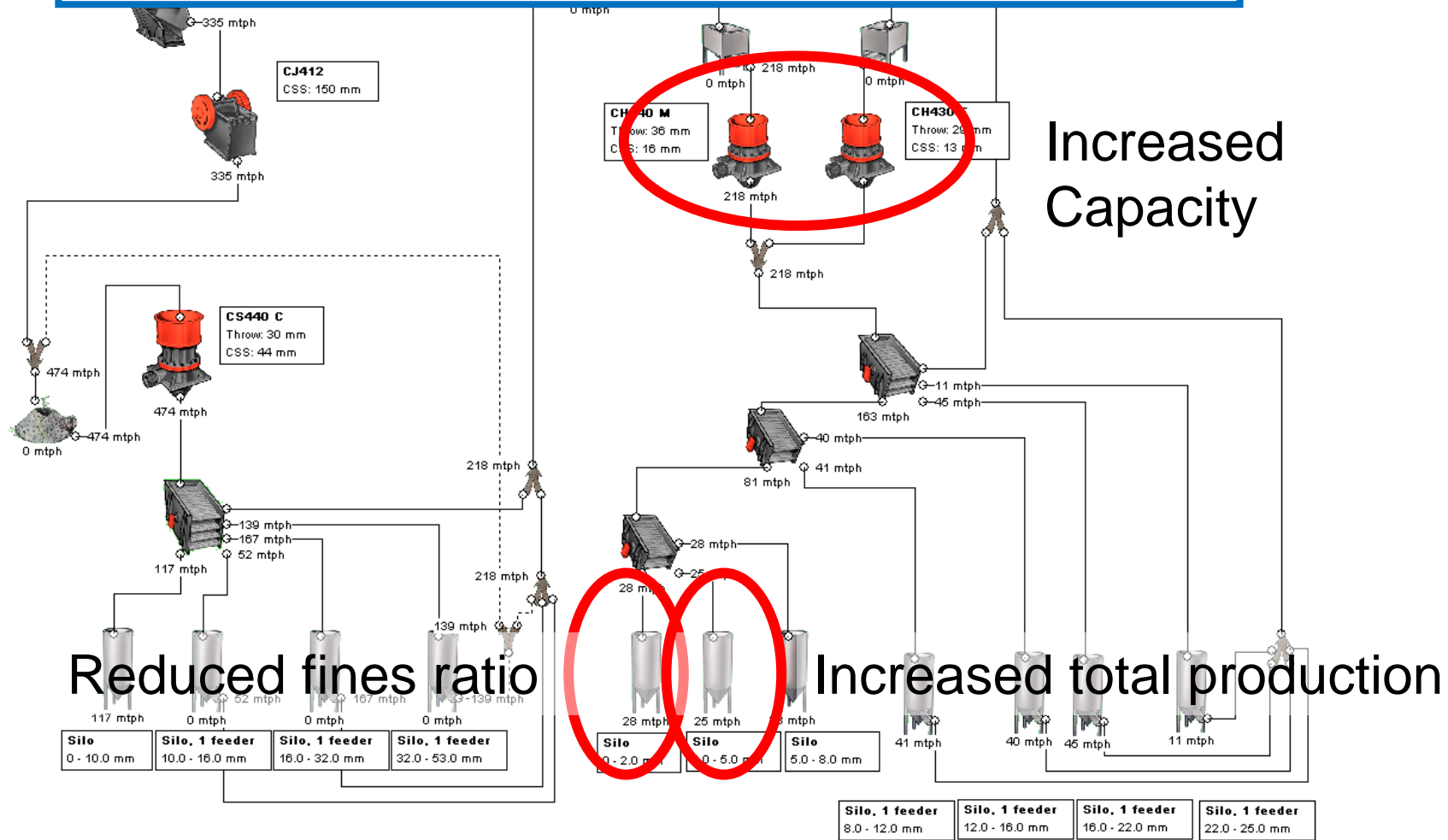**The computer tool automatically finds the best solution using an optimization algorithm**

The solution that yields the best profit:

- **Secondary crusher – CSS 50 mm (44), 1.96'' (1.73'')**
- **Tertiary crusher –   CSS 20 mm (16) 0.78'' (0.63'')**
- **Quaternary crusher – CSS 14 mm (13) 0.55'' (0.51'')**

Feed
Material: Granite
Maximum feed amount: 400 mtph
Actual feed amount: 400 mtph
Work Index: 16
Abrasion Index: 0.46

C140

GP300S

Belt conveyor 1
Test

Belt conveyor 2
Test

Stockpile

Stockpile

H4000

H3000

Belt conveyor 3
Test

Crushing plant optimization using TCO Results

Result: +11 % in Calculated Gross Profit

Increased Capacity

Reduced fines ratio

Increased total production

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**