



Tecnología de alta velocidad y configuración simple e intuitiva al servicio de la Planificación Estratégica y Táctica

Rodrigo Valenzuela



Rodrigo Valenzuela V.

www.maptek.cl





Rodrigo Valenzuela V.

www.maptek.cl

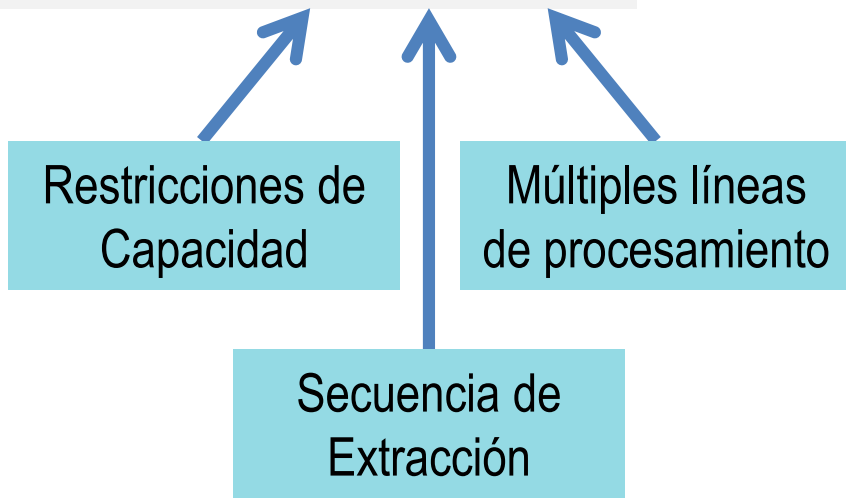
Métodos de
Optimización

Configuración Simple: Maximizar NPV

Restricciones de
Capacidad

Múltiples líneas
de procesamiento

Secuencia de
Extracción





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Métodos de Optimización

Configuración Simple: Maximizar NPV

$$\text{Max NPV} = \sum_{n=1}^N \frac{P_n}{(1+d)^n}$$

Where:

d = discount rate

$$P = \text{profit } (\$) = (P_{\text{process}_1} + P_{\text{process}_2} + \dots + P_{\text{process}_n}) - fT$$

And

$$P_{\text{process}_n} = (s-r)\bar{g}_n y_n Q_{c_n} - mQ_{m_n} - cQ_{c_n}$$

s = price (\$/unit of product)

r = selling cost (\$/ unit of product)

\bar{g}_n = average grade of material presented at process n

y_n = recovery at process n

m = mining cost (\$/ton)

c = processing cost (\$/ton)

f = fixed cost (\$/year)

T = length of period considered

Q_{c_n} = quantity of ore presented at process n

Q_{m_n} = quantity of material presented at process n



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Métodos de
Optimización

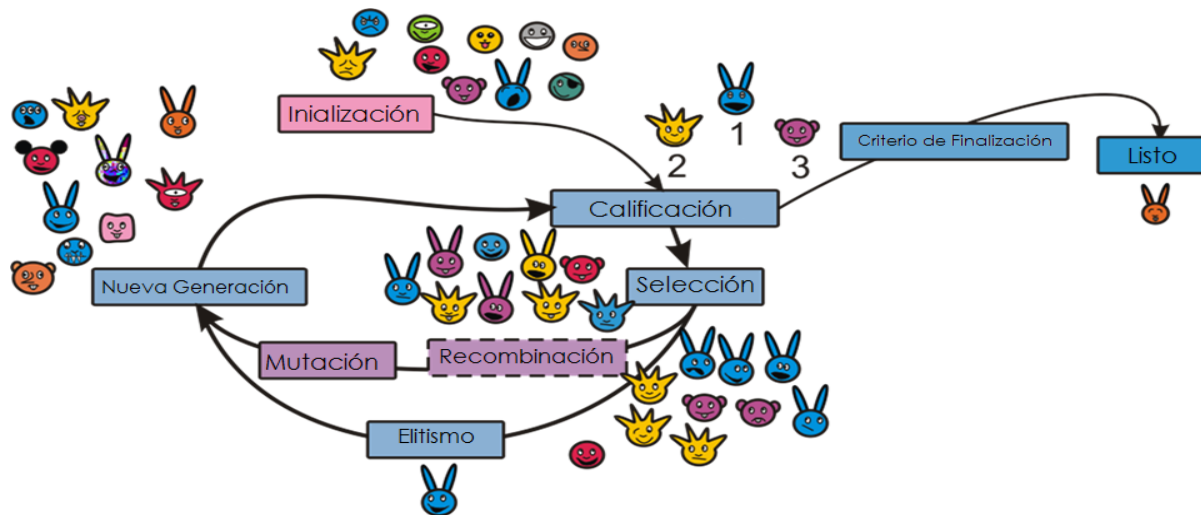
Algoritmos Evolutivos Genéticos

La computación evolutiva es una de las ramas de la Inteligencia Artificial que se aplica para la resolución de problemas de optimización combinatoria. Está inspirada en los mecanismos de evolución biológica propuestos por Darwin, Medel y Lamark.

La inteligencia artificial es una rama que trata de "imitar" a la inteligencia natural y por tanto la computación evolutiva se basa en imitar la evolución biológica tal y como la entendemos. La Computación Evolutiva trata de resolver problemas de optimización combinatoria, con el fin de encontrar el mejor resultado al problema, tal como pasa en la naturaleza solo los más fuertes y mejor adaptados al entorno son capaces de sobrevivir y reproducirse; en otras palabras, son los mejores individuos posibles o la mejor solución al problema.

Métodos de Optimización

Algoritmos Evolutivos Genéticos





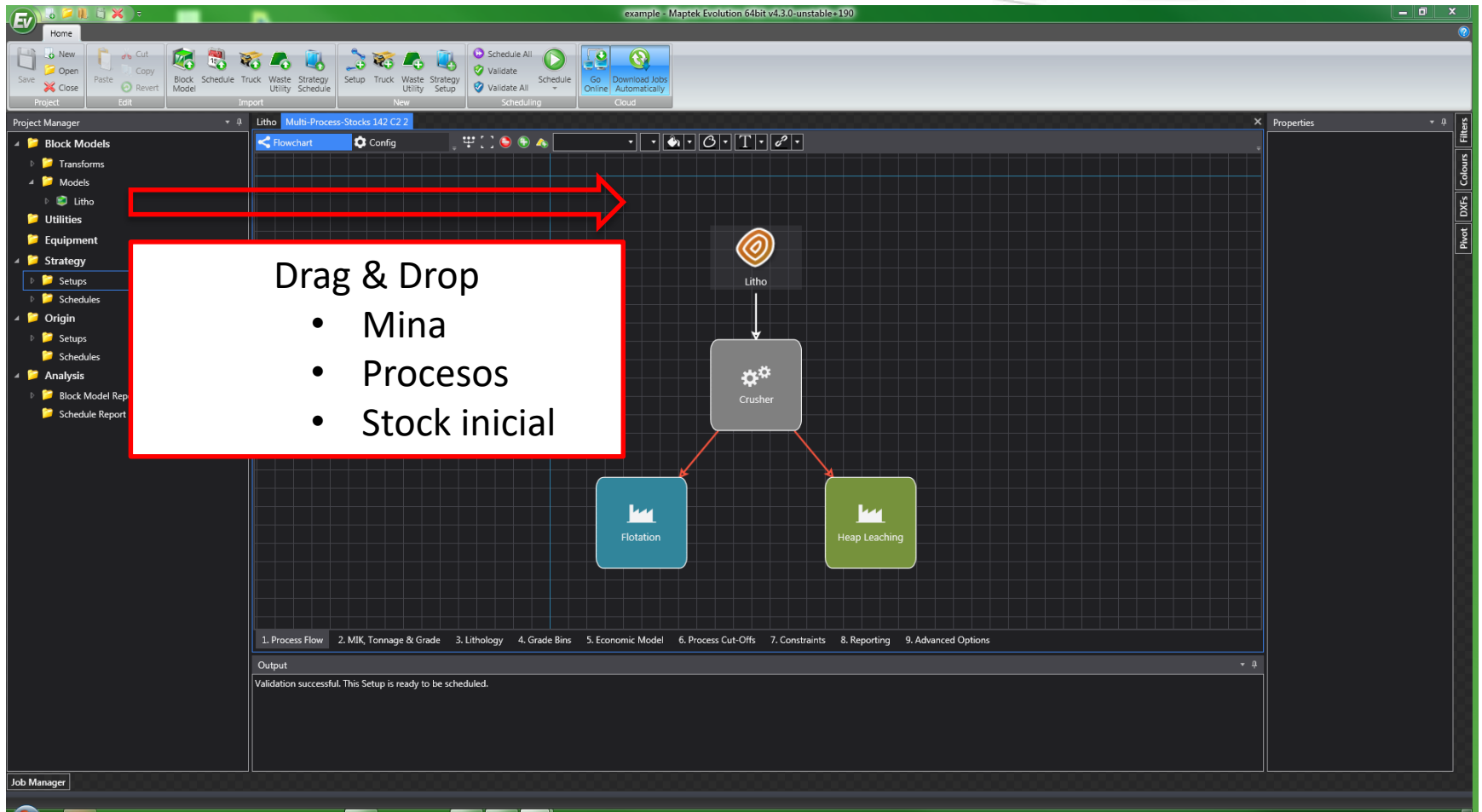
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Establecer
Modelo

The screenshot displays the MAPTEK software interface. The central window shows a 3D block model of a mine, rendered with a color gradient from red (top) to blue (bottom). The interface includes a Project Manager on the left, a Properties panel on the right, and a central 3D view area. The Properties panel is currently showing the 'Block Detail' section for a selected block.

Property	Value
Position	30971.715638, 81216
stage	1.000
Toe	False
alter	6.000
an_4x	16.000
as	331.466
as_2001	549.587
aux	0.000
aux_3	2.420
aux2	1.000
auxiliar	0.000
caf_m	0.000
caf_p	0.000
categ	1.000
check	14,099.999
cus	0.002
cut	0.014
density	2.350
fases_prefs	2.000
id_x	80.000



The screenshot displays the Maptek Evolution software interface. The main workspace shows a flowchart with three nodes: 'Litho' at the top, 'Crusher' in the middle, and 'Flotation' and 'Heap Leaching' at the bottom. A red callout box with a white background and a red border is overlaid on the left side of the workspace. It contains the text 'Drag & Drop' followed by a bulleted list: 'Mina', 'Procesos', and 'Stock inicial'. A red arrow points from the 'Litho' node in the flowchart towards the callout box. The software interface includes a top menu bar with options like 'Home', 'Project', 'Edit', 'Import', 'New', 'Scheduling', and 'Cloud'. A left sidebar shows a 'Project Manager' tree with folders for 'Block Models', 'Transforms', 'Models', 'Litho', 'Utilities', 'Equipment', 'Strategy', 'Setups', 'Schedules', 'Origin', 'Analysis', 'Block Model Rep', and 'Schedule Report'. A bottom status bar shows a progress indicator with steps from '1. Process Flow' to '9. Advanced Options'. An 'Output' window at the bottom displays the message: 'Validation successful. This Setup is ready to be scheduled.'

Drag & Drop

- Mina
- Procesos
- Stock inicial



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example - Maptek Evolution 64bit v4.3.0-unstable-190

Home

Project Manager

Block Models

Transforms

Models

Utilities

Equipment

Strategy

Setups

Schedules

Origin

Analysis

Calendar View

Config View

Variable Costs

Dynamic Capital

Start Date

01-ene-2015

	Period 1	Period 2	Period 3	Period 4	Period 5
Start Date	01-Jan-2015	01-Jan-2016	01-Jan-2017	01-Jan-2018	01-Jan-2019
End Date	31-Dec-2015	31-Dec-2016	31-Dec-2017	31-Dec-2018	31-Dec-2019
Admin/Fixed Cost	\$44,000,000.00	\$44,000,000.00	\$44,000,000.00	\$44,000,000.00	\$44,000,000.00
Mining Capacity (tonnes)	170,000,000	173,350,000	173,350,000	173,350,000	173,350,000
Capital Injection	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Total Crusher Capacity (tonnes)	15,000,000	30,000,000	40,000,000	45,000,000	45,000,000
Total Processing Capacity (tonnes)	15,000,000	30,000,000	40,000,000	45,000,000	45,000,000
Total Refining Capacity (units)	1,999,999,998	1,999,999,998	1,999,999,998	1,999,999,998	1,999,999,998
Rehabilitation Cost (\$ per tonne)	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Mining Cost Escalation	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Crusher Capacity (tonnes)	15,000,000	30,000,000		1,000,000	45,000,000
Flotation Capacity (tonnes)	13,000,000	28,000,000		1,000,000	43,000,000

Modelo Económico

- Precios
- Costos
- Capacidades

Tasa de descuento
Definición de Stocks

Alternativas de Costos y Recuperaciones (variables del modelo)

Inyección dinámica de Capital

Calendar View

Config View

Variable Costs

Dynamic Capital

Discount Factor

The fraction by which cash flows for a period are multiplied to calculate the Net Present Value (NPV)

Discount Rate (%)

10.00

Cut-off Grade Optimisation

Turn-off cut-off grade optimisation.

Global Minimum Cut-off

0.3000

Stockpiles

Allowing stockpiles will cause the schedule to auto-create stockpiles for each process defined in your process flow. You will also need to define stockpile rehandle and recovery values within the calendar.

Allow Stockpiles

Process Stockpile Capacity

Name	Capacity (tonnes)	Fixed Cut-off
Flotation	999,999,999	0.0000
Heap Leaching	999,999,999	0.0000

Calendar View

Config View

Variable Costs

Dynamic Capital

Optional. Select an item in the model to use as the cost. You will also need to define the cost escalation factor within the calendar.

Mining Cost

most

Rehabilitation Cost

Grade

Variable Process Costs

Processes

Flotation

Processing Cost

pc_flot

Processing Cost Default

3.25

Recovery

rec_flot

Recovery Default (%)

89.40

Stage	Capital
Stage 1	\$0.00
Stage 2	\$0.00
Stage 3	\$0.00
Stage 4	\$0.00
Stage 5	\$10,000,000.00
Stage 6	\$0.00
Stage 7	\$0.00
Stage 8	\$0.00
Stage 9	\$0.00
Stage 10	\$0.00
Stage 11	\$0.00



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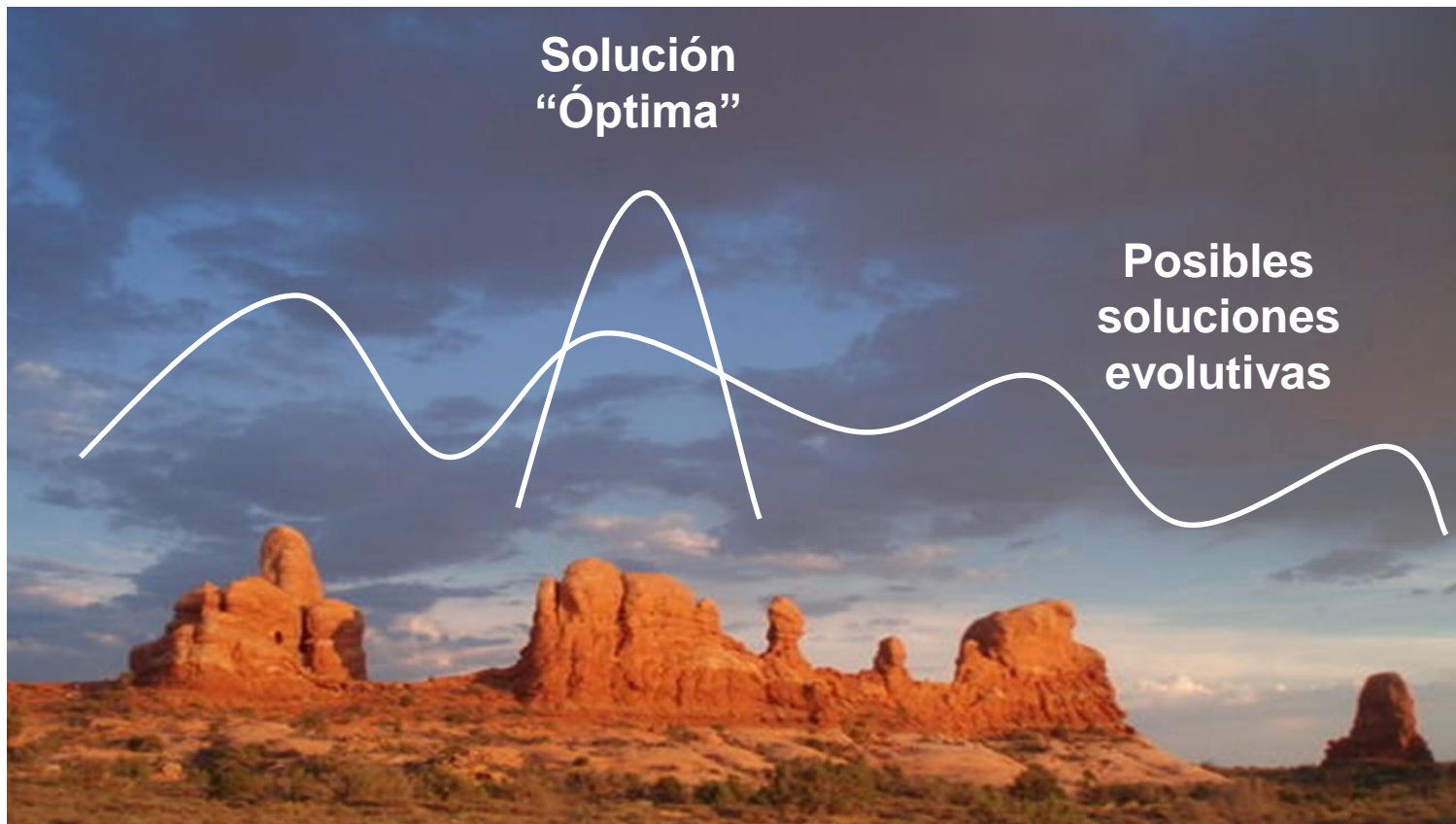
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The screenshot shows the MAPTEK software interface with several callouts:

- Validación**: A red box pointing to the 'Validate' button in the top toolbar.
- Conexión a la nube**: A red box pointing to the 'Go Online' button in the top toolbar.
- Optimización de múltiples modelos de planificación**: A red box pointing to a dropdown menu showing multiple 'Multi-Process-Stocks' models.
- Creación de múltiples modelos de planificación**: A red box pointing to the 'Multi-Process-Stocks 142 C2 2' model in the left sidebar.

The interface includes a top toolbar with buttons for 'New', 'Open', 'Save', 'Cut', 'Copy', 'Paste', 'Revert', 'Block Model', 'Schedule', 'Truck', 'Waste Utility', 'Strategy Schedule', 'Setup', 'Truck Utility', 'Waste Utility', 'Strategy Setup', 'Schedule All', 'Validate', 'Go Online', and 'Download Jobs Automatically'. The left sidebar shows a 'Project Manager' tree with folders for 'Block Models', 'Transforms', 'Models', 'Utilities', 'Equipment', 'Strategy', 'Schedules', 'Origin', and 'Analysis'. The main workspace displays 'Report Items' and 'Additional Grade It'.

Criterio de Selección del Optimo





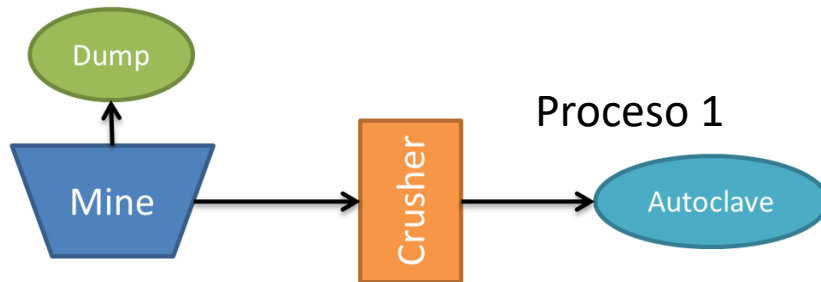
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Caso de Estudio

- Para demostrar la calidad de los resultados se realizaron comparaciones con los casos de estudio de la siguiente publicación, donde se utilizó el software comercial OptiPit[®] que trabaja con técnicas de programación lineal entera mixta (MILP):
 - “Value Creation Through Strategic Mine Planning and Cutoff Grade Optimization”
 - Dagdelen, K. Kawahata, K.
 - Publication Date: Jan 1, 2007

- 1 Proceso



Price	600	\$/oz
Sales Cost	5	\$/oz
Mining Cost	1.2	\$/ton
Recovery	90	%
Processing Cost	19	\$/ton
Fixed Cost	8.35	M
Mining Capacity	Unlimited	
Processing Capacity	1.05	M
Discount Rate	15	%

Interval	From (oz/ton)	To (oz/ton)	MidPoint (oz/ton)	Ktons (oz/ton)
1	0	70	0.01	70000
2	0.02	7.257	0.023	7257
3	0.025	6.319	0.028	6319
4	0.03	5.591	0.033	5591
5	0.035	4.598	0.038	4598
6	0.04	4.277	0.043	4277
7	0.045	3.465	0.048	3465
8	0.05	2.428	0.053	2428
9	0.055	2.307	0.058	2307
10	0.06	1.747	0.063	1747
11	0.065	1.64	0.068	1640
12	0.07	1.485	0.073	1485
13	0.075	1.227	0.078	1227
14	0.08	1.799	0.085	1799
15	0.09	1.799	0.095	1799
16	0.1	0.371	0.105	371
17	0.11	0.371	0.115	371
18	0.12	0.371	0.125	371
19	0.13	0.371	0.135	371
20	0.14	0.371	0.145	371
21	0.15	0.371	0.155	371
22	0.16	0.371	0.165	371
23	0.17	0.371	0.175	371
24	0.18	0.371	0.185	371
25	0.19	0.371	0.195	371
26	0.2	5.864	0.279	5864



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- OptiPit®

Year	Mining (Mtons)	COG (oz/ton)	Avg Grade (oz/ton)	Processing (Mtons)	Refining (koz)	Profits (\$M)
1	18.40	0.160	0.261	1.05	246.60	96.5
2	16.90	0.150	0.253	1.05	239.10	93.9
3	16.10	0.140	0.248	1.05	234.40	92.0
4	14.70	0.120	0.238	1.05	224.90	87.9
5	14.10	0.110	0.233	1.05	220.20	85.8
6	13.60	0.100	0.228	1.05	215.50	83.6
7	11.00	0.094	0.202	1.05	190.90	72.1
8	8.20	0.070	0.171	1.05	161.60	58.0
9	6.80	0.060	0.152	1.05	143.60	49.3
10	5.50	0.050	0.133	1.05	125.70	39.7
Total	125.80			10.50	2002.50	758.8 (NPV @ 15%) 414.4

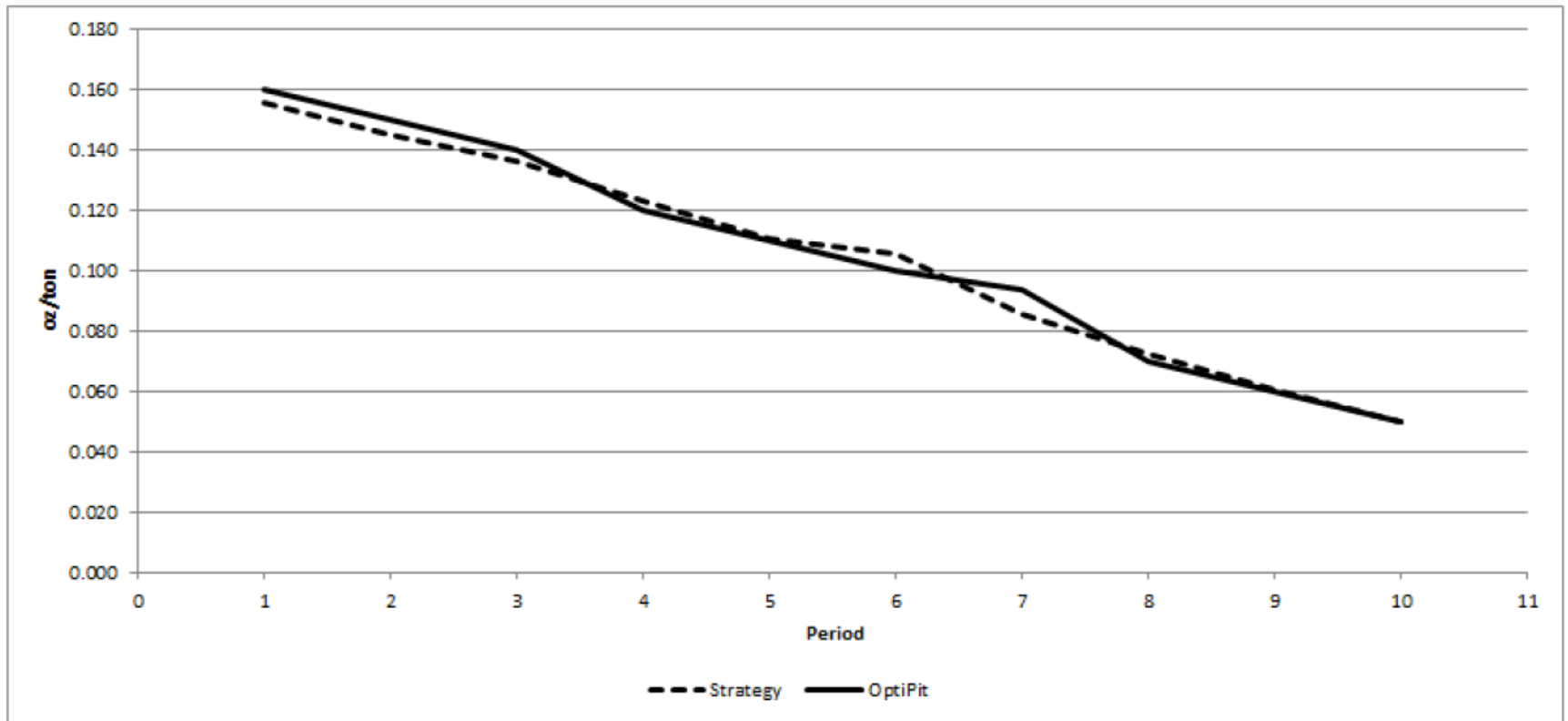
- Evolution Strategy

Year	Mining (Mtons)	COG (oz/ton)	Avg Grade (oz/ton)	Processing (Mtons)	Refining (koz)	Profits (\$M)
1	17.55	0.156	0.257	1.05	242.7	95.0
2	16.66	0.145	0.251	1.05	237.6	93.1
3	16.03	0.137	0.247	1.05	233.7	91.5
4	15.11	0.123	0.240	1.05	227.2	88.8
5	14.37	0.111	0.234	1.05	221.6	86.3
6	14.06	0.105	0.232	1.05	219.0	85.1
7	10.83	0.086	0.200	1.05	189.0	71.2
8	8.55	0.072	0.174	1.05	164.7	59.4
9	6.87	0.061	0.153	1.05	144.6	49.5
10	5.49	0.050	0.134	1.05	126.2	40.2
Total	125.80			10.50	2006.22	760.1 (NPV @ 15%) 413.8



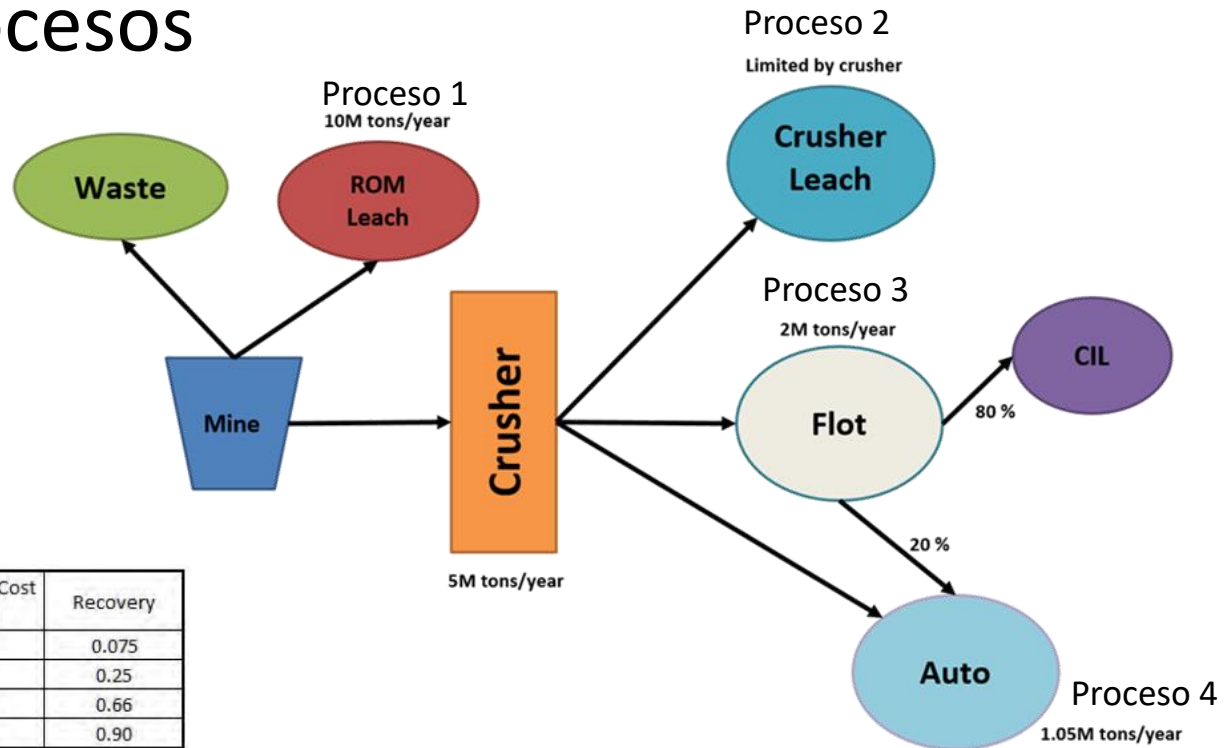
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Caso 2

- Multi procesos



Processes	Processing Cost (\$/ton)	Recovery
ROM LCH	0.90	0.075
CRUSHER LCH	3.00	0.25
FLOT TO AUTO	10.25	0.66
DIRECT AUTO	19.00	0.90



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- OptiPit®

Year	RCM Lch			CP Lch			Flot to Autoclave			Direct Autoclave			Refining (\$M)	Profits	
	Mining (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)			Processing (Mtons)
1	33.91	0.02	0.036	10	0.062	0.078	2.5	0.099	0.209	2.0	0.20	0.79	0.65	511.9	215
2	25.25	0.02	0.033	6.17	0.049	0.062	2.5	0.08	0.162	2.0	0.20	0.79	0.65	428.7	179.4
3	19.3	0.02	0.029	3.54	0.039	0.05	2.5	0.066	0.125	2.0	0.20	0.79	0.65	365.3	151.1
4	4.98	0.02	0.025	1.62	0.03	0.041	2.5	0.057	0.094	1.75	0.20	0.79	0.7	313.5	128.2
5	13.46	0.02	0.023	0.95	0.026	0.037	2.43	0.05	0.084	1.97	0.19	0.74	0.67	294.7	118.8
6	10.57				0.02	0.029	2.02	0.04	0.066	2.0	0.15	0.54	0.65	250.4	97.4
7	8.65				0.02	0.027	1.23	0.035	0.054	1.6	0.09	0.08	0.73	202	76.5
Total	125.5			22.3			15.3			13.3			4.7	2366.5	966.4 NPV @ 15% \$625.2

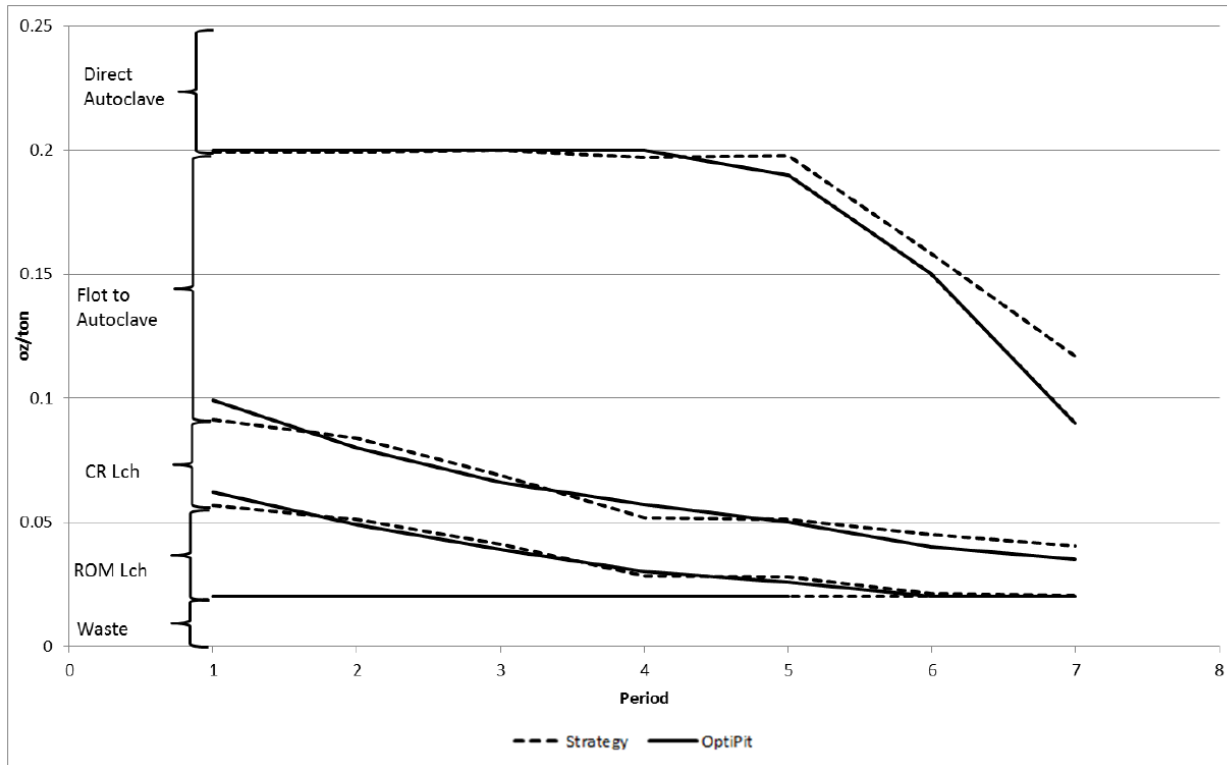
- Evolution Strategy

Year	RCM Lch			CP Lch			Flot to Autoclave			Direct Autoclave			Refining (koz)	Profits (\$M)	
	Mining (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)	Processing (Mtons)	COG (oz/ton)	Avg grade (oz/ton)			Processing (Mtons)
1	29.8	0.02	0.035	8.15	0.057	0.071	2.5	0.091	0.188	2.0	0.199	0.79	0.65	473.90	199.0
2	26.5	0.02	0.034	6.65	0.051	0.065	2.7	0.084	0.170	1.97	0.199	0.79	0.66	441.62	185.2
3	20.1	0.02	0.030	3.86	0.041	0.052	2.8	0.069	0.131	1.95	0.200	0.79	0.66	374.77	155.7
4	14.0	0.02	0.024	1.18	0.028	0.038	2.8	0.052	0.088	1.97	0.197	0.77	0.66	302.96	122.6
5	13.9	0.02	0.024	1.12	0.028	0.038	2.8	0.051	0.087	1.97	0.198	0.78	0.66	301.24	121.8
6	11.5	0.02	0.021	0.07	0.021	0.032	2.7	0.045	0.072	1.85	0.158	0.58	0.68	265.74	105.0
7	9.8	0.02	0.020	0.01	0.020	0.020	1.44	0.040	0.063	1.77	0.117	0.38	0.70	231.57	91.8
Total	125.5			21.05			16.18			13.43			4.65	2391.8	981.1 NPV @ 15% \$625.9



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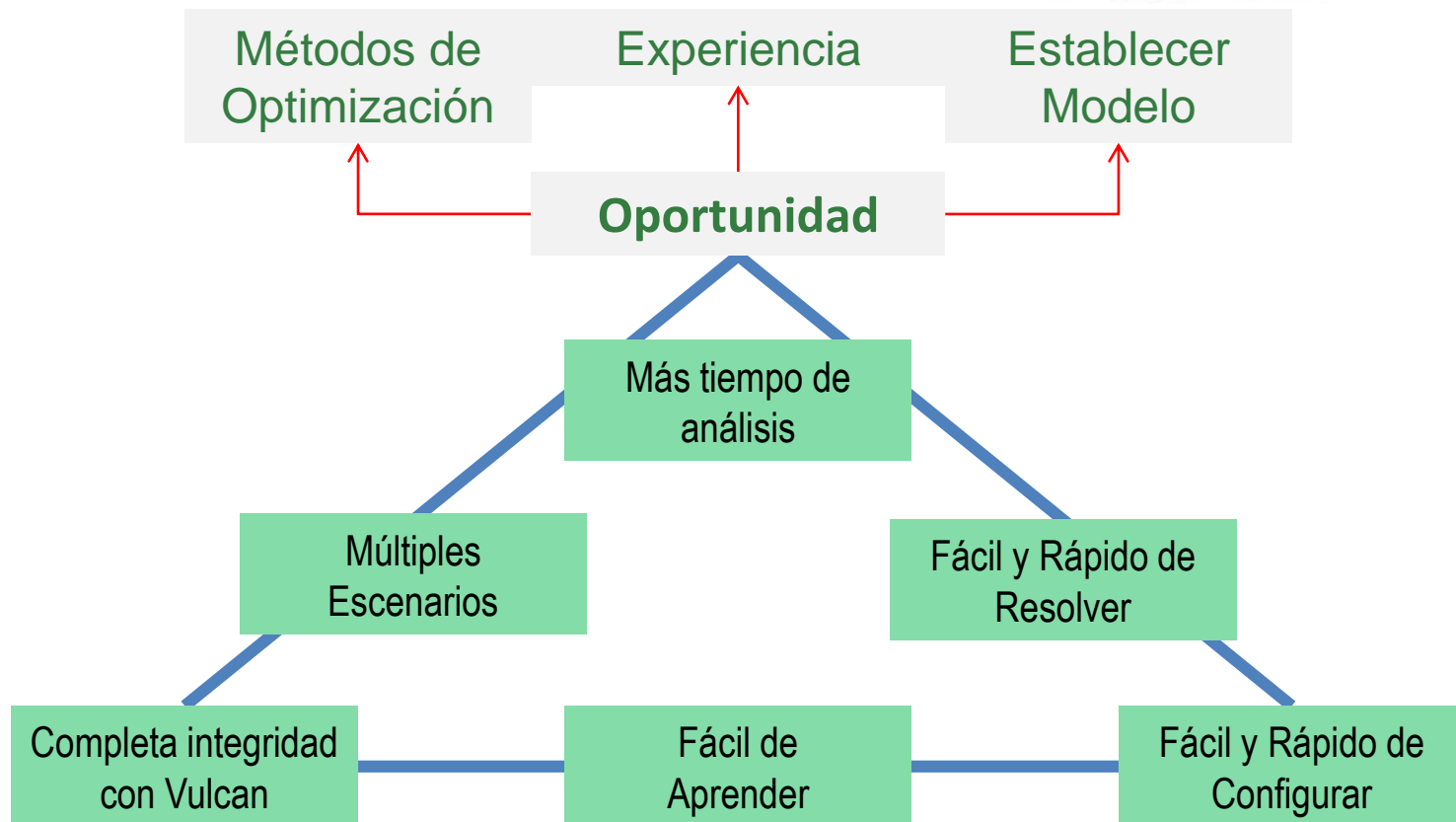
Experiencia

- Los resultados de Maptek Evolution están garantizando productos de alto valor utilizando este tipo de técnicas.
- Maptek Evolution brinda estas técnicas a la industria minera que están orientadas en el desarrollo de planes mineros productivos.
- Herramienta de planificación muy simple de usar, con interfaz intuitiva y basada en el uso de objetos.
- El usuario trabaja directamente con la información del Modelo de Bloques.
- Incorpora conceptos económicos para agregar valor al proyecto.
- Incorpora conceptos mineros para generar planes operativos y factibles (número de bancos por periodo, Sinking Rate y Blending entre otros).
- Los resultados son exportables en planillas Excel y gráficas instantáneas.



Rodrigo Valenzuela V.

www.maptek.cl





¡Muchas gracias!

Rodrigo Valenzuela V.
Ingeniero Senior de Ventas
rodrigo.valenzuela@maptek.cl
+56 9 75495181