Minemax Planner and GEOVIA Whittle
Open Pit Optimization Software Comparison

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1 Introduction

At the request of Minemax Pty Ltd (Minemax), AMC Consultants Pty Ltd (AMC) provided impartial and independent testing (the Study) of the open pit optimization capability of the latest version of the Minemax Planner (Planner) mine planning software.

The Study was timed to coincide with the release of a new version of Planner at the Society of Mining, Metallurgy and Exploration Annual Meeting in February 2014 in Utah, USA.

The Study was completed on an AMC computer using fictional block models and pit optimization inputs created by AMC.

AMC was not paid to complete the Study. However, Minemax provided AMC with a temporary Minemax software license at no cost to AMC.

2 Objectives

The Study brief, advised by Minemax, was:

- Compare the optimal pit shells generated by Planner and GEOVIA Whittle (Whittle) pit optimization software, for a single metal price.
- Compare the computing time required to generate a single optimized pit shell using Planner and Whittle.
- Use a range of block models, including large block models, in the order of 16 million non-air blocks.
- Use the same inputs for Planner and Whittle.

The Study was not aimed at comparing the functionality or usability of Planner and Whittle, although these are discussed briefly in this paper.

3 Software

A brief description of the software used in the Study is given below. Appendix A contains further detail relating to Planner and Whittle.

3.1 Minemax Planner

Planner was originally developed in 2001 by Minemax. The current version of Planner comprises several modules that focus on pit optimization and strategic mine scheduling. Only the open pit optimization module was tested in the Study.

Planner determines the optimal shape for an open pit in three dimensions through implementation of a high performance maxflow algorithm[1], generating the maximum undiscounted operating surplus for the set of economic parameters used to develop that pit optimization shell.

The version tested was "4.0.0.523 beta", using a dongle license.

[1] Minemax website, marketing release for Minemax Planner, 4 February 2014, http://www.minemax.com/news/news-2014-02-04

3.2 GEOVIA Whittle

Whittle, which was originally developed by Whittle Programming Ltd in the 1980s, is now owned by Dassault Systèmes GEOVIA Inc.

Whittle comprises a number of modules that focus primarily on pit optimization and strategic mine scheduling. For the Study, only the modules associated with pit optimization were utilized – the Core and Multi-Element modules.

Whittle determines the optimal shape for an open pit in three dimensions through implementation of the Lerchs-Grossmann algorithm[2], also generating the maximum undiscounted operating surplus for the set of economic parameters used to develop that pit optimization shell.

The version tested was "4.5.4 Hotfix 1", using a network license.

3.3 CAE Studio 3

AMC imported the results from Planner and Whittle, in block model format, into CAE's Studio 3 mine planning software (Studio 3), to compare the pit shells on a block by block basis. Also, the Planner and Whittle optimal shell inventories and financials, as reported by those packages, were compared against the inventories and financials within the optimal pit shells, as calculated by AMC in the input models.

No pit optimization work was completed in Studio 3.

4 Hardware

The specifications of the laptop computer used in the Study were:

- Processor speed 2.6 GHz.
- Memory (RAM) 16 GB.

Details relating to the computer specifications are contained in Appendix B.

Operating conditions for all runs were the same – no other programmes were running, there was no user interference via the keyboard or mouse, antivirus software and wireless network connection were disabled.

5 Inputs and Parameters

5.1 Block Model Scenarios

Four block model scenarios were considered for the Study, as summarized in Table 5.1. All models were fundamentally the same except for parent cell size, which was varied to generate different sized models, with respect to the number of non-air blocks.

The models represent a fictional gold deposit where mineralization is controlled by a large complex system of structurally controlled vein and shear systems that combine to form a central stockwork zone. Mineralized zones, as modelled, vary in width from 5m on the ore body extremities, to over 200m in the central stockwork zone.

The topography is fictional but typical of projects located in areas of steep terrain.

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[2] Whittle Programming Pty Ltd, Four-X, Strategic Planning Software for Open Pit Mines, Reference Manual, 1999.

Table 5.1 Block Model Properties

Scenario	No. of Blocks (millions of non-air blocks)	Parent Cell Dimensions (X, Y & Z dimensions) (m)	Run No./ Model Name
2M	2.0	15 x 15 x 10	15_2m
5M	4.6	10 x 10 x 10	16_5m
9M	9.1	10 x 10 x 5	17_9m
16M	16.2	7.5 x 7.5 x 5	18_16m

Using Studio 3, the models were populated with additional fields for recovered gold, processing cost adjustment factor (PCAF) and mining cost adjustment factor (MCAF), as shown in Table 5.2.

Table 5.2 Additional Fields For Pit Optimization

Parameter	Unit	Value	Comment
PCAF	$/t	20	
MCAF	$/t	3.00	Reference mining cost for benches at or above 325 mRL.
		0.33	Incremental increase per 10m bench below 325 mRL.
Process recovery	%	85	Recovered grade field for Planner, recovered metal quantity field for Whittle.

Additional details relating to the block models, including the conversion from Studio 3 format to formats suitable for Planner and Whittle are contained in Appendix C.

5.2 Pit Optimization Parameters

For each bock model, one scenario only was considered, based on the pit optimization parameters shown in Table 5.3. All parameters were fictional but indicative of those currently presenting in the mining industry.

Table 5.3 Pit Optimization Parameters

Parameter	Unit	Value	Comment
Pit slope angle	degrees	45	Single zone only
Gold price	$/oz	1200	38.5809 $/g
Reference mining cost	$/t	1	Multiplied by MCAF
Reference processing cost	$/t	1	Multiplied by PCAF
Benches for slope generation	No.	8	
Optimize with air blocks	N/A	No	Optional in Whittle. Option does not exist in Planner so air blocks were excluded from input models.
Process recovery	%	100	Multiplied by the recovered gold field in the input models, to return 85% recovery of in situ metal.
Mining dilution and ore loss	%	No adjustment to input models	These parameters can be set in Whittle, but not Planner. Dilution and ore loss assumed to be accounted for in the input models.
Revenue factors	Factor	1	Ultimate shell only was generated, not nested shells.
Ore selection method	N/A	Cash flow	Planner by default utilizes a "cash flow" ore selection method, rather than cut-off grade, whereas either option can be selected in Whittle. The "cash flow" option was selected for the Study to generate a like for like comparison, although for single element projects there should be no difference.
Elements (metals)	No.	2	Gold and recovered gold. Revenue was assigned only recovered gold.
Material Types	No.	3	MIN1 (mineralized, >= COG) MIN2 (mineralized, < COG) WAST (unmineralized)

6 Results

6.1 Pit Shells

The pit shells generated by the Planner and Whittle pit optimizers were spatially identical, based on analysis of the exported block models from each package. Spatially, every block contained within the Planner pit shells corresponded exactly with every block contained within the Whittle pit shells, for the respective scenarios. Analysis of each scenario was completed by superimposing block models of the pit shells from each package, and then flagging the individual blocks of the combined model for differences in the two pit limits, of which there were none. Visual checks were also completed that verified the block model analysis.

With respect to the pit shell inventories and financials shown in Table 6.1, AMC considers both packages generate exactly the same result. There are some extremely minor differences in overall rock tonnes that occur at the 8th significant figure, which are attributed to differences in either rounding or precision. The undiscounted operating surpluses varied slightly, at the 5th and 6th significant figures, which is also attributed to rounding or precision differences.

Table 6.1 Optimal Pit Shell Inventories and Financials

Scenario	Item	Unit	Minemax Planner	GEOVIA Whittle	Check Against Input Models	Difference: Minemax Planner v GEOVIA Whittle
2M	Ore	t	73,291,694	73,291,695	73,291,694	-1
	Waste	t	531,580,352	531,580,347	531,580,352	5
	Total Rock	t	604,872,046	604,872,042	604,872,046	4
	Recovered Gold	kg	195,894	195,894	195,894	0
	Undiscounted Operating Surplus	$	4,015,593,313	4,015,564,658	4,015,593,667	28,655
5M	Ore	t	72,906,143	72,906,143	72,906,143	0
	Waste	t	542,817,681	542,817,659	542,817,681	22
	Total Rock	t	615,723,824	615,723,802	615,723,824	22
	Recovered Gold	kg	194,467	194,467	194,467	0
	Undiscounted Operating Surplus	$	3,935,717,613	3,935,688,968	3,935,717,964	28,645
9M	Ore	t	73,882,768	73,882,768	73,882,768	0
	Waste	t	535,178,869	535,178,850	535,178,869	19
	Total Rock	t	609,061,637	609,061,618	609,061,637	19
	Recovered Gold	kg	198,067	198,067	198,067	0
	Undiscounted Operating Surplus	$	4,068,713,418	4,068,684,480	4,068,713,776	28,938
16M	Ore	t	73,056,771	Not completed	Not completed	N/A
	Waste	t	525,786,806	Not completed	Not completed	N/A
	Total Rock	t	598,843,577	Not completed	Not completed	N/A
	Recovered Gold	kg	195,172	Not completed	Not completed	N/A
	Undiscounted Operating Surplus	$	4,014,318,913	Not completed	Not completed	N/A

6.2 Computing Time

Planner completed the same tasks much faster than Whittle, within the range of block model sizes tested, as demonstrated by the pit optimization computing times shown in Table 6.2 and Figure 6.1.

The pit optimization times reported herein for each scenario are the average of three runs, as detailed in Appendix D. The individual times that comprised the averages showed very little variation.

No pit optimization time for Whittle was recorded for the model comprising 16.2 million non-air blocks because the run was terminated by the user after approximately 40 hours. AMC could not determine whether the optimization was progressing or whether the computer had reached its processing limit, however the result was consistent with the trend of increasing computing time with increasing block model size. The run was attempted several times, with similar outcomes each time.

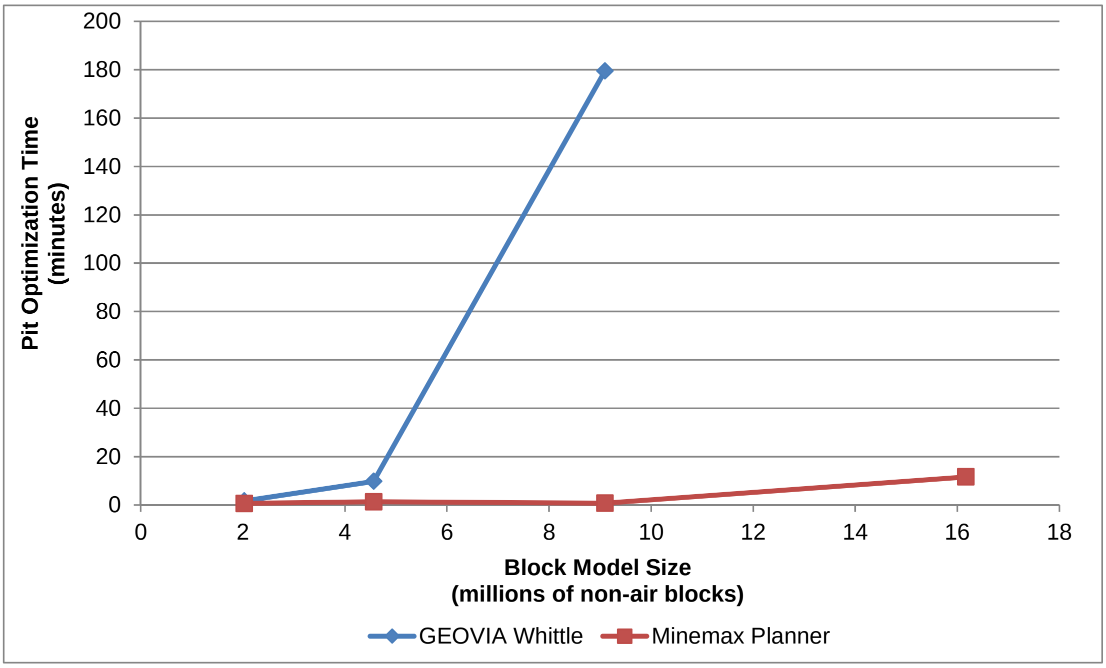
The pit optimization computing times are inclusive of the computing times required to apply the pit slope constraints. The pit optimization computing times exclude the time required to import models and complete other set-up tasks.

Table 6.2 Pit Optimization Computing Time

Scenario	No. of Blocks (millions of non-air blocks)	Average Pit Optimization Computing Time[1]	
		GEOVIA Whittle (minutes)	Minemax Planner (minutes)
2M	2.0	1.6	0.6
5M	4.6	9.7	1.3
9M	9.1	179.5	0.7
16M	16.2	Not Available	11.6

1 Whittle computing time is the aggregated time for structure arcs generation and pit optimization, whilst these two tasks are combined within the Planner optimization task.

Figure 6.1 Pit Optimization Computing Time



7 Summary

The objectives of the Study were successfully fulfilled:

- Comparison of optimal pit shells. Planner and Whittle generated exactly the same optimal pit shells with respect to spatial location and pit inventories, when the same input parameters were used. Pit shell spatial location was verified to an accuracy of single block (parent cell) resolution.
- Comparison of pit optimization computing time. The Planner pit optimization computing times were significantly faster than the Whittle pit optimization times, up to several orders of magnitude for the model comprising 9.1 million non-air blocks. Computers with different specifications may give different relative computing times.
- Capability to optimize large block models. Planner efficiently managed and optimized a large model comprising 16.2 million non-air blocks. Whittle was unable to effectively manage a block model of this size, using the test computer (the run was terminated after 40 hours).

Planner and Whittle optimizers implement different algorithms in determining the optimal open pit. However both algorithms return the same result suggesting both programmes do in fact generate an optimal open pit limit for a given set of economic parameters and pit slope constraints.

Appendix A
Planner and Whittle – Similarities and Differences

Both Minemax and Whittle have greater capability than was explored in the narrow brief of the Study. The Study was based on fictional scenarios for a single element and single process stream, with only a single open pit shell generated at the base case metal price for each input model. However, both Planner and Whittle have the capability to:

- Generate optimal open pit shells for projects with multiple elements and process streams.
- Generate nested pit shells through the factoring of metal prices.
- Modify pit shells to maintain minimum mining widths.
- Generate strategic schedules that optimize for Net Present Value (NPV).
- Reblock models to different parent cells sizes.

AMC did not test the aforementioned capabilities for either package as part of the Study.

The main differences in the packages centre around:

- Ease of use. Planner was intentionally designed for ease of use, which is reflected in the low number of user inputs required. Whittle allows greater adjustment of the input parameters and programme settings, which results in more inputs entered by the user in the graphical user interface (GUI).
- Scenario management. Planner requires a new project for each scenario whilst Whittle utilizes a structure of branches and nodes to organize multiple scenarios within the one project.
- Reporting. Planner utilizes default report templates whereas Whittle reports are largely user defined.

Appendix B
Computer Specifications

Component	Details	Subscore	Base score
Processor	Intel(R) Core(TM) i7-3720QM CPU @ 2.60GHz	7.6	5.9
Memory (RAM)	16.0 GB	7.9	
Graphics	Intel(R) HD Graphics 4000	6.9	
Gaming graphics	1696 MB Total available graphics memory	6.9	Determined by lowest subscore
Primary hard disk	49GB Free (688GB Total)	5.9	
Windows 7 Professional			

System

Manufacturer	Dell Inc.
Model	Precision M4700
Total amount of system memory	16.0 GB RAM
System type	64-bit operating system
Number of processor cores	4

Storage

Total size of hard disk(s)	688 GB
Disk partition (C:)	49 GB Free (688 GB Total)
Media drive (D:)	CD/DVD

Graphics

Display adapter type	Intel(R) HD Graphics 4000
Total available graphics memory	1696 MB
Dedicated graphics memory	64 MB
Dedicated system memory	0 MB
Shared system memory	1632 MB
Display adapter driver version	9.18.13.1144
Secondary monitor resolution	1920x1080
Primary monitor resolution	1920x1200
DirectX version	DirectX 10

Network

Network Adapter	Intel(R) 82579LM Gigabit Network Connection
Network Adapter	Intel(R) Centrino(R) Ultimate-N 6300 AGN
Network Adapter	Bluetooth Device (Personal Area Network)
Network Adapter	Microsoft Virtual WiFi Miniport Adapter
Network Adapter	Microsoft Virtual WiFi Miniport Adapter

Notes

Appendix C
Background on Block Models

Features of all the block models:

- Cut by the same topography
- Air blocks excluded
- Single element – gold
- Mineralized material modelled at 5m x 5m x 5m. This resolution was retained in all models using sub-cells in Studio 3.
- Waste material modelled at the parent cell size.
- Populated with inputs for pit optimization and validation – mining costs, processing costs, in situ metal, recovered metal, and revenue from metal sales.

To convert the models from Studio 3 format to the relevant formats for the pit optimization software, the following was completed:

- Planner. Assigned the parent cell co-ordinates to each sub-cell within Studio 3 and then exported the model from Studio 3 in comma-separated values (CSV) format. The parent cell co-ordinates were specified as the block co-ordinates upon importation to Planner, and the sub-celled models were successfully accepted by Planner. This process was followed because it was a requirement of an earlier version of Planner. However, after completion of the Study, AMC verified that the beta version used in the Study could in fact automatically recognize and accept sub-celled models, using the block model from Scenario 2M.
- Whittle. Exported the Studio 3 block model in Whittle format (mod) using the FXOUT function. Each sub-cell from the Studio 3 model was converted to a parcel located within the bounds of the respective parent cell in the Whittle model.

Appendix D
Pit Optimization Computing Times

Scenario	Iteration	Parent Cell Size			Model Size[1]	Computing Time[2]	
		X (m)	Y (m)	Z (m)	(Millions of Blocks)	GEOVIA Whittle (minutes)	Minemax Planner (minutes)
15_2m	1	15	15	10	2.03	1.60	0.61
15_2m	2	15	15	10	2.03	1.59	0.59
15_2m	3	15	15	10	2.03	1.62	0.61
15_2m	**Average**					**1.60**	**0.60**
16_5m	1	10	10	10	4.57	9.80	1.30
16_5m	2	10	10	10	4.57	9.71	1.25
16_5m	3	10	10	10	4.57	9.73	1.30
16_5m	**Average**					**9.74**	**1.28**
17_9m	1	10	10	5	9.10	179.49	0.70
17_9m	2	10	10	5	9.10	179.56	0.68
17_9m	3	10	10	5	9.10	179.41	0.70
17_9m	**Average**					**179.49**	**0.69**
18_16m	1	7.5	7.5	5	16.17	Run terminated	11.59
18_16m	2	7.5	7.5	5	16.17	Run terminated	11.58
18_16m	3	7.5	7.5	5	16.17	Run terminated	11.55
18_16m	**Average**					**N/A**	**11.57**

[1] Non-air blocks

[2] Whittle computing time is the aggregated time for structure arcs generation and pit optimization.