CHAPTER 4 INDIRECT APPLICATIONS OF THE HALF-LEVEL PLANNING MODEL

4.1 Revenue calculations

The revenue is calculated by making use of an equivalent value per 4e gram delivered to surface. The term "4e gram" refers to the sum of 4 different elements, namely platinum, palladium, rhodium and gold. A grade of 5 g/t may mean that every reef ton delivered to surface contains 3 g platinum, 1 g palladium, 0,2 g rhodium and 0,8 g gold. Some other elements, like osmium, iridium, ruthenium, nickel, cobalt, copper, chromite and sulphuric acid, are also produced and sold, but the total revenue is allocated back to the 4 main elements or 4e group. To thus arrive at a value per shaft head 4e gram, the total revenue (after all concentrating and refining losses) has to be divided by the assayed shaft head grams. In the example a R100 per 4e gram was used for all revenue calculations. This equivalent value per shaft head 4e gram simplifies revenue calculations, i.e. if the shaft head 4e grade is 5 g/t, the final revenue per ton would be R500 per ton. The total cost including amortisation will result in break-even conditions when it reaches R500 per ton.

4.2 Half-level monthly management

The current norm of most mining houses is to manage on a shaft level. The total shaft output is compared with the total shaft cost. If, however, a specific half level or group of half levels are more or less profitable, it may be hidden. The HLP model contains a monthly management sheet that allows key inputs after measuring has occurred. The HLP model will automatically feed the information back to the progress variance tables where the ideal and the actual values are compared (Tables 3.14 and 3.15). The variance column serves as an attention director for management and each half level can be monitored separately to thus optimise the overall shaft output.

The current HLP model contains no costing information and it would be wise to design the on-mine cost structure in such a way that cost per half level can be monitored allowing half-level profitability management.

It is important to understand that half levels will indicate financial losses whilst building up to full production. In this case the value of the loss must be managed. At the same time some half levels may still be producing at a steady-state production rate whilst the development slows down as the mine boundary is reached. This decrease in development should offset areas being built to steady-state conditions as previously mentioned. The net effect on the shaft should thus remain zero.

4.3 Incentive schemes

Half-level management may be used as a performance remuneration guideline where the actual output is measured against the ideal output. From actual assessments done, the current output level was found to be approximately 65% of the ideal performance level. All activities as measured by the half-level model can be incentivised on specific merits (specific variance between ideal and actual performance). It is important to have the ideal and actual profit values under control in any specific management system. This may prevent incentivisation of improvements due to additional investment as opposed to true efficiency improvements – introducing technology may have caused the improvement; not workforce initiatives.

Example:
Machine operator A produces 180 square meters per month with a normal hand-held pneumatic rock drill. Machine operator B uses a more expensive hydraulic drill rig requiring half the effort of a hand-held drill. Operator B manages 360 square meters per month. Should B get a higher incentive than A?

Table 4.1: Cost break-even example

COST BREAK-EVEN CALCULATION FOR INCENTIVE CALCULATION PURPOSES			
Operator	A	B	Cost break-even output
Operator cost per month (R)	R10,000	R10,000	R10,000
Monthly production (square meters)	180	360	365
Capital cost of equipment (R)	R4,000	R250,000	R250,000
Equipment life (months)	24	24	24
Monthly capital cost of equipment (R)	R167	R10,417	R10,417
Monthly maintenance cost (2% of capital)	R3.33	R208.33	R208.33
Labour cost per square meter (R)	R55.56	R27.78	R27.39
Capital cost per square meter (R)	R0.93	R28.94	R28.54
Maintenance cost per square meter (R)	R0.02	R0.58	R0.57
Total drilling cost per square meter (R)	R56.50	R57.29	R56.50

By examining Table 4.1, operator B should not get any more incentive than operator A unless he produces more than 365 square meters per month. Operator B's incentive may be aligned with that of operator A by multiplying the conventional hand-held system's incentive per square meter by (180/365).

The same concept applies to half-level outputs – equalise the base before incentivising efficiencies.

It is however not the purpose of this document to focus on designing incentive schemes but it is important to realise other applications of the HLP model.

4.4 Equipment requirements

4.4.1 Micro rock handling

A winch (Appendix 13) in the underground sense is an electrical winding device with normally two steel rope drums rotating in opposite directions enabling the linear movement of a scraping device. The rope is deflected and directed through one or more pulleys (snatch blocks) and basically forms a continuous unit from the one drum to the other. Both drums can feed or collect rope but are contra-rotating thus creating an endless rope effect. Winches are mainly used to transport or scrape rock between different locations inside the reef horizon. The number of winches required can be calculated by using the HLP model's steady-state principles. This is done by equipping all common blocks to the point where the first common block reaches the reclamation phase. At the point where this reclamation phase is reached, winches are being fed back into the newly developed common blocks from reclamation activities being completed elsewhere.

It is however suggested that a pool of refurbished winches are kept at a central location. This will allow winches to be sent for repairs directly after reclamation and new common blocks may then be equipped with refurbished winches – service exchange system.

To do the calculation for the winch requirements of a specific layout and mining rate, the winch requirements of the first common block must be specified after completion of the scheduling phase. The HLP model then duplicates this data to the following blocks based on when the relevant activities that require winches start. This duplication will cease to continue the moment the first winches are reclaimed from the initial common block. The number of winches required is most important for power requirement calculation purposes, as winches are the biggest underground power-consuming equipment on the half level. The only two winch types the model allows for are 37 kW and 56 kW winches. The 37 kW winches are generally used inside a stope panel to scrape ore into a collecting point referred to as an advance strike gully in breast layouts and dip gully in dip layouts. From this point, a series of normally 56 kW winches is used to scrape the ore into the ore silos or ore passes where it is collected by the tramming or hauling system.

Table 4.2: Winch requirements per half level

WINCH REQUIREMENTS PER HALF LEVEL																
END IN COMMON BLOCK	75Hp	50Hp	Mth 12	Mth 13	Mth 14	Mth 19	Mth 21	Mth 23	Mth 24	Mth 25	Mth 26	Mth 28	Mth 30	Mth 31	Mth 32	Mth 35
Travelling way			10													
Raise					33	33										
LEDGING 1							1000	400								
EQUIPPING 1								1000	1000	400						
RECLAMATION 1																3000
75Hp	8		1		1		1	2	2	1						
50Hp		5						2	2	1						
Travelling way						10										
Raise							33	33	33	33	33					
LEDGING 1												1000	400			
EQUIPPING 1													1000	1000	400	
75Hp	8					1	1					1	2	2	1	
50Hp		5											2	2	1	
Travelling way											10					
Raise												33	33	33	33	
LEDGING 1																1000
EQUIPPING 1																
75Hp	3										1	1				1
50Hp																
TOTAL	19	10														

From Table 4.2 it can be seen how the winches are cascaded down until reclamation starts in month 35 where the last winch is added to the half level. The only manual entries are made on the right of the bright yellow 75Hp and 50Hp, and in this example the first 75Hp (56 kW) winch is required in month 12 when the "Travelling way" is started, the next two in months 14 and 15 when the "Raise" and "LEDGING 1" start, and finally five more over months 23 to 25 when "EQUIPPING 1" takes place. An additional five smaller 50Hp (37 kW) winches are also required during the same "EQUIPPING 1" phase when face winches will be installed. A total of 8 x 56 kW and 5 x 37 kW winches will serve the first common block through its life cycle. Note that the winches decrease as new blocks are entered. The second (green) common block still gets the same number of winches as the first block, but the third (pink) block only receives 3 x 56 kW "outside source" winches. The difference in this case, will however be supplied from reclamation activities in the first block.

4.4.2 Macro rock handling

In most conventional underground platinum mines, rock is transported between the mining activities where it is generated, and a main tipping point at the shaft by track-bound locomotives pulling one or more containers known as hoppers. Loading rock into the hoppers is mostly done with mechanical loaders or through chutes acting as bleeding points from ore passes directly into the hoppers. The platinum industry mainly uses battery-powered locomotives, but diesel and overhead electrical units are also found (Appendix 14).

Before the user can calculate the transport equipment requirements, a basic work-study for a specific area has to be conducted and the information is contained in Table 4.3. The HLP model states the required tonnage to be handled (reef and waste) based on previously mentioned inputs and calculates whether these tons can be handled by the current equipment using the work-study information[31].

Table 4.3: Calculation of the tramming equipment requirements

ROCK HANDLING: TRAMMING EQUIPMENT REQUIREMENTS		
INPUT PARAMETERS	**REEF**	**WASTE**
Max current tramming distance (m) (ONE WAY)	1500	1500
Relative density of reef (over mined width)	3.86	3.1
Hopper factor (tons per hopper)	3.5	3.5
Average tramming speed (km/hr)	6	6
Hoppers per loco (average)	10	10
Number of locos (mixed)	2	2
Hopper loading time (mins)	2	6
Hopper discharge time (mins)	1	1
Trip length (m)	3000	3000
Trip time (hours)	1.00	1.67
Tramming shift length (hours)	8.5	8.5
Tramming shifts per day	2	1.5
Equipment availability	70%	70%
Equipment utilisation	70%	70%
Average tramming time per day (hours)	8.33	6.2475
Trips per day per loco	8.33	3.75
Total trips per day	16.66	7.50
Total hoppers per day	166.6	75.0
Total tons per day	583.1	262.4
Required tramming rates (tons per day)	772	70
Tramming shortfall or spare capacity (tons per day)	-189	193
Combined tramming shortfall or spare capacity (tons per day)	3	

In Table 4.3 the information required upfront is indicated by the red text on the light yellow background. In this example a total of 772 + 70 tons has to be transported over 1 500 meters during a 24-hour period. There is a shortfall on the reef capacity of 189 tons per day, but the waste side has a surplus of 193 tons per day leaving a net surplus of 3 tons per day. By studying Table 4.3 it can be seen that a fleet of four locomotives with ten hoppers each is the optimum requirement for this situation. The waste fleet only works 1,5 shifts per day due to other transport commitments. The system can be optimised by focusing on various of the yellow shaded areas, for example tramming speed, loading time, discharge time, availability and utilisation, etc., but additional knowledge is not required for the purpose of this study.

4.4.3 Other equipment

Other equipment, for example rock drills, fans, pumps, loaders, material cars, drilling platforms, explosives cars, etc., are not mentioned in the model but can easily be calculated with the information made available by the HLP model. These items were purposely omitted due to the large numbers of permutations and combinations of available equipment and applications.

4.5 Services required[32]

There are four basic services used in conventional underground operations, namely ventilation, power, water and compressed air. None of these form a detailed part of this discussion but their requirements cannot be calculated without the outputs similar to those generated by the HLP model. For example, as an integral part of the power requirements on a half level, the number of winches, fans, pumps and smaller equipment, like battery chargers, are required. The HLP model calculates the number of winches, winch sizes and tonnages handled. The maximum different development and stoping ends and blasts per end are calculated allowing the user to calculate rock drill and fan requirements. With this information, most of the ventilation volumes, fan requirements, water and compressed air required can be calculated. Water and compressed air are mainly used for drilling applications and the return water pump capacity needed is the sum of water consumed plus natural water generated.

4.6 Layout selection and optimisation

Selecting the best layout, optimising current layouts and forecasting realistic production targets are some of the biggest concerns mining companies are faced with. Anglo Platinum is an expanding company and various new systems or layouts are introduced frequently. At existing operations, layout changes cause expensive production losses. Some shafts have up to three different systems in place mining under exactly the same conditions everywhere.

To indicate how this problem may be overcome by using the HLP model, a comparison between a down-dip and a scattered breast layout was done. The assumptions were that it is a new mine and that any mining direction could be used. Increasing the reef block dimensions further optimised the breast layout.

Table 4.4: The standard down-dip layout

DOWN-DIP LAYOUT	STANDARD
Development end name	Length (m)
Haulage	140
X/cut	20
Timber bay	10
Travelling way	20
Box 1	25
Box 2	25
Box 3	25
Box 4	25
SPD1	140
SPD2	140
Raise1	160
Raise2	160
Raise3	160
Raise4	160

Table 4.4 contains the down-dip layout's common block development requirements. The reef area covered by this development is 140 m wide with a back length of 160 m. Down-dip layouts should, under normal conditions, not exceed a 160 m back length due to winch pull distance constraints.

Table 4.5: The standard and improved breast layout

BREAST LAYOUT	STANDARD	IMPROVED
Development end name	Length (m)	Length (m)
Haulage	200	210
X/cut	120	120
Timber bay	10	10
Travelling way	10	10
Box 1	24	24
Box 2	30	30
Box 3	36	36
Haulage Box	42	42
Funkhole	12	12
Step over	5	5
Raise	200	240

Table 4.5 contains the common block development requirements for both the standard and improved breast layouts. Note that the only differences between the standard and improved layout are the haulage and raise dimensions. The size of the reef block increased from 40 000 to 50 400 square meters. A breast layout is known for its ability to accommodate longer back lengths due to the inclusion of a cross-cut (x/cut).

Figure 4.1 graphically indicates that the down-dip layout requires about 140% more upfront development when compared with the standard breast layout.

When these layouts are compared on a value (4e gram) generation basis, down-dip is superior to standard breast for the first five years in the life of the half level. This is mainly caused by the amount of on-reef development required for down-dip mining. After year 5 the breast layout is superior to the down-dip layout if compared on a value basis. When selecting a mining method, the cost of this increased development in the case of down-dip mining has to be compared with the benefit of gaining value earlier.

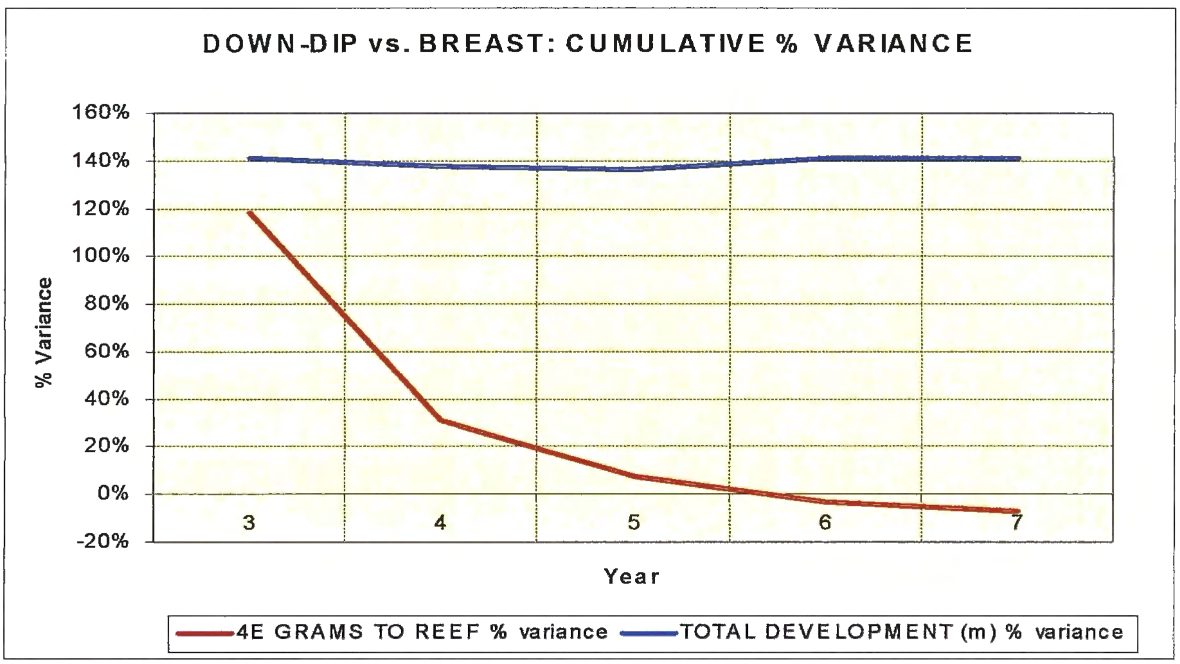

Figure 4.1: Down-dip versus standard breast cumulative variance comparison

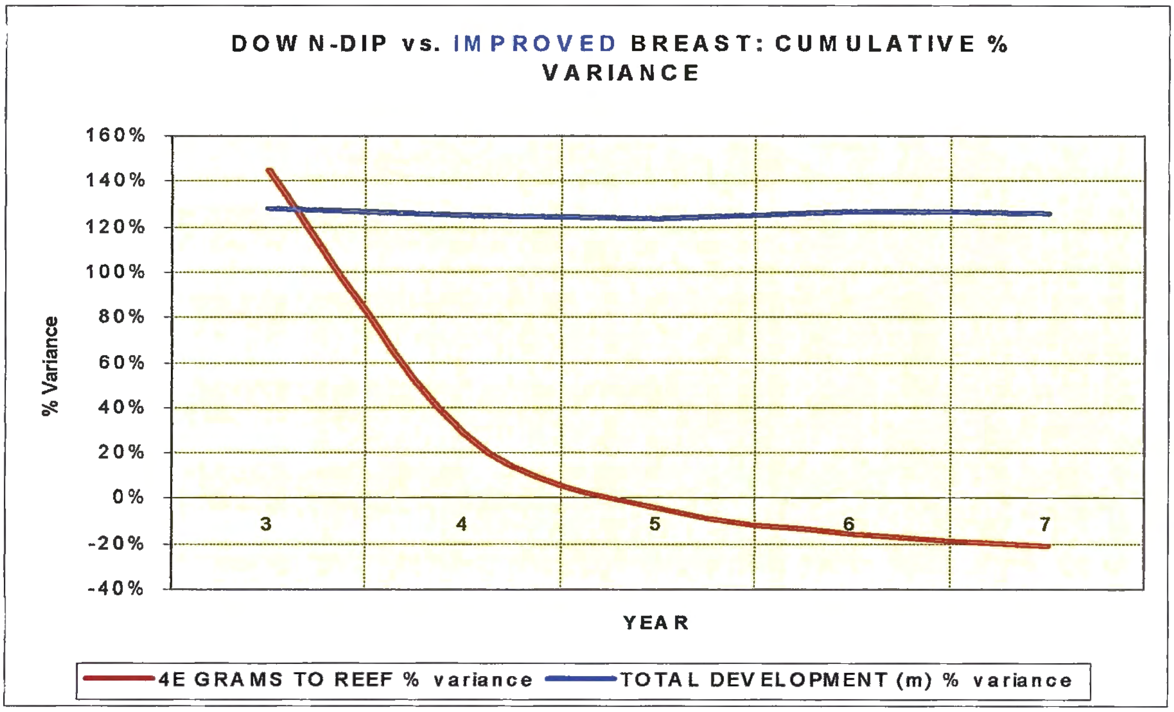

Figure 4.2: Down-dip versus improved breast cumulative variance comparison

Figure 4.2 indicates that the value output of the breast layout can be improved by making minor changes. It may however not be possible to change layouts on existing operations – back lengths are limited to the vertical distances between levels.

When comparing layouts on a steady-state output basis, both the breast layouts are superior to the down-dip layout. Table 4.6 illustrates that the breast layouts can deliver between 20% and 50% more revenue per month for 43% of the development meters. Breast layouts also require less ventilation per common block, the ventilation is cascaded along the stope faces and thus used more than once.

Table 4.6: Layout comparisons under steady-state conditions

LAYOUT COMPARISONS UNDER STEADY STATE CONDITIONS			
Parameters	Breast	Improved Breast	Down-dip
Monthly pre-development (m)	101	108	245
Development per shift (m)	4	5	11
Monthly square meters (m^2)	4886	6156	3830
Square meters per shift (m^2)	212	268	167
Monthly revenue (R)	R 10,796,150	R 13,596,333	R 9,015,364
Monthly tons to REEF (t)	18,925	23,814	15,653
Monthly tons to WASTE (t)	1,566	1,608	1,268

4.7 Shaft capacities based on half-level principles

In general, shaft capacities are specified by the hoisting capacity or in some cases the services supply capacity, with ventilation topping the list. Most shafts are also deepened beyond the initial design depth by using the initial capital infrastructure. This is the reason why sub, tertiary and sometimes further extensions are in existence. One of the most important factors mostly overlooked is the shaft's ore reserve replacement capability. In a previous discussion, mention was made of ongoing capital which refers to the requirements to replace a level or two half levels (Appendix 15).

If a shaft system is turned through 90 degrees, in other words, imagine the shaft being a strike tunnel that can be viewed as a half level. By doing this, every level of the shaft can now also be viewed as a common block. At this point the same model or approach can be used to calculate a shaft's steady-state capacity. The HLP model runs out of range due to the long life of these large (6000 m back lengths) common blocks, but optimum shaft capacities can be calculated. Deeper levels can also be stepped to simulate the lower advance rates with increasing depths.

By applying the above procedure, some shafts in Anglo Platinum indicated severe overmining conditions, in other words a higher depletion rate than replacement rate. This means that some half levels will be mined out before they can be replaced – which will result in production dips. These dips in turn result in higher unit costs, slower capital paybacks and in some cases operations running at a loss.

An actual example[33] (Appendices 7 and 8) indicated that the maximum extraction rate of a specific shaft is 28 000 square meters per month if a level can replaced in less than 31 months. The current level replacement rate is around 40 months and the extraction at 32 000 square meters per month. This is 15% higher than the shaft's ore reserve replacement ability. Planning the shaft's output in line with the hoisting capacity as well as historical production achievements together with poor capital advance rates, caused this situation.