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**A SPREADSHEET COMPUTER PROGRAM  
FOR OPEN-PIT PRODUCTION  
SCHEDULING**

By

Theodore G. Montague

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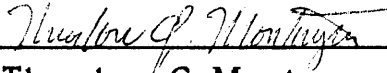
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## **ABSTRACT**

Low commodity prices in the 1980s have kindled the mining industry's interest in production scheduling. This study describes and discusses a spreadsheet computer program, DRIFT, which allows on-site, user-friendly production scheduling.

Production scheduling objectives include general requirements as well as imperatives unique to particular mines. Commonly, these objectives conflict; so scheduling is always a compromise. Scheduling techniques include traditional, deterministic calculations; microeconomic procedures, operations research methods, simulation, and now, spreadsheets. No technique is universally virtuous; each method has its merits and demerits. Currently there is a movement towards combining different techniques into modular, symbiotic models with interactive computer graphics.

The DRIFT program is a short-term scheduling model for a small, open-pit mine with a relatively homogeneous ore body. The

program takes cost, productivity, demand, and strip ratios imputed by the mining engineer and converts the data into tables, where the lowest cost production configuration can be determined by trial and error. DRIFT is designed to use the engineer's expertise, solve the scheduling problem quickly, use data readily available at the mine, and produce a good, feasible solution. Deficiencies include non-optimal solutions, potential for errors, undeveloped outputs, and restricted detail.

A series of hypothetical examples show the model can successfully calculate a feasible lower cost schedule within ten trials. Sensitivity analysis on labor and equipment costs is also possible. Furthermore, the DRIFT model can answer equipment replacement and other "what if" questions.

This study demonstrates that an appropriate spreadsheet model offers a useful, cost effective method of production scheduling, particularly for smaller mines. Additional enhancements to this system would be building heuristic logic and stripping functions into the spreadsheet to improve its effectiveness.

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## Chapter 1

### INTRODUCTION

"Men are always opposed to ventures in which they foresee difficulties."

Niccolo Machiavelli

#### 1.1 Problem Statement

Depressed prices in the 1980s caused mineral firms to increase or maintain mine profits by increasing mine productivity. Improved production scheduling has attracted some firms because it allows decreases in costs without large capital outlays.

The search for improved scheduling has encouraged the development of sophisticated computer methods. Many of these new techniques, however, have not been applied successfully to actual mines (Fytas, Pelley, and Calder, 1987) due to their reliance on vast quantities of data, computer specialists who do not relate to the mine, and competition for available mainframe computer time. The black box compartmentalization of this process has in some cases

produced a planning system in which mining engineers convert data they understand (grades, tonnages, cost rates) into an output they partially understand (cash flow, internal rates of return, NPV) via a process they only vaguely understand (Hichens and Duffy, 1984).

In response to this problem, this thesis describes and discusses a spreadsheet computer program which allows on-site, user-friendly, production scheduling. The program, called DRIFT, is designed for short-term, open-pit production scheduling of an existing mine. The focus is restricted to the excavation and haulage of waste and ore; the program does not consider scheduling at the processing plant.

## 1.2 Definitions

Production scheduling, used here, refers to the process of establishing a production timetable which organizes and coordinates the available productive resources. It is useful to distinguish four temporal horizons in production scheduling: feasibility, long term, short term, and bootstrap. Feasibility scheduling generates a rough estimate of a mineral project's economic desirability. It is not a real

plan for mineral development. Long-term scheduling constructs detailed production plans over a period of years, where price, reserves, and productive inputs are fluid. Short-term scheduling is concerned with planning production periods of weeks or months; price, reserves, and production inputs are relatively static.

Bootstrap scheduling is the daily rostering of available resources. In practice, productive inputs can be highly variable on a daily basis.

It is also important to note that production scheduling has a circular and sequential relationship with "mine planning," which is essentially the strategic extraction plan of the operator. The organizational barriers which commonly bound these activities (scheduling being a line function and planning a staff function) means that certain constraints arise within real production scheduling that have little or nothing to do with operations or economics.

### 1.3 Methods

This thesis utilizes an IBM or compatible personal computer with a 20 M-byte hard disk and utilities for a 5.5 inch, 360 K-byte

floppy discs. The software comprises MS DOS as the operating system and Lotus 1-2-3 as the spreadsheet program. DRIFT is written within Lotus 1-2-3 using the "Macro" language. The microcomputer spreadsheet method is used because Lotus 1-2-3 is widely understood, easy to learn, and microcomputers allow scheduling at the mine itself.

#### 1.4 Roadmap

The analysis proceeds as follows: Chapter 2 reviews mine scheduling issues, methods, and current trends; Chapter 3 details the objectives, structure, and mechanics of the DRIFT program; Chapter 4 discusses the results of hypothetical problems run on DRIFT; and Chapter 5 presents conclusions and recommends areas needing further study.

## **Chapter 2**

### **CURRENT MINE SCHEDULING PRACTICE**

The rationalistic approach is characterized by the pretension to universality of its solutions, its intolerance of tradition and authority, quantification, simplification, lack of flexibility. Its very efficiency prevents flexibility by eliminating what does not contribute to achieving the current objective so that alternative means are not available if the objective is changed.

Col. Harry G. Summers, Jr.

#### **2.1 Scheduling Objectives**

Production scheduling objectives comprise items which are general to all mines as well as circumstantial objectives controlled by the unique qualities of individual mines. General scheduling objectives (Fytas and Calder, 1986) include the following:

- Meeting the tonnage requirements of the processing plant
- Meeting the quality requirements of the processing plant
- Lying within standards of good mining practice
- Being feasible (i.e., practical)
- Ensuring compatibility with the strategic mine plan

- Maximizing equipment utilization
- Minimizing costs during the scheduling period
- Maximizing profits during the scheduling period, yet
- Ensuring future mineability and profitability.

Circumstantial objectives, such as minimizing groundwater contamination or mineral rights litigation arise because all deposits are virtually unique in terms of their geography, geologic, political, and business environment.

It is reasonably apparent that scheduling is a compromise between conflicting objectives. In practice, achieving this compromise is so difficult that the quest for the best schedule is commonly overridden by the effort to find a workable schedule (Gershon, 1987).

## 2.2 Scheduling Techniques

Presently, there are five classes of scheduling techniques in the literature: traditional, microeconomic, operations research, simulation, and spreadsheet methods. The array of techniques

reflects, in part, changes in production and computer technology.

Despite enthusiastic claims that application will bring on the millennium, each technique has only advantages mixed with disadvantages.

"Traditional techniques" is a grab bag term for pencil and paper calculated production schedules. Generally these are single run, deterministic, tabular or graphical methods which determine what is feasible. Occasionally, traditional methods are augmented by heuristic algorithms (Gershon, 1987) which direct the calculations towards an optimal solution. Supporters of traditional methods contend that they incorporate engineering expertise, provide a workable result, and compel engineers to understand what they are doing. Detractors complain that sensitivity analysis is difficult, the process is labor intensive, time consuming, the results are not optimal, and that users tend to ignore the time value of money (i.e., that not all time is of equal economic importance).

"Microeconomic techniques" are optimization methods commonly used in economic analysis, such as Lagrangian Multipliers and partial differential equations. Recent attempts to apply these



methods (Dagdelen and Johnson, 1986) have focused on identifying classes of problems, such as ultimate pit limit, and solving for the general case. This approach is (in theory) quicker than solutions using OR programs; however, the difficulty in understanding the mathematics and the accompanying simplifying assumptions apparently hinder direct application.

"Operations research techniques" are a family of mathematical methods designed to optimize an objective, given functional constraints. The three most common methods in the literature are linear, integer, and dynamic programming.

Linear programming optimizes a linear function given a series of linear equality or inequality constraints. The variables must be nonnegative and continuous. Models are usually solved using a simplex-based, computerized procedure. The output yields an optimal solution as well as sensitivity indicators. Linear programming is the most common OR technique used in open-pit scheduling (Fytas and Calder, 1986). Supporters of this method point to its optimal results, its ability to handle detail, and its success in solving complicated problems. However, applications of linear

programming are restricted owing to the availability of large mainframe computers, data availability, computing cost, and impractical results (Kim, 1980; Wilke and Reimer, 1980; Gershon, 1987).

One mathematical deficiency of linear programming is that results are commonly nonintegers, while actual scheduling is in integers. Rounding a noninteger, optimal solution may cause a suboptimal result. Integer programming is a method which converts linear noninteger optimals to integer ones, usually via the "branch and bound" or "cutting-plane" methods. The integer mathematics allows the formulation of special 0 or 1 models, allowing an "on" or "off" designation for production blocks or equipment. Despite these advantages, integer programming is used less frequently because of limited computer time availability, processing costs, the difficulties in developing a good model, and the apparent lack of interactive capacity between the model and mine engineers (Fytas and Calder, 1986).

Dynamic programming is a collection of mathematical procedures for analyzing sequential decision problems and

calculating an optimum "policy." It differs from linear and integer programming in that there is no standard problem formulation. Instead, dynamic programming tries to dissect the problem into a series of manageable, single-phase propositions. Since formulation is not standardized, the results often are dependent on the skill of the analyst (Puterman, 1987). The application of dynamic programming to scheduling has been hampered by the limited number of variables and constraints which can be incorporated (Fytas and Calder, 1986) and the intrinsic simplifying assumptions used in formulation (Lizotte and Elbrond, 1982), which differ from real mining practice.

Computer simulation is a method which attempts to replicate the behavior of "system" using sets of equations (algebraic or differential). There are basically two types of simulation models: discrete-event simulation, which assumes that changes in state occur at discrete points, and continuous-event simulation, where changes in state may occur at any point. Simulation techniques have successfully analyzed the productivity of trucks and loaders (Runge 1983; Fytas, Calder, and Stefandis, 1985) and facilitated planning and replacement. The Catapiller Tractor Company uses such simulated

productivity studies in selling new trucks and loaders. Recent studies show simulation scheduling is feasible (Fytas, Pelley, and Calder, 1987) although the results are not necessarily optimal. One impediment lies in the general scope of software packages; to be really useful the model should have some mine specific detail (Gershon, 1987).

Spreadsheets are relative newcomers to the realm of production scheduling, having become available only with the development of microcomputers in the 1980s. Spreadsheets are computerized, tabular models which combine the production figures, related costs, and expected revenues of a mine to derive total cost, cash flow, discounted cash flow, and various measures of profitability. The "built in" nature of the functions in the spreadsheet make it ideal for trial-and-error and sensitivity calculations. The ability of commercially available software to handle logic statements suggests some heuristical functions may be applicable within the spreadsheet. Applications of spreadsheets in the mining literature have focused on mine planning (Chatterjee, Scheck, and Li, 1985; Douglas and Knoebel, 1985) and equipment

maintenance (Patrick, Wyatt, and Trent, 1985). Spreadsheets are easy to use and understand, produce usable results, have interactive capacity, and are relatively easy to alter (giving flexibility). The bad news is that detail is limited by the computer capacity and that results are not optimal.

### 2.3 Technique Problems

Reviewing the currently used techniques, some general problems and tradeoffs arise which appear fundamental to scheduling problems. These include the problems of optimization, data availability, and solution practicality, as well as the tradeoffs of cost vs. benefit, and complexity vs. simplicity.

The desirability of an "optimal" solution continues to be controversial. The rational view maintains that since maximizing profits is the principal goal of the firm, optimal mathematical techniques are the logical tools of choice. Skeptics of the rational view remain cautious because:

- o Optimal is always relative to some criterion; there is always a potential downside to the factor not optimized (Woolsey,

1982)

- o Given the volatility of today's mineral industry, it is often difficult, if not impossible, to define what the "optimal" should be (Hernandez and Proth, 1982)
- o Using the "optimal" as the basis for planning may limit flexibility and diminish response should any of the assumptions change.

Current scheduling techniques have varying degrees of data intensity. Crudely, the more sophisticated the model, the more data intensive it becomes. Formulators of the sophisticated models rarely consider a) whether the data exists, b) how much it will cost to obtain the data (if possible), and c) the cost of maintaining the database in order to update the model. The accuracy of the data is also seldom questioned, a tribute to the psychological power of numbers. As a result, considerable expense is sometimes incurred by running highly complicated and precise models with data one would charitably describe as "informed estimates." So, when considering the merits of a particular technique, the user should consider the balance between the precision of the method and the accuracy of the data.

The question of practicality is also central to the choice of technique. The more data intensive, sophisticated techniques suffer from certain technical and psychological afflictions (Gershon, 1987; Mathieson, 1982; Dagdelen and Johnson, 1986; Fytas, Pelley, and Calder, 1987).

- o The models are preset "black boxes" which do not allow users to set their own priorities.
- o The methods are not well understood, so users are hesitant to accept the results.
- o The credibility of the methods is adversely affected when an infeasible solution is calculated (or proposed to the mine management!).
- o The time required to calculate a solution may exceed the time available to make a decision.
- o Organizational rivalries between corporate staffs (who commonly develop the models) and line operators (who hate having systems shoved down their throat by headquarters) hinder the practical applications.

Considering the spectrum of scheduling techniques from traditional to the most mathematically elegant, it is inevitable some fundamental tradeoffs exist which affect the desirability of any method. Probably the most important compromise is the incremental cost of increasing the mathematical intricacy vs. the

expected benefit of the new information which results.

Unfortunately, there are few or no case studies in the literature which examine this problem in production scheduling. A related conflict is the balance between model complexity and simplicity. Given the uncertainties in commodity prices, operating costs, ore grades, and pit slope stability forecasts, some researchers (Mathieson, 1982) feel scheduling methods must prioritize detail to keep things simple. Others (Hichens and Duffy, 1984) maintain that the more detail, the more accurate and real the results and sensitivities are. A sampling of the literature suggests that preferences concerning these modeling tradeoffs are very much dependent on the style and objectives of individual firms.

#### 2.4 Current Trends in Production Scheduling

In response to many of the problems and method limitations outlined above, there is a move away from the all-embracing, mono-model and towards a symbiosis of methods: discrete modules (using different methods) linking together to form an integrated whole. This approach focuses the strengths of each method towards



a specific task. Thus, scheduling models now contain mixes of linear and integer programming (Barbaro and Ramani, 1986), simulation and linear programming (Fytas and Calder, 1986), and simulation with dynamic programming (Zhang, Yun, and Xu, 1986).

To facilitate user input, interactive graphics are also becoming an important part of long-term scheduling, using either mainframes (Douglas and Knoebel, 1985) or microcomputers (Chatterjee, Scheck, and Li, 1985; Hinde, Newton, and Rickus, 1984). The ability to visualize the process and results of mineral extraction aids engineering planning as well as communications with management. The use of computer aided planning (CAP) in mining is essentially equivalent to the CAD systems used with great success in manufacturing (Barva and Kim, 1984).

Recent changes in production scheduling practice reflect the continuing evolution of computer hardware and software. The ability to link work stations to a mainframe and the increasing speed and power of the microcomputer have influenced both where scheduling is done and who does it. There has also been a corresponding change in users from the computer specialists to

engineers. This has prompted a change to software which is generally easier to use and understand. The advance of the microcomputer has also augmented the adaptation of spreadsheets, the topic of the remaining chapters.

## Chapter 3

### THE DRIFT COMPUTER PROGRAM

"As we mathematize the world we proceed to lose or throw away those parts of the world that cannot be mathematized. . . . Let us remember that numbers are only the shadow, that life is the reality."

Philip Davis and Reuben Hersh

#### 3.1 Objectives and Assumptions

The DRIFT program is a short-term, open-pit scheduling model using a spreadsheet format. The program is designed to

- o solve for a low-cost, feasible solution by trial and error;
- o have sensitivity analysis capability;
- o be user friendly;
- o be used in conjunction with other planning/scheduling methods;
- o schedule production over a twelve-month period;
- o account for the time value of money.

As well as functional objectives, DRIFT has exogenous requirements:

- o To design the model requiring only data which is likely to be available at the mine
- o To keep the size of the model within the memory of the 5.5 inch floppy disc
- o To make the program amenable to improvements and expansion
- o To generate some hard copy output.

Although the program intentionally accommodates the non-technical user, the model's empiric method is enhanced when used by mining engineers or managers. This is because the interactive format allows users to consider their expertise and qualitative issues when running the trials.

Spreadsheets are large tables of "cells" designated by column and rows. Formulas or logic statements can be entered into the cells, giving the table an internal mathematical capacity. Cells in a table can be intergrated so that a change in the value of one cell will automatically change the values in related cells. This ability makes the spreadsheet an ideal tool for repetitive runs and trials. However, the logic statements needed to solve the table must be specific. This makes formulating a general mine scheduling

model difficult. Therefore, it is desirable, both from a programming and application viewpoint, to design certain specific attributes of the mine into the spreadsheet.

DRIFT assumes a hypothetical, small, pre-existing, open-pit mine with the following characteristics:

- o Soft rock, only minor blasting needed
- o Homogeneous ore, bulk commodity (like kaolin or gravel)
- o Scraper/loader excavation; haulage by truck
- o Visual cutoff grades (this means the operators can determine ore from waste)
- o Maintenance requirements on equipment preclude three shifts per day
- o The mine currently runs seven days per week
- o The costs associated with a production level (i.e., the number of shifts) is that of capacity, even if the actual production is below capacity.

In this hypothetical mine there is relatively minimal cost accounting. All the engineers have available are equipment operating costs per hour (cash costs only), labor costs per hour, effective operating hours per shift, and basic productivity data on

the trucks and loaders. Admittedly, there are mines operating without even this information. DRIFT converts these inputs into capacities and costs of the mine per shift, per month. Restricting the program to data readily available at the mine

- o reduces the effort and cost to collect and maintain data;
- o increases user compatibility;
- o diminishes the possibility of erroneous inputs.

### 3.2 Program Design Problems

The first rule of programming is to develop a model using input and feedback from the users. Since this is only a hypothetical example, specific constraints and requirements concerning the kind of data available and the desired model outputs were assumed. Given this restriction, the design premise was to make inputs manipulation and outputs easy for any operator.

While the microcomputer spreadsheet combination is a useful tool, it has limited screen size, some trouble handling simultaneous equations, and a limited amount of memory.

Running an interactive trial-and-error program presumes that the user has access to all relevant information. The limited size of the computer screen restricts the amount of information a user can see at any time. DRIFT tries to circumvent this problem by a) printing out some of the relevant data, so that the user has access to it and b) restricting the detail on the manipulation screen to vital factors only.

Lotus 1-2-3, like other spreadsheet models, has some problems solving simultaneous equations. DRIFT helps the software out by sequentially ordering data and function inputs. This helps Lotus 1-2-3 establish priorities when solving. The downside to this design is that the program takes time to run.

User mistakes are always a problem when a program requires user inputs. In DRIFT, one of the larger anxieties is the potential for a user to mistakenly erase a cell formula or label, rendering the program useless. To preclude this possibility, DRIFT is designed to replicate all the tables, schedules, logic, and formulas each time it runs. Consequently, the basic set-up portion of the program takes up considerable memory and significantly increases the running time.

In summary, the limitations in hardware and software requirements tend to restrict the amount of detail possible in the model. DRIFT uses only those factors over which the mine management has some control. Noncash items (such as depreciation) and accounting costs (such as corporate overhead) are omitted. As a result, the key decision variable is Total Controllable Costs not Net Income, Cash Flow, or NPV. The purist will correctly point out that this is improper. My response is twofold.

- o First, that many mining engineers (and economists for that matter) do not really understand what Net Income or Cash Flow actually are, so including them in the model does not necessarily prove useful.
- o Second, given the vicissitudes of commodity prices, many mining firms rate their cost per ton position in the industry as an index of their well-being. So emphasizing the total controllable costs in mine scheduling is not without merit or importance.

### 3.3 The Structure of DRIFT

DRIFT contains six working areas: Inputs, Tables, Logic Codes, Messages, Macros, and the Index (Figure 1). The Input area contains all the data inputs and schedule calculations. The Tables comprise



the Production and Cost Modules. The Logic Codes are the "what if" statements which control the calculations in the Tables. The Message area contains information screens which appear to the user as directed by the Macros. The Macros themselves reside separately in

		COLUMNS		
ROWS		A to Z	AA to AZ	BA to BZ
1-100	Inputs		Macros	Macros
100-150	Tables		Macros	Index
150-300	Logic Codes		Macros	
300-400	Messages		Macros	
400-900			Macros	

**Figure 1**  
A Map of the Work Areas

the Macro areas. Finally, the Index contains listings and cell locations of all the trunk and subroutine Macros in order to facilitate alterations.

DRIFT operates in two phases. The initial "controlled" mode (directed by the Macros) asks the user for the relevant inputs (via a

series of menus) and sets up schedules and tables. The subsequent "trial" mode allows manual manipulation of the tables. The trial mode is not menu driven or controlled by Macros and so relies on the user's cleverness.

The initial mode contains phases for inputting data, compiling schedules, and generating tables. In the input phase the computer prompts the user to enter specific factors:

- o Beginning inventory (in thousands of short tons)
- o Minimum allowable inventory (in thousands of short tons)
- o Labor wage rate (in \$ per hour)
- o Labor overtime wage rate (in \$ per hour)
- o Effective truck productivity (in tons per hour)
- o Effective loader productivity (in tons per hour)
- o Per truck operating costs (in \$ per hour)
- o Per loader operating costs (in \$ per hour)
- o Per dozer operating costs (in \$ per hour)
- o The firm's yearly discount rate (as a decimal only).

DRIFT automatically enters the following factors:

- o The number of trucks loaders and dozers
- o The effective hours worked per shift
- o Costs associated with changing the number of shifts
- o The inventory holding rate (in \$ per ton) per period
- o The cost of running out of ore for the plant (in \$ per ton) per period ( DRIFT calls this the "stockout cost").

These factors can be changed either within the DRIFT Macros (see Appendix 3) or in the Input area by changing the value in the relevant cell.

After entering the production and cost factors, DRIFT computes a series of cost schedules for the equipment (in \$ per day and month) and a capacity schedule for the mine (in M tons of output per shift, per month). The costs and capacities per month are used in the logic statements to assign costs to a given level of activity or to decide whether a given level of production is feasible.

With the schedules completed, DRIFT moves on to set up two tables: a Production Module and a Cost Module. The Production Module (Figure 3) asks the user for the following:

- o Demand per month (in M tons)
- o The Strip Ratio per month (this is waste divided by ore)
- o Production level per month (in M tons)

The Module then calculates the total ore and waste production by multiplying the ore production by the strip ratio. To test whether the level of total production is feasible, the Module compares the output with the maximum capacity (in the capacity schedule). If the production is equal to or below the capacity, the "production flag" column in the Module reads "OK"; if not, the column reads "NOGOOD". The Module then ends by calculating ending inventory (ore production plus beginning inventory minus demand) and assigning the number of shifts required to meet the total production level.

DRIFT then moves to the Cost Module. Logic statements assign costs to labor, shift changes, inventory, stockouts, and equipment.

An example of a logic statement:

If in January the production level is one shift plus overtime (designated as 1.2 in the Production Module), then assign \$158,320 to January Labor Costs.

Total costs are the summation of all the costs associated with production in the Module.

The Cost Module also contains a section for escalating and discounting costs. To the right of the total costs column is the escalation factor (always designated as 1 plus the decimal escalation rate). By changing this factor, the user can escalate the total costs over the schedule interval. To the right of the Escalation Factor is the Discount Factor. This number discounts the value of the costs at the firm's discount rate. The discounting equation assumes discrete cost outflows with continuous discounting as described below:

$$\text{discounted cost} = (\text{total cost}) 1/e^{rt}$$

where

r - the period interest rate

t = length of the period (in years)

e - base of the natural logarithm

Finally, the Cost Module calculates the Discounted Total Cost by multiplying the Total Costs by the Escalation Factor and again by the

Discount Factor.

After the modules are complete, DRIFT moves into the trial phase by moving the total costs column into the Production Module so that the user can observe (on one computer screen) the impact of ore production and strip ratio changes on total costs. After this adjustment, the controlled macro portion of the program ends. The user is free to arrange the ore production and strip ratios to achieve a lower total cost. Moving around within the two modules is facilitated by pushing the pointer-movement keys on the keyboard. The user may print out the Production and Cost Modules at anytime by pressing and holding the "ALT" key and then pressing the letter "X" key.

### 3.4 A Walk with DRIFT

As the user retrieves the DRIFT file from the floppy disk into Lotus 1-2-3, the program will automatically activate the control

mode and start the user on a new session. The first screen welcomes the user to DRIFT, gives a map of the work areas, and instructs the user to press the RETURN key to continue. Screen two describes the work areas and what they do (press RETURN to continue). Screen three allows the user to access either the Index (this is useful only if the user wishes to make modifications) or to continue on with the program (press RETURN, then press "I" if you want the index of "C" if you wish to continue).

Now the user is in the input phase of the initial mode. The program will prompt the user at the top left of the screen (just above the column labels) with commands such as

Enter Beginning Inventory (M short tons):

To enter a factor, type in the number from the keyboard and press RETURN. The program will automatically place the figure in its correct cell and return to give another command. The program continues with inputs until a menu appears:

Continue    Go Back  
Continue with program    Go back to Paradata

If you wish to continue, press the letter "C"; if you made a mistake and wish to return to the input section, press the letter "G". Please note: Paradata is the name of the macro which controls the input portion of DRIFT, not some faraway castle!

Once through the inputs, the program goes merrily about its business setting up the schedules. No input is required by the user. After generating all the schedules, DRIFT will prompt the user with another menu:

Continue    Go Back    Print  
Continue with program    Go Back to Paradata    Print Cost Schedules

If you wish to continue onto the table section, press "C" or RETURN; if you wish to go back and correct some inputs, press the letter "G". We recommend printing out a copy of the inputs and schedules at this point, since this information will be useful in the trial mode. To print, press the letter "P". The program will automatically format and print the inputs and schedules. When finished printing, the



program will bring you back to the above menu again. Press RETURN or "C" to continue.

As outlined, the table phase contains Production and Cost Modules. DRIFT first constructs the Production Module and then asks the user for inputs on demand, strip ratios, and production by a prompt in the upper left corner (as in inputs). Such a question would be

Enter January Demand (M tons):

Type in the appropriate number and press RETURN as we did before.

When asked to input strip ratios for a certain period as in

Enter January Strip Ratio.

You can enter a ratio such as "3/1" or just "3". (By this time it is fairly obvious that the user needs to be aware of the units used in the Production Module). After the user inputs the necessary data, DRIFT continues on and fills out the remaining portions of the Production Module automatically.

Moving on to the Cost Module, DRIFT fills in almost all of the table by itself. The only user input is the escalation rate which is

prompted by

Enter Escalation Factor (a decimal + 1, per period):

The "decimal + 1" means to add 1 to the (decimal) escalation rate.

For example, if your costs are increasing at 0.8% per month, you would add 1 to 0.008 and enter 1.008, then press RETURN. If you do not want the costs to be increased, then just enter 1 and press

RETURN.

After the tables are finished, DRIFT presents Screen Four, giving instructions on how to run the trial mode. Press RETURN to leave Screen four and continue on. DRIFT will then move the total cost column to the Production Module and automatically place the curser in the ore production column . At this point the Macro ends, leaving the user free to change the ore production and strip ratios at will. These values can be changed by moving the curser (via the movement keys) onto the relevant cell, entering the appropriate number, and pressing RETURN. To view the discounted total costs, press the F5 key at the top of the keyboard, and then "L103," and

then RETURN. To return to the Production Module press F5, then "B103," and then RETURN. To print out the Production and Cost Modules, press and hold the "ALT" key (it is located just to the left of the space bar) and press the letter "X". The modules will print out automatically.

There is no formal ending to DRIFT. A user can save the worksheet manually or just quit the program by typing: /QY.

## **Chapter 4**

### **EXAMPLE PROBLEMS**

**'Work expands as to fill the time available for its completion.'**

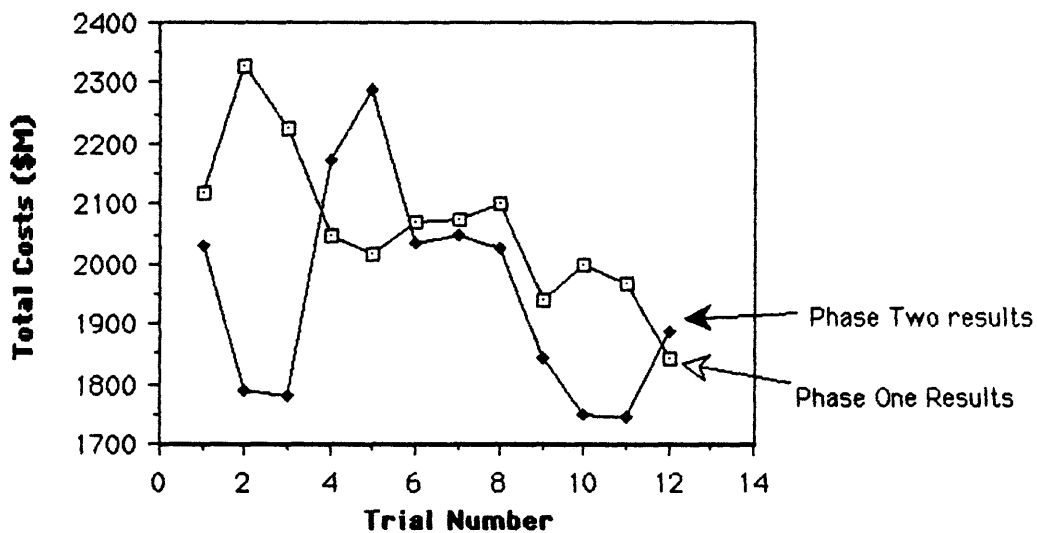
**C. Northcote Parkinson**

This chapter illustrates the ability of DRIFT to calculate lower cost production schedules and answer certain operations questions. Examples 1 and 2 summarize and discuss production scheduling problem results; example three demonstrates an equipment replacement application.

#### **4.1 Example 1**

Example 1 calculates a production schedule for a hypothetical mine in two phases. For the purposes of comparison, phase 1 assumes a static strip ratio while phase 2 allows the user the freedom to adjust both production and the strip ratio (adhering to certain constraints). This example uses only nominal cost dollars. The mine configuration, production constraints, and input parameters are detailed in Appendix 2.

The initial attempt to solve phase one by matching production with demand proved infeasible because the higher strip ratio ores required more tons to be moved than the mine could handle. Twelve trials were then run to find a feasible, low cost solution (Figure 2). The lowest cost trial proved to be 13% less than the first feasible solution, representing a savings of \$278,000 (equivalent to the cost of a new 35-ton truck). The lowest cost production configuration



**Figure 2**  
Example 1: Results of the Trials

assigned the maximum production capacity to the highest grade ores, and minimum production of the lowest grade ores. A sensitivity

analysis (Table 1) on labor and equipment costs shows that changes in labor have more impact on the total cost than equipment (assuming no equipment failure!).

**Table 1**  
Example 1, Phase 1: Sensitivity Analysis on the Average Cost Schedule

<u>Item</u>	<u>Item % Change</u>	<u>Total Cost Change (\$M)</u>	<u>Total Cost % Change</u>	<u>Total Cost to Item Elasticity</u>
Labor	+5	56	2.78	0.556
Labor	+10	112	5.57	0.557
Equipment	+5	26	1.29	0.258
Equipment	+10	52	2.58	0.258
Labor&Equip	+5	82	4.07	0.814
Labor&Equip	+10	164	8.15	0.815

Phase 2 allows the user to schedule the strip ratio (subject to constraints) as well as production. This is accomplished by manually changing the strip ratios in the Production Module. The strip ratios and constraints used in phase two are listed in Appendix 2. The results (Figure 3 ) show a lowest cost solution which is \$96,000 (5%) less than the minimum result in phase 1 and \$374,000 (17%) less than the first feasible part 1 solution. Sensitivity analysis (Table 2)

shows that changes in labor still have more impact on total costs than do changes in equipment. However, the elasticities for both are higher than phase 1.

**Table 2**

Example 1, Phase 2: Sensitivity Analysis on Lowest Cost Schedule

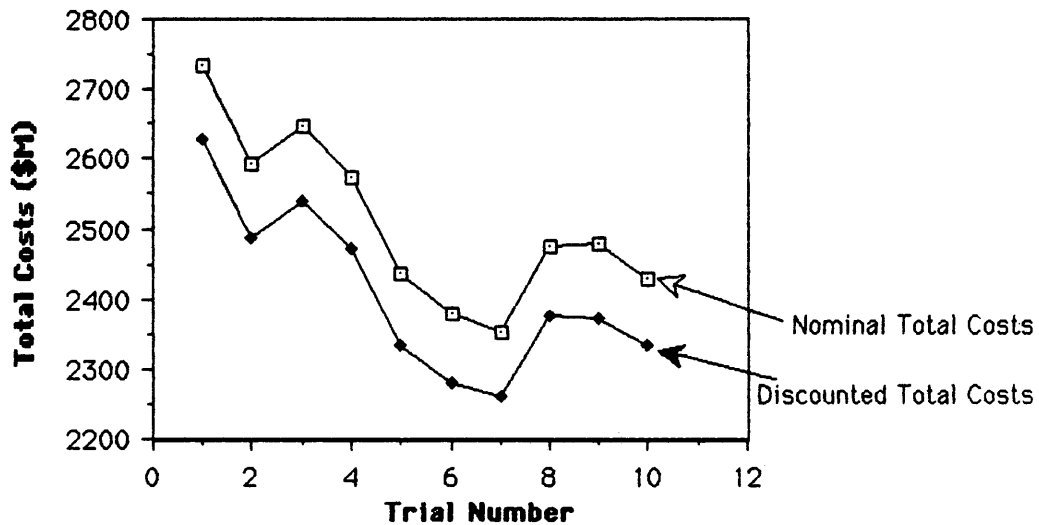
<u>Item</u>	<u>Item % Change</u>	<u>Total Cost Change (\$M)</u>	<u>Total Cost % Change</u>	<u>Total Cost to Item Elasticity</u>
Labor	+5	54	3.12	0.624
Labor	+10	109	6.25	0.625
Equipment	+5	26	1.47	0.294
Equipment	+10	51	2.95	0.295
Labor&Equip	+5	80	4.60	0.920
Labor&Equip	+10	160	9.20	0.920

## 5.2 Example 2

Example 2 brings the effect of discounting into the scheduling. The mine configuration, production constraints, and input parameters are listed in Appendix 2.

The initial solution of matching production with demand proved infeasible when mining the lower grade ores. Ten trials were then run to calculate a feasible lower cost schedule by varying production and strip ratios. The lowest cost solution was the same in

both nominal and discounted dollars (Figure 3 ). This lowest cost schedule was \$382,000 (14%) below the first feasible solution in nominal dollars and \$219,000 (8%) in discounted dollars. Four of the ten trials produced schedules with costs within 5% of the lowest cost solution. This lowest cost configuration was achieved by delaying mining the low grade ore until the last half of the year and then



**Figure 3**  
Example 2: Results of the Trials

alternating low-grade extraction periods with high-grade extraction periods.

Sensitivity analysis on labor and equipment costs (Table 3) shows that changes in these two inputs have virtually the same



magnitude impact on total costs. A 5% change in either will cause about a \$55,000 increase in total costs. So the minimum schedule cost of \$235,000 has a 5% error of \$55,000. Other feasible solutions lie within this error range.

**Table 3**

Example 2: Sensitivity Analysis on the Lowest Cost Schedule

<u>Item</u>	<u>Item % Change</u>	<u>Total Cost Change (\$M)</u>	<u>Total Cost % Change</u>	<u>Total Cost to Item Elasticity</u>
Labor	5	55	2.34	0.468
Labor	10	111	4.72	0.472
Equipment	5	55	2.34	0.468
Equipment	10	112	4.72	0.472
Labor&Equip	5	111	4.72	0.944
Labor&Equip	10	223	9.47	0.947

Further sensitivity analysis shows the impact of escalating total costs per period (Table 4). If in aggregate the costs are growing at 10% per year, this causes Total Costs to increase \$110,000 (in discounted dollars).

**Table 4**

Example 2: Escalated Cost Sensitivity on the Lowest Cost Schedule

<u>Total Cost Escalation % per period</u>	<u>Discounted Total Cost change (\$M)</u>	<u>Discounted Total Cost % change</u>
+ 0.8	+ 110	+ 4.86
+ 1.5	+ 212	+ 9.37

### 5.3 Other Questions

DRIFT can be manipulated to answer other operational questions. In equipment replacement the productivity cost-benefit can be calculated for new equipment and compared with old equipment on a year-by-year basis (Table 5). The savings can then be discounted to year zero and compared to the purchase price.

DRIFT can also address other "what if" questions:

- o What are the extra costs to carry a minimum of 5 M tons inventory?
- o Is it economically feasible to add another truck per shift?
- o What is the cost impact of the unions new position on lunch breaks?

Thus, when a schedule is established, DRIFT allows the user to

analyze an array of questions related to the mine productivity and cost.

**Table 5**

Example of Cost Benefits (over one year) Accruing From New Trucks

	<u>Mine Configuration</u>	<u>Operating Cost per Hr.</u>	<u>Mine Total Cost (\$M)</u>	<u>Year One Savings(\$M)</u>
(old)	4, 35-ton trucks	\$30	2,353	-
(new)	3, 50-ton trucks	\$20	2,298	55

## Chapter 5

### CONCLUSIONS AND RECOMMENDATIONS

"The methods of Social Scientists condemn those who practice them to the agony of making universal and general what is stubbornly local and particular."

John Keegan

DRIFT is a spreadsheet program which takes both internalized and inputed mine data and builds two tables, one for production, the other for costs. These tables interact to simulate the costs associated with various production and strip ratio scenarios. The user can then construct a relatively lower cost, feasible production schedule by trial and error. Built-in equipment and labor factors allow sensitivity calculations on the solution of choice.

Spreadsheets can be run on a microcomputer at the mine itself (eliminating the need for expensive headquarters staff?). The DRIFT program is easy to use, not data intensive, and uses simple algebraic or "what if" logic in the calculations. The ease in understanding how the model works should enhance the program's acceptability to the

mine engineer or manager. DRIFT is written within Lotus 1-2-3; the macro language is easy to learn and the structure of DRIFT makes alterations and additions relatively straightforward. The interactive, trial and error method is designed to assimilate engineering and management expertise. The system presents a useful alternative to large, data intensive mainframe computer models, especially for small mines.

Potential improvements to spreadsheet scheduling models include

- o building heuristic algorithms into the logic functions of the model;
- o developing a strip function to facilitate strip scheduling;
- o developing an internal, inventory cost rate calculation.

This thesis demonstrates that appropriate spreadsheet models are feasible for open-pit production scheduling. Similar work has validated this method in factory production scheduling (Baker, Clark, and Frund, 1987). In the final analysis, relatively simple spreadsheet models may prove more cost effective in some situations than the mathematically sophisticated systems now in use.

**REFERENCES CITED**

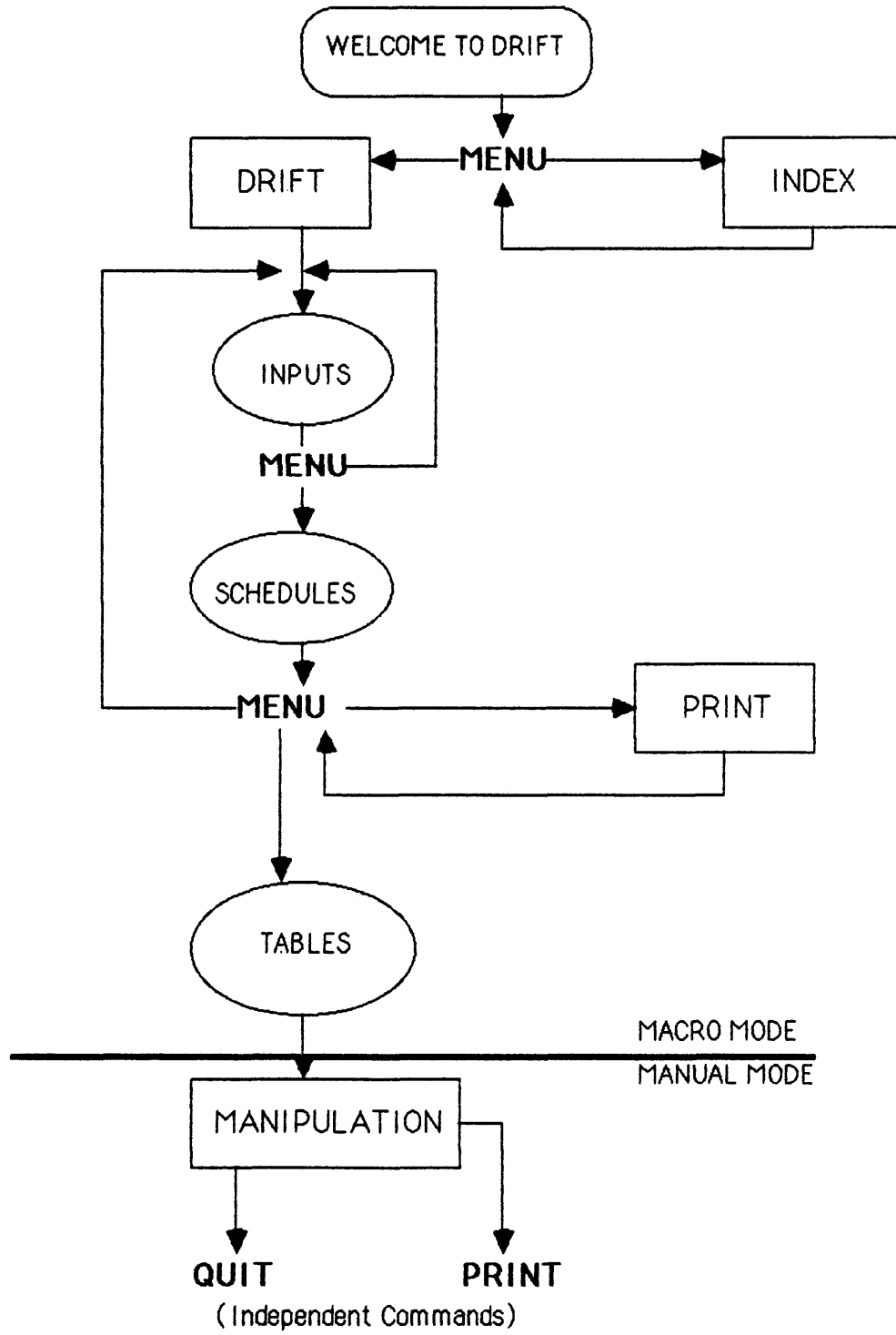
- Baker, G.L., W.A. Clark, and J.S. Frund. 1987. Production Planning and Cost Analysis on a Microcomputer. *Interfaces*, Vol. 17, 53 - 60.
- Barbaro, R.W., and R.V. Ramani. 1986. Generalized Multiperiod MIP Model for Production Scheduling and Processing Facilities Selection and location. *Mining Engineering*, Feb., 107 - 114.
- Barva, S.L. and Y.C.Kim.1984. Coal Mine Planning with Interactive Graphics. In *Eighteenth APCOM Symposium*, ed. R.J.Banks, 191-200. Society of Mining Engineers of AIME, New York.
- Chatterjee, P.K.,D.E. Scheck, and B.S.Li. 1985. Interactive Underground Coal Mine Planning Using a Macintosh. In *Use of Computers in Coal Industry II*, ed. T. Novak, R.L. Sanford, and Y.J. Wang, 193-202. Society of Mining Engineers of AIME, New York.
- Dagdelen, K., and T.B. Johnson. 1986. Optimum Open Pit Mine Production Scheduling by Lagrangian Parameterization. In *Nineteenth APCOM Symposium*, ed. R.V. Rawani, 127-139. Society of Mining Engineers of AIME, New York.
- Douglas, W.J. and K.Y.Knoebel. 1985. Graphical Mine Production Scheduling and Financial Planning System. In *Use of computers in Coal Industry II*, eds. T. Novak, R.L. Sanford, and Y.J. Wang, 203-213. Society of Mining Engineers of AIME, New York.
- Fytas, K. , C. Pelley, and P. Calder. 1987. Optimization of Open Pit Short and Long-Range Production Scheduling, *CIM Bull*, Aug., 55 - 61.

- Fytas, K. and P. Calder. 1986. A Computerized Model of Open Pit Short and Long Range Production Scheduling, In Nineteenth APCOM Symposium, ed R.V. Ramani, 250-257, Society of Mining Engineers of AIME, New York.
- Fytas, K.G., P.N. Calder, and D. Stefandis. 1985. Computer Simulation of Stripping Operations in Open Pit Lignite Mines, In *Use of Computers in Coal Industry II*, ed. T. Novak, R.L. Sanford, and Y.J. Wang, 250-257, Society of Mining Engineers of AIME, New York.
- Gershon, M.E. 1987. An Open-Pit Production Scheduler: Algorithm and Implementation, *Mining Engineering*, Aug., 793 - 796.
- Gershon, M.E. 1986. Developments in computerized Mine Production Scheduling, *Soc Min Eng Transactions*, Vol. 280, 1801 - 1804.
- Hichens, A.P. and S.P. Duffy. 1984. Financial Evaluation and Planning, In *Eighteenth APCOM Symposium*, London, ed. M. Norvick, 225-236, Society of Mining Engineers of AIME, New York.
- Hinde, C.G., M.J. Newton, and J.E. Rickus. 1984. Application of an Interactive Graphics Mine Planning System at Malanjhand Open-Pit Copper Mine, India, In *Eighteenth APCOM Symposium*, London, ed. M. Norvick, 175-190, Society of Mining Engineers of AIME, New York.
- Hernandez, J.P. and J.M. Proth. 1982. A Good Solution Instead of an Optimal One, *Interfaces*, Vol. 12, 37 - 41.
- Kim, Y.C. 1980). Production Scheduling, A Technical Review, In *Computer Methods for the 80's*, ed. A. Weiss, 365-370, Society of Mining Engineers of AIME, New York.

- Lizotte, Y. and J. Elbrond. 1982. Choice of Mine-Mill Capacities and Production Schedules Using Open-Ended Dynamic Programming, *CIM Bull*, Vol. 75, 154 - 167.
- Mathieson, G.A. 1982. Open Pit Sequencing and Scheduling. Paper read at SME-AIME Meeting, Honolulu, Sept., Preprint 82-368
- Patrick, W.C., R. Wyatt, and R.H. Trent. 1985. Integrating Microcomputer Commercial Software with Mining Applications, In *Use of Computers in Coal Industry II*, eds T. Novak, R.L.Sanford, and Y.J. Wang, 18-26, Society of Mining Engineers of AIME, New York.
- Puterman, M.L. 1987. Dynamic Programming, In *Ency. of Phy. Sci. & Tech.*, Vol 4, ed R.A. Meyes, 438-63., Academic Press, Orlando, Florida.
- Runge, I.C. 1983. Designing for Maximum Production from Trucks and Loaders, In *AIMM Computers in Mining Symposium*, May, 456-62, Australian Institute of Mining and Metallurgy, Sydney.
- Wilke, F.L. and T.H. Reimer. 1980. Optimizing the Short-Term Production Schedule for an Open-Pit Iron Ore Operation, In *Computer Methods for the 80's*, ed A. Weiss, 472-480, Society of Mining Engineers of AIME, New York.
- Woolsey, G. 1982. The Fifth Column: Production Scheduling as it Really Is, *Interfaces*, Vol. 12, 115 - 118.
- Zhang, Y.G., Q.X. Yun, and L.J. Xu. 1986. A New Approach for Production Scheduling in Open Pit Mines, in *Nineteenth APCOM Symposium*, ed. R.V. Ramani, 71- 78, Society of Mining Engineers of AIME, New York.



### Appendix A A DRIFT FLOWSHEET



## APPENDIX B

### EXAMPLE PROBLEMS

#### EXAMPLE PROBLEM ONE PHASE ONE

##### 1 Assumptions

- o Period strip ratios are fixed by the mineplan.
- o Maintenance on equipment prohibits three shifts per day
- o Mine operates seven days per week.
- o Thirty day months.
- o Union rules prohibit more than two hours of overtime.
- o Ore body is homogeneous; cutoff grade is visible.
- o Minimal blasting needed; major restoration work deferred.

##### 2. Mine Configuration

- o 1 loader , 1 dozer , 2 35-ton trucks per shift.
- o 10 hourly employees per shift.
- o Travel Times from pit to waste dump and pit to plant are equal.

##### 3. Input Parameters

Beginning Inventory (M tons):	2
Minimum Allowable Inventory (M tons):	0
Labor Wage Rate (\$/Hr):	12
Overtime Labor Rate (\$/Hr):	18
Tons Moved per Truck per Hour:	80

Tons Loaded per Loader per Hour:	180
Truck Operating Cost Rate (\$/Hr):	35
Dozer Operating Cost Rate (\$/Hr):	40
Loader Operating Cost Rate (\$/Hr):	32

## EXAMPLE PROBLEM ONE PHASE TWO

### 1. Assumptions

- o Yearly strip ratios defined by mineplan; monthly scheduling is changable.
- o Equipment maintenance precludes three shifts per day
- o Mine operates seven days per week.
- o Union prohibits more than two overtime hours per shift.
- o Soft, homogeneous ore; visible cutoff grades.
- o Minimal blasting; major reclamation work deferred.
- o All output is contract consigned; demand is flat (not seasonal).

### 2. Constraints

- o The mine has available for extraction:
  - 100 tons ore with strip ratio 1 : 1
  - 300 tons ore with strip ratio 1.5 : 1
  - 200 tons ore with strip ratio 2 : 1
- o Demand is 50 tons per month.

### 3. Mine Configuration

- o 1 loader, 1 dozer, 2 35-ton trucks per shift.
- o 10 employees per shift.
- o Travel time from the pit to either dump or plant is equal.

### 4. Input Parameters

Beginning Inventory (M tons):	2
Minimum Allowable Inventory (M tons):	0
Labor Wage Rate (\$/Hr):	12
Overtime Labor Rate (\$/Hr):	18
Tons Moved per Truck per Hour:	80
Tons Moved per Loader per Hour:	180
Truck Operating Cost Rate (\$/Hr):	35
Dozer Operating Cost Rate (\$/Hr):	40
Loader Operating Cost Rate (\$/Hr):	32

## TRIAL RESULTS

<u>Trial</u>	<u>Phase One Total Costs (\$M)</u>	<u>Phase Two Total Costs (\$M)</u>
Initial	infeasible	—
1	2119	3031
2	2330	1789
3	2226	1782
4	2049	2174
5	2017	2290
6	2070	2035
7	2076	2047
8	2103	2026
9	1941	1844
10	1997	1750
11	1969	1745
12	1841	1889
Average	2061	1950
Minimum	1841	1745
5% Cluster	0	3

## EXAMPLE PROBLEM TWO

1. Assumptions

- o Strip ratios defined by the mineplan with freedom of monthly scheduling.
- o Equipment maintenance precludes three shifts per day.
- o Mine operates seven days per week.
- o Union rules prohibit more than two hours overtime per shift.
- o Soft, homogeneous ore; visible cutoff grades.
- o Minimal blasting; major reclamation work deferred.
- o All output is contract consigned; demand is flat (not seasonal).
- o Demand per month is 80M tons.

2. Constraints

- o the mine has available for extraction:
  - 300M tons ore at strip ratio 1:1
  - 400M tons ore at strip ratio 2:1
  - rest of ore has strip ratio 3:1

3. Mine Configuration

- o One central open pit.
- o 4 35-ton trucks; 2 loaders, 1 dozer per shift.
- o 9 hourly employees per shift.
- o travel time form pit to plant or dump is equal.

4. Input Parameters

Beginning Inventory (M tons):	5
Minimum Allowable Inventory (M tons):	0
Labor Wage Rate (\$/Hr):	10
Overtime Labor Rate (\$/Hr):	15
Tons Moved per Truck per Hour:	80
Tons Moved per Loader per Hour:	180
Truck Operating Cost Rate (\$/Hr):	30
Dozer Operating Cost Rate (\$/Hr):	40
Loader Operating Cost Rate (\$/Hr):	32
Discount Rate/Yr (decimal):	0.08

5. Results of the Trials

<u>Trial</u>	<u>Nominal Total Cost (\$M)</u>	<u>Discounted Total Cost (\$M)</u>
Initial*	infeasible	infeasible
1	2736	2627
2	2592	2488
3	2649	2542
4	2574	2472
5	2436	2332
6	2380	2280
7	2354	2262
8	2474	2374
9	2478	2373
10	2429	2335
Average	2510	2408
Minimum	2354	2262
5% Cluster**	4	4

\* Initial trial sets production = demand per period

\*\* 5% Cluster is the number of trials with results within 5% of the minimum.

## **APPENDIX C**

### **NOTES ON THE MACRO STRUCTURE IN DRIFT**

The Lotus 123 software and its program language, called "Macros", provide some adaptability to DRIFT. The Macro language is based on english and so easy to comprehend and change if need be. The Lotus 123 system makes moving and adding Macro subroutines within DRIFT relatively easy.

The Macro structure within DRIFT is also designed to ease modifications. The program contains main "trunk" Macros which control the order of the operations and "subroutine" Macros which perform specific tasks. Trunk Macros are designated by a backslash and a letter (/A), while subroutines are named after their respective tasks (as in 'Labor' for executing the Labor Cost Schedule). This structure allows rapid modifications because the location of the task to be modified is readily found. Users can also build their own model for another mine simply by selecting the subroutines they require and copying them to another file.

The most difficult part of DRIFT to modify are the logic statements, which occupy both their own area (see Figure 1) and parts of several subroutines. These can be modified by simply rewriting the statements in the subroutines. Expanding the logic statements requires expanding their work area on the spreadsheet and this is time consuming.



## APPENDIX D

### THE DRIFT PROGRAM

(Written in Lotus Macro Language)

Line	Name	Macro
1	\A	/XCIntro~
2		/XCPeriods~
3		/XCParaset~
4		/XCPrardata~
5		{MENUBRANCH Menu1}~
6		
7		
8	Intro	{home}~
9		PRODUCTION SCHEDULE MODEL{down}~
10		THE CATATONIA MINE{down (2)}~
11		I MATRIX INPUTS{down}\=~
12		/WCS 25~
13		/XR~
14		
15		
16	Periods	{goto}A6~
17		Period Dimensions~
18		{down}~{right (2)}~
20		First Peiod{down}\=~
21		{goto} E7~
22		Increment{down}\=~
23		{goto}G7~
24		Last Perion{down}~/=~
25		{goto}C10~
26		Interval{down}~/=~
27		{goto}E10~
28		Interval +2{down}\=~
29		{goto}G10~
30		Interval -1{down}~/=~
31		{LET C9,1}~
32		{LET E9,12}~
33		{LET C12, (G9-C9)+1}~
34		{LET E12, (G9-C9)+3}~
35		{LET G12, G9-C9}~
36		/XR~
37		
38		
39	Paraset	{goto}A14~

```

40      Cost & Production Parameters~
41      {goto}C16~
42      Beg{right}~
43      Min{right}~
44      Labor{right}~
45      OT Labor{right}~
46      Labor{right}~
47      Loaders{right}~
48      Trucks~
49      {goto}C17~
50      Inv{down}~-~{right}~{up}~
51      Inv{down}~/~{right}~{up}~
52      Rate$/Hr{down}~/~{right}~{up}~
53      Rate$/Hr{down}~/~{right}~{up}~
54      Factor{down}~-~{right}~{up}~
55      On Shift{down}~-~{right}~{up}~
56      On Shift{down}~/~
57      {goto}C20~
58      Truck{right}~
59      Loader{right}~
60      Truck{right}~
61      Dozer{right}~
62      Loader{right}~
63      Equip{right}~
64      Discount~
65      {goto}C21~
66      Tons/Hr{down}~-~{right}~{up}~
67      Tons/Hr{down}~/~{right}~{up}~
68      Rate$/Hr{down}~/~{right}~{up}~
69      Rate$/Hr{down}~/~{right}~{up}~
70      Rate$/Hr{down}~/~{right}~{up}~
71      Factor{down}~-~{right}~{up}~
72      Rate/Yr{down}~/~
73      /XR~
74
75
76  Paradata      {GETNUMBER "Enter Beginning INventory: ",C19}~
77              {GETNUMBER "Enter Minimum Allowable Inventory: ",D19}~
78              {GETNUMBER "Enter Labor Wage Rate ($/Hr): ",E19}~
79              {GETNUMBER "Enter Overtime Wage Rate ($/Hr): ",F19}~
80              {LET G19,1.0}~
81              {LET H19,1}~
82              {LET I19,2}~
83              {GETNUMBER "Enter Productivity per Truck (tons/Hr): ",
84                  C23}~
              {GETNUMBER "Enter Productivity per Loader (tons/Hr): ",

```

```

                                D23}~
85      {GETNUMBER "Enter Truck Cost per Hour: ",E23}~
86      {GETNUMBER "Enter Dozer Cost per Hour: ",F23}~
87      {GETNUMBER "Enter Loader Cost per Hour: ",G23}~
88      {LET H23, 1}~
89      {GETNUMBER "Enter the Yearly Discount Rate (decimal): ",
                                123}~
90      /XR~
91
92
93      Menu1      Continue Go Back
94      Continue Go Back Paradata
95      {BRANCH \ {BRANCH Paradata}~
96
97
98      \B      /XCLabor~
99      /XCMisc~
100     /XCTruck~
101     /XG\C~
102
103
104     \C      /XCLoad~
105     /XCDozer~
106     /XCCapacity~
107     {MENUBRANCH Menu2}~
108
109
110     Labor   {goto}A25~
111     Labor Cost Schedule{down}~{right (2)}~
112     Shift{right}~
113     Tot{right}~
114     Labor{right}~
115     Labor{right}~
116     Labor{right}~
117     Labor{right}~
118     Labor{right}~
119     Labor~
120     {goto}C27~
121     Level{down}~-~{right}~{up}~
122     Hours{down}~-~{right}~{up}~
123     Rates$/Hr{down}~-~{right}~{up}~
124     Force{down}~-~{right}~{up}~
125     Factor{down}~-~{right}~{up}~
126     Cost/day{down}~-~{right}~{up}~
127     Cost/Mo{down}~-~
128     {goto}C29~
129     One{down}~
130     One W OT{down}~

```

```

131      Two{down}~
132      Two W OT{down}~
133      {LET D29,8}~
134      {LET D30,10}~
135      {LET D31,16}~
136      {LET D32,20}~
137      {LET E29,E19}~
138      {LET E30,F19}~
139      {LET E31,E19}~
140      {LET E32,F19}~
141      {LET F29,10}~
142      {LET F30,10}~
143      {LET F31,20}~
144      {LET F32,20}~
145      {goto}G29~(G19){down}~
146      (G19){down}~
147      (G19){down}~
148      (G19)~
149      {goto}H29~(D29*E29*F29*G29){down}~
150      (D29*E29*F29*G29)+(2*E30*F30*G30){down}~
151      (D31*E31*F31*G31){down}~
152      (D31*E31*F31*G31)+(4*E32*F32*G32)~
153      {goto}I29~
154      (30*H29){down}~
155      (30*H30){down}~
156      (30*H31){down}~
157      (30*H32)~
158      {goto}B35~
159      *Production Level Cannot be Zero~
160      /XR~
161
162
163      Misc      {goto}A37~
164      Misc Cost Items{down (2)}~{right}~
165      Shift Changeover{right (2)}~
166      One Shift to Two($):{down}~
167      Two Shifts to One($):~
168      {goto}B42~
169      Inventory{right (2)}~
170      Inventory Holding Rate ($/ton):{down}~
171      Per Period~
172      {goto}B45~
173      Stockout{right (2)}~
174      Stockout Cost ($/M tons short):{down}~
175      Per Period~
176      {LET H39,1500}~

```

```

177      {LET H40,1000}~
178      {LET H42,300}~
179      {LET H45,25000}~
180      {goto}C48~
181      If Inventory at the End of the Period is Zero~
182      {down}~
183      Then there is no Holding Cost~
184      /XR~
185
186
187  Truck      {goto}A51~
188              Truck Cost Schedule{right (2)}~{down}~
189              Shift{right}~Number{right}~OP{right}~
190              Running{right}~Running{right}~Running~
191              {goto}C53~
192              Level{down}~\-~{right}~{up}~
193              Trucks{down}~\-~{right}~{up}~
194              Hours{down}~\-~{right}~{up}~
195              Cost/hr{down}~\-~{right}~{up}~
196              Cost/dy{down}~\-~{right}~{up}~
197              Cost/mo{down}~\-~
198              {goto}D55~
199              +119{down}~+119{down}~+119{down}~+119~
200              {goto}E55~
201              8{down}~10{down}~16{down}~20~
202              {goto}C55~
203              One{down}~One W OT{down}~Two{down}~Two W OT~
204              {goto}F55~
205              {LET F55,E23}~
206              /C~.{down (3)}~
207              {down}~
208              {goto}G55~(D55*E55*F55*H23){down}~
209              (D56*E56*F56*H23){down}~
210              (D57*E57*F57*H23){down}~
211              (D58*E58*F58*H23)~
212              {goto}H55~
213              (G55*30){down}~
214              (G56*30){down}~
215              (G57*30){down}~
216              (G58*30)~
217              /XR~
218
219
220
221  Load      {goto}A61~
222              Loader Cost Schedule{down}~{right (2)}~
223              Shift{right}~Number{right}~OP{right}~
224              Running{right}~Running{right}~Running~

```

225 {goto}C63~  
 226 Level{down}~\~{right}~{up}~  
 227 Loaders{down}~\~{right}~{up}~  
 228 Hours{down}~\~{right}~{up}~  
 229 Cost/hr{down}~\~{right}~{up}~  
 230 Cost/dy{down}~\~{right}~{up}~  
 231 Cost/mo{down}~\~  
 232 {goto}C65~  
 233 One{down}~One W OT{down}~Two{down}~Two W OT~  
 234 {goto}D65~  
 235 {LET d65,H19}~  
 236 /c~.{down (3)}~  
 237 {goto}E65~  
 238 8{down}~10{down}~16{down}~20~  
 239 {goto}F56~  
 240 {LET f65,G23}~  
 241 /C~.{down (3)}~  
 242 {goto}G65~  
 243 (D65\*E65\*F65\*H23){down}~  
 244 (D66\*E66\*F66\*H23){down}~  
 245 (D67\*E67\*F67\*H23){down}~  
 246 (D68\*E68\*F68\*H23)~  
 247 {goto}H65~  
 248 (G65\*30){down}~  
 249 (G66\*30){down}~  
 250 (G67\*30){down}~  
 251 (G68\*30){down}~  
 252 /XR~  
 253  
 254  
 255 Dozer {goto}A70~  
 256 Dozer Cost Schedule{down}~{right (2)}~  
 257 Shift{right}~Hours{right}~Running{right}~  
 258 Running{right}~Running~  
 259 {goto}C72~  
 260 Level{down}~\~{right}~{up}~  
 261 A Shift{down}~\~{right}~{up}~  
 262 Cost/hr{down}~\~{right}~{up}~  
 263 Cost/dy{down}~\~{right}~{up}~  
 264 Cost/mo{down}~\~  
 265 {goto}C75~  
 266 One{down}~One W OT{down}~Two{down}~Two W OT~  
 267 {goto}D75~  
 268 8{down}~10{down}~16{down}~20~  
 269 {goto}E75~  
 270 {LET E75,F23}~  
 271 /C~.{down (3)}~

272		{goto}F75~
273		(D75*E75*H23){down}~
274		(D76*E76*H23){down}~
275		(D77*E77*H23){down}~
276		(D78*E78*H23)~
277		{goto}G75~
278		(F75*30){down}~
279		(F76*30){down}~
280		(F77*30){down}~
281		(F78*30)~
282		/XR~
283		
284		
285	Capacity	{goto}A80~
286		Capacity Schedule{down}~{right ( 20)}~
287		Shift{right}~Truck{right}~Loader{right}~Capacity~
288		Capacity{right}~Slack~
289		{goto}C82~
290		Level{down}~\~{right}~{up}~
291		Output{down}~\~{right}~{up}~
292		Output{down}~\~{right}~{up}~
293		Per day{down}~\~{right}~{up}~
294		Per Mo*{down}~\~{right}~{up}~
295		Per day{down}~\~
296		{goto}C84~
297		One{down}~One W OT{down}~Two{down}~Two W OT~
298		{goto}D84~
299		(119*C23)~
300		/C~.{down ( 3)}~
301		{goto}E84~
302		(H19*D23)~
303		/C~.{down ( 3)}~
304		{goto}F84~
305		(D84*8){down}~
306		(D85*10){down}~
307		(D86*16){down}~
308		(D87*20)~
309		{goto}G84~
310		(F84*30)/1000{down}~
311		(F85*30)/1000{down}~
312		(F86*30)/1000{down}~
313		(F87*30)~
314		{goto}H84~
315		(D84-E84)8{down}~
316		(D85-E85)10{down}~
317		(D86-E86)16{down}~
318		(D87-E87)*20~

```

319      {goto}B89~*in M tons~
320      /XR~
321
322
323  Menu2      Continue Go Back Print
324      Continue Go Back to Paradata Print Cost Schedules
325      {BRANCH \{BRANCH P{BRANCH Print 1}~
326
327
328  Print1     /PPOS\015~
329      ML5~MR220~
330      QRA1..J90~
331      0Q~
332      {MENUBRANCH menu2}~
333
334
335  \D         /XCAprd~
336      /XCBprd~
337      /XG\E~
338
339
340  Aprd       {goto}A101~
341      || Tables(down)\={down(2)}~{right}~
342      /WCS10~{right}~/WCS10~{right}~/WCS10~{right}~
343          /WCS10~{right}~
344      /WCS10~{right}~/WCS10~{right}~/WCS10~{right}~
345          /WCS10~{right}~
346      /WCS10~{right}~/WCS10~{right}~/WCS10~
347      {goto}B104~
348      ^Ore{right}~^start{right}~^Ore{right(2)}~^Ore&Waste
349          {right(2)}~
350      {goto}B105~
351      ^Demand{right}~^Inventory{right}~^Production{right}~
352          ^Strip{right}~
353      ^Production{right}~^Production{right}~^Inventory{right}~
354          ^Number{right}~
355      {goto}A106~
356      ^Periods{right}~^M Tons{right}~^M Tons{right}~
357          ^M tons{right}~
358      ^Ratio{right}~^M Tons{right}~^Flag{right}~
359          ^M Tons{right}~^Shifts~
360      {goto}A107~
361      \={/C~.{right(18)}~
362      {goto}E103~PRODUCTION MODULE~
363      /XR~

```



```

358
359
360 Bprod      {goto}A108~
361           January{down}~February{down}~March{down}~
                April{down}~
362           May{down}~June{down}~July{down}~August{down}~
                September{down}~
363           October{down}~November{down}~December~{down}~
364           \~/C~.{right ( 18)}~{down}~
365           Total{down}~Average~
366           /XR~
367
368
369 \E          /XCPdata~
370           /XCPpdata~
371           /XCStrip~
372           /XCRock~
373           /XCFlag~
374           /XGVF~
375
376
377 Pdata      {goto}B 121~
378           {GETNUMBER "Enter January Demand: ",B108}~
379           {GETNUMBER "Enter February Demand: ",B109}~
380           {GETNUMBER "Enter March Demand: ",B110}~
381           {GETNUMBER "Enter April Demand: ",B111}~
382           {GETNUMBER "Enter May Demand: ",B112}~
383           {GETNUMBER "Enter June Demand: ",B113}~
384           {GETNUMBER "Enter July Demand: ",B114}~
385           {GETNUMBER "Enter August Demand: ",B115}~
386           {GETNUMBER "Enter September Demand: ",B116}~
387           {GETNUMBER "Enter October Demand: ",B117}~
388           {GETNUMBER "Enter November Demand: ",B118}~
389           {GETNUMBER "Enter December Demand: ",B119}~
390           @SUM(B108..B119){down}~+B121/12~
391           /XGac413~
392
393
394 Ac413      {goto}C108~
395           +C19{down}~+H108{down}~+H109{down}~+H110{down}~
396           +H111{down}~+H112{down}~+H113{down}~+H114{down}~
397           +H115{down}~+H116{down}~+H117{down}~
                +H118{down ( 2)}~
398           @SUM(C108..C119){down}~+C121/12~
399           /XR~
400
401

```

```

402 Ppdata      {goto}D121~
403             {GETNUMBER "Enter January Production: ",D108}~
404             {GETNUMBER "Enter February Production: ",D109}~
405             {GETNUMBER "Enter March Production: ",D110}~
406             {GETNUMBER "Enter April Production: ",D111}~
407             {GETNUMBER "Enter May Production: ",D112}~
408             {GETNUMBER "Enter June Production: ",D113}~
409             {GETNUMBER "Enter July Production: ",D114}~
410             {GETNUMBER "Enter August Production: ",D115}~
411             {GETNUMBER "Enter September Production: ",D116}~
412             {GETNUMBER "Enter October Production: ",D117}~
413             {GETNUMBER "Enter November Production: ",D118}~
414             {GETNUMBER "Enter December Production: ",D119}~
415             @SUM(D108..D119){down}~+D121/12~
416             /XR~
417
418
419 Strip       {goto}E108~
420             {GETNUMBER "Enter January Strip Ratio: ",E108}~
421             {GETNUMBER "Enter February Strip Ratio: ",E109}~
422             {GETNUMBER "Enter March Strip Ratio: ",E110}~
423             {GETNUMBER "Enter April Strip Ratio: ",E111}~
424             {GETNUMBER "Enter May Strip Ratio: ",E112}~
425             {GETNUMBER "Enter June Strip Ratio: ",E113}~
426             {GETNUMBER "Enter July Strip Ratio: ",E114}~
427             {GETNUMBER "Enter August Strip Ratio: ",E115}~
428             {GETNUMBER "Enter September Strip Ratio: ",E116}~
429             {GETNUMBER "Enter October Strip Ratio: ",E117}~
430             {GETNUMBER "Enter November Strip Ratio: ",E118}~
431             {GETNUMBER "Enter December Strip Ratio: ",E119}~
432             /XR~
433
434
435 Rock        {goto}F108~
436             +D108*E108{down}~
437             +D109*E109{down}~
438             +D110*E110{down}~
439             +D111*E111{down}~
440             +D112*E112{down}~
441             +D113*E113{down}~
442             +D114*E114{down}~
443             +D115*E115{down}~
444             +D116*E116{down}~
445             +D117*E117{down}~
446             +D118*E118{down}~
447             +D119*E119{down (2)}~
448             @SUM(F108..F119){down}~F121/12~

```

```

449
450
451 Flag      {goto}G108~
452          @IF(F108<=G87,"OK","NOGOOD"){down}~
453          @IF(F109<=G87,"OK","NOGOOD"){down}~
454          @IF(F110<=G87,"OK","NOGOOD"){down}~
455          @IF(F111<=G87,"OK","NOGOOD"){down}~
456          @IF(F112<=G87,"OK","NOGOOD"){down}~
457          @IF(F113<=G87,"OK","NOGOOD"){down}~
458          @IF(F114<=G87,"OK","NOGOOD"){down}~
459          @IF(F115<=G87,"OK","NOGOOD"){down}~
460          @IF(F116<=G87,"OK","NOGOOD"){down}~
461          @IF(F117<=G87,"OK","NOGOOD"){down}~
462          @IF(F118<=G87,"OK","NOGOOD"){down}~
463          @IF(F119<=G87,"OK","NOGOOD")~
464          /XR~]
465
466
467 End      {goto}H108~
468          (C108+D108_B108)~
469          /C~.{down(11)}~
470          {goto}H121~
471          @SUM(H108..H119){down}~+H121/12~
472          /XR~
473
474
475 \F      /XCEnd~
476          /XCShift~
477          /XG\G~
478
479
480 Shift    {goto}I108~@IF(F108<=G84,1,B153)~
481          {goto}B153~@IF(F108<=G85,1.2,B154)~
482          {goto}B154~@IF(F108<=G86,2,B155)~
483          {goto}B155~@IF(F108<=G87,2.2,"error")~
484          {goto}I109~@IF(F109<=G84,1,B156)~
485          {goto}B156~@IF(F109<=G85,1.2,B157)~
486          {goto}B157~@IF(F109<=G86,2,B158)~
487          {goto}B158~@IF(F109<=G87,2.2,"error")~
488          {goto}I110~@IF(F110<=G84,1,B160)~
489          {goto}B160~@IF(F110<=G85,1.2,B161)~
490          {goto}B161~@IF(F110<=G86,2,B162)~
491          {goto}B162~@IF(F110<=G87,2.2,"error")~
492          {goto}I111~@IF(F111<=G84,1,B164)~
493          {goto}B164~@IF(F111<=G85,1.2,B165)~
494          {goto}B165~@IF(F111<=G86,2,B166)~
495          {goto}B166~@IF(F111<=G87,2.2,"error")~

```

```

496 {goto}I112~@IF(F112<=G84,1,B168)~
497 {goto}B168~@IF(F112<=G85,1.1,B169)~
498 {goto}B169~@IF(F112<=G86,2,B170)~
499 {goto}B170~@IF(F112<=G87,2.2,"error")~
500 {goto}I113~@IF(F113<=G84,1,B172)~
501 {goto}B172~@IF(F113<=G85,1.2,B173)~
502 {goto}B173~@IF(F113<=G86,2,B174)~
503 {goto}B174~@IF(F113<=G87,2.2,"error")~
504 {goto}I114~@IF(F114<=G84,1,B176)~
505 {goto}B176~@IF(F114<=G85,1.2,B177)~
506 {goto}B177~@IF(F114<=G86,2,B178)~
507 {goto}B178~@IF(F114<=G87,2.2,"error")~
508 {goto}I115~@IF(F115<=G84,1,B180)~
509 {goto}B180~@IF(F115<=G85,1.2,B181)~
510 {goto}B181~@IF(F115<=G86,2,B182)~
511 {goto}B182~@IF(F115<=G87,2.2,"error")~
512 {goto}I116~@IF(F116<=G84,1,B184)~
513 {goto}B184~@IF(F116<=G85,1.2,B185)~
514 {goto}B185~@IF(F116<=G86,2,B186)~
515 {goto}B186~@IF(F116<=G87,2.2,"error")~
516 {goto}I117~@IF(F117<=G84,1,B188)~
517 {goto}B188~@IF(F117<=G85,1.2,B189)~
518 {goto}B189~@IF(F117<=G86,2,B190)~
519 {goto}B190~@IF(F117<=G87,2.2,"error")~
520 {goto}I118~@IF(F118<=G84,1,B192)~
521 {goto}B192~@IF(F118<=G85,1.2,B193)~
522 {goto}B193~@IF(F118<=G86,2,B194)~
523 {goto}B194~@IF(F118<=G87,2.2,"error")~
524 {goto}I119~@IF(F119<=G84,1,B196)~
525 {goto}B196~@IF(F119,+G85,1.2,B197)~
526 {goto}B197~@IF(F119<=G86,2,B198)~
527 {goto}B198~@IF(F119<=G87,2.2,"error")~
528
529
530 \G          /XCCst~
531           /XCLab~
532           /XG/H~
533
534
535 Cst        {goto}K103~
536           COSTS (M$) MODULE~
537           {goto}L105~
538           Shift{right}~In Process{right}~Stockout{right}~
539           Equipment{right}~total{right}~Esc{right}~Discount
           {right}~Discount{right}~
540           {goto}K106~
541           Labor{right}~Change{right}~Inventory{right}~Cost{right}~

```

```

542          Cost{right}~Cost{right}~Factor{right}~Factor{right}~
              Cost~
543          /XR~
544
545
546 Lab      {goto}K108~@IF(1108=1,129,D153)~
547          {goto}D153~@IF(1108=1.2,130,D154)~
548          {goto}D154~@IF(1108=2,131,D155)~
549          {goto}D155~@IF(1108=2.2,132,"error")~
550          {goto}K109~@IF(1109=1,129,D156)~
551          {goto}D156~@IF(1109=1.1,130,D157)~
552          {goto}D157~@IF(1109=2,131,D158)~
553          {goto}D158~@IF(1109=2.2,132,"error")~
554          {goto}K110~@IF(1110=1,129,D160)~
555          {goto}D160~@IF(1110=1.1,130,D161)~
556          {goto}D161~@IF(1110=2,131,D162)~
557          {goto}D162~@IF(1110=2.2,132,"error")~
558          {goto}K111~@IF(1111=1,129,D164)~
559          {goto}D164~@IF(1111=1.1,130,D165)~
560          {goto}D165~@IF(1111=2,131,D166)~
561          {goto}D166~@IF(1111=2.2,132,"error")~
562          {goto}K112~@IF(1112=1,129,D168)~
563          {goto}D168~@IF(1112=1.1,130,D169)~
564          {goto}D169~@IF(1112=2,131,D170)~
565          {goto}D170~@IF(1112=2.2,132,"error")~
566          {goto}K113~@IF(1113=1,129,D172)~
567          {goto}D172~@IF(1113=1.1,130,D173)~
568          {goto}D173~@IF(1113=2,131,D174)~
569          {goto}D174~@IF(1113=2.2,132,"error")~
570          {goto}K114~@IF(1114=1,126,D176)~
571          {goto}D176~@IF(1114=1.2,130,D177)~
572          {goto}D177~@IF(1114=2,131,D178)~
573          {goto}D178~@IF(1114=2.2,132,"error")~
573          {goto}K115~@IF(1115=1,129,D180)~
574          {goto}D180~@IF(1115=1.2,130,D181)~
575          {goto}D181~@IF(1115=2,131,D182)~
576          {goto}D182~@IF(1115=2.2,132,"error")~
577          {goto}K116~@IF(1116=1,129,D184)~
578          {goto}D184~@IF(1116=1.2,130,D185)~
579          {goto}D185~@IF(1116=2,131,D186)~
580          {goto}D186~@IF(1116=2.2,132,"error")~
581          {goto}K117~@IF(1117=1,129,D188)~
582          {goto}D188~@IF(1117=1.2,130,D189)~
583          {goto}D189~@IF(1117=2,131,D190)~
584          {goto}D190~@IF(1117=2.2,132,"error")~
585          {goto}K118~@IF(1118=1,129,D192)~
586          {goto}D192~@IF(1118=1.2,130,D193)~

```

```

587 {goto}D193~@IF(I118=2,I31,D194)~
588 {goto}D194~@IF(I118=2.2,I32,"error")~
589 {goto}K119~@IF(I119=1,I29,D196)~
590 {goto}D196~@IF(I119=1.2,I30,D197)~
591 {goto}D197~@IF(I119=2,I31,D198)~
592 {goto}D198~@IF(I119=2.2,I32,"error")~
593 {goto}K121~
594 @SUM(K108..K119){down}~+K121/12~
595 /XR~
596
597
598 Chg {goto}L108~
599 +0{down}~
600 @IF(I108-I109<=-0.8,H39,F153)~
601 {goto}F153~@IF(I108-I109<0.8,0,F154)~
602 {goto}F154~@IF(I108-I109>=0.8,H40,"error")~
603 {goto}L110~@IF(I109-I110=-0.8,H39,F156)~
604 {goto}F156~@IF(I109-I110<0.8,0,F157)~
605 {goto}F157~@IF(I109-I110>=0.8,H40,"error")~
606 {goto}L111~@IF(I110-I111<=-0.8,H39,F159)~
607 {goto}F159~@IF(I110-I111<0.8,0,F160)~
608 {goto}F160~@IF(I110-I111>=0.8,H40,"error")~
609 {goto}L112~@IF(I111-I112<=-0.8,H39,F162)~
610 {goto}F162~@IF(I111-I112<0.8,0,F163)~
611 {goto}F163~@IF(I111-I112>=0.8,H40,"error")~
612 {goto}L113~@IF(I112-I113<=-0.8,H39,F165)~
613 {goto}F165~@IF(I112-I113<0.8,0,F166)~
614 {goto}F166~@IF(I112-I113>=0.8,H40,"error")~
615 {goto}L114~@IF(I113-I114<=-0.8,H39,F168)~
616 {goto}F168~@IF(I113-I114<0.8,0,F169)~
617 {goto}F169~@IF(I113-I114>=0.8,H40,"error")~
618 {goto}L115~@IF(I114-I115<=-0.8,H39,F171)~
619 {goto}F171~@IF(I114-I115<0.8,0,F172)~
620 {goto}F172~@IF(I114-I115>=0.8,H40,"error")~
621 {goto}L116~@IF(I115-I116<=-0.8,H39,F174)~
622 {goto}F174~@IF(I115-I116<0.8,0,F175)~
623 {goto}F175~@IF(I115-I116>=0.8,H40,"error")~
624 {goto}L117~@IF(I116-I117<=-0.8,H39,F177)~
625 {goto}F177~@IF(I116-I117<0.8,0,F178)~
626 {goto}F178~@IF(I116-I117>=0.8,H40,"error")~
627 {goto}L118~@IF(I117-I118<=-0.8,H39,F180)~
628 {goto}F180~@IF(I117-I118<0.8,0,F181)~
629 {goto}F181~@IF(I117-I118>=0.8,H40,"error")~
630 {goto}L119~@IF(I118-I119<=-0.8,H39,F183)~
631 {goto}F183~@IF(I118-I119<0.8,0,F184)~
632 {goto}F184~@IF(I118-I119>=0.8,H40,"error")~
633 {goto}L121~@SUM(L108..L119){down}~+L121/12~

```

```

634' /XR~
635
636
637 Inv {goto}M108~
638 @If(H108<0,0,H42*H108){down}~
639 @If(H109<0,0,H42*H109){down}~
640 @If(H110<0,0,H42*H110){down}~
641 @If(H111<0,0,H42*H111){down}~
642 @If(H112<0,0,H42*H112){down}~
643 @If(H113<0,0,H42*H113){down}~
644 @If(H114<0,0,H42*H114){down}~
645 @If(H115<0,0,H42*H115){down}~
646 @If(H116<0,0,H42*H116){down}~
647 @If(H117<0,0,H42*H117){down}~
648 @If(H118<0,0,H42*H118){down}~
649 @If(H119<0,0,H42*H119){down (2)}~
650 @SUM(M108..M119){down}~+M121/12~
651 /XR~
652
653
654 \I /XCStk~
655 /XCEquip~
656 /XGVJ~
657
658
659
660 Stk {goto}N108~
661 @If(H108<0,-(H108)*H45,0){down}~
662 @If(H109<0,-H109)*H45,0){down}~
663 @If(H110<0,-(H110)*H45,0){down}~
664 @If(H111<0,-(H111)*H45,0){down}~
665 @If(H112<0,-(H112)*H45,0){down}~
666 @If(H113<0,-(H113)*H45,0){down}~
667 @If(H114<0,-(H114)*H45,0){down}~
668 @If(H115<0,-(h115)*H45,0){down}~
669 @If(H116<0,-(H116)*H45,0){down}~
670 @If(H117<0,-(H117)*H45,0){down}~
671 @If(H118<0,-(H118)*H45,0){down}~
672 @If(H119<0,-(H119)*H45,0){down (2)}~
673 @SUM(N108..N119){down}~+N121/12~
674 /XR~
675
676
677 Equip {goto}O108~@If(I108=1,H55+H65+F75,H153)~
678 {goto}H153~@If(I108=1.2,H56+H66+F76,H154)~
679 {goto}H154~@If(I108=2,H57+H67+F77,H155)~
680 {goto}H155~@If(I108=2.2,H58+H68+F78,"error")~
681 {goto}O109~@If(I109=1,HH55+H65+F75,H157)~

```

```

682 {goto}H157~@IF(1109=1.2,H56+H66+F76,H158)~
683 {goto}H158~@IF(1109=2,H57+H67+F77,H159)~
684 {goto}H159~@IF(1109=2.2,H58+H68+F78,"error")~
685 {goto}0110~@IF(1110=1,H55+H65+F75,H161)~
686 {goto}H161~@IF(1110=1.2,H56+H66+F76,H162)~
687 {goto}H162~@IF(1110=2,H57+H67+F77,H163)~
688 {goto}H163~@IF(1110=2.2,H58+H68+F78,"error")~
689 {goto}0111~@IF(1111=1,H55+H65+F75,H165)~
690 {goto}H165~@IF(1111=1.2,H56+H66+F76,H166)~
691 {goto}H166~@IF(1111=2,H57+H67+F77,H167)~
692 {goto}H167~@IF(1111=2.2,H58+H68+F78,"error")~
693 {goto}0112~@IF(1112=1,H55+H65+F75,H169)~
694 {goto}H169~@IF(1112=1.2,H56+H66+F76,H170)~
695 {goto}H170~@IF(1112=2,H57+H67+F77,H171)~
696 {goto}H171~@IF(1112=2.2,H58+H68+F78,"error")~
697 {goto}0113~@IF(1113=1,H55+H65+F75,H173)~
698 {goto}H173~@IF(1113=1.2,H56+H66+F76,H174)~
699 {goto}H174~@IF(1113=2,H57+H67+F77,H175)~
700 {goto}H175~@IF(1113=2.2,H58+H68+F78,"error")~
701 {goto}0114~@IF(1114=1,H55+H65+F75,H177)~
702 {goto}H177~@IF(1114=1.2,H56+H66+F76,H178)~
703 {goto}H178~@IF(1114=2,H57+H67+F77,H179)~
704 {goto}H179~@IF(1114=2.2,H58+H68+F78,"error")~
705 {goto}0115~@IF(1115=1,H55+H65+F75,H181)~
706 {goto}H181~@IF(1115=1.2,H56+H66+F76,H182)~
707 {goto}H182~@IF(1115=2,H57+H67+F77,H183)~
708 {goto}H183~@IF(1115=2.2,H58+H68+F78,"error")~
709 {goto}0116~@IF(1116=1,H55+H65+F75,H185)~
710 {goto}H185~@IF(1116=1.2,H56+H66+F76,H186)~
711 {goto}H186~@IF(1116=2,H57+H67+F77,H187)~
712 {goto}H187~@IF(1116=2.2,H58+H68+F78,"error")~
713 {goto}0117~@IF(1117=1,H55+H65+F75,H189)~
714 {goto}H189~@IF(1117=1.2,H56+H66+F76,H190)~
715 {goto}H190~@IF(1117=2,H57+H67+F77,H191)~
716 {goto}H191~@IF(1117=2.2,H58+H68+F78,"error")~
717 {goto}0118~@IF(1118=1,H55+H65+F75,H193)~
718 {goto}H193~@IF(1118=1.2,H56+H66+F76,H194)~
719 {goto}H194~@IF(1118=2,H57+H67+F77,H195)~
720 {goto}H195~@IF(1118=2.2,H58+H68+F78,"error")~
721 {goto}0119~@IF(1119=1,H55+H65+F75,H197)~
722 {goto}H197~@IF(1119=1.2,H56+H66+F76,H198)~
723 {goto}H198~@IF(1119=2,H57+H67+F77,H199)~
724 {goto}H199~@IF(1119=2.2,H58+H68+F78,"error")~
725 {goto}0121~
726 @SUM(0108..0119){down}~+0121/12
727 /XR~
728

```



```

729
730  \J          /XCTotal~
731             /XCDis~
732             /XCExc~
733             {quit}~
734
735
736  Total       {goto}P108~@SUM(K108..0108){down}~
737             @SUM(K109..0109){down}~
738             @SUM(K110..0110){down}~
739             @SUM(K111..0111){down}~
740             @SUM(K112..0112){down}~
741             @SUM(K113..0113){down}~
742             @SUM(K114..0114){down}~
743             @SUM(K115..0115){down}~
744             @SUM(K116..0116){down}~
745             @SUM(K117..0117){down}~
746             @SUM(K118..0118){down}~
747             @SUM(K119..0119){down (2)}~
748             @SUM(P108..P119){down}~
749             +P121/12~
750             /XR~
751
752
753
754
755  Exc         {goto}A360~
756             {? }~
757             {goto}J103~
758             {right (6)}~
759             /WWV~
760             {left (13)}~
761             {goto}D103~
762             {down (5)}~
763             /XR~
764
765
766  Dis         {goto}Q108~
767             {GETNUMBER "Enter Escatation Factor: ",Q108}~
768             {down}~
769             (Q108^2){down}~
770             (Q108^3){down}~
771             (Q108^4){down}~
772             (Q108^5){down}~
773             (Q108^6){down}~
774             (Q108^7){down}~
775             (Q108^8){down}~
776             (Q108^9){down}~
777             (Q108^10){down}~

```

```
778 (Q108^11){down}~
779 (Q108^12)~
780 {goto}R108~
781 (1/@EXP(123*1/C12)){down}~
782 (1/@EXP(123*0.166)){down}~
783 (1/@EXP(123*0.250)){down}~
784 (1/@EXP(123*0.333)){down}~
785 (1/@EXP(123*0.416)){down}~
786 (1/@EXP(123*0.500)){down}~
787 (1/@EXP(123*0.583)){down}~
788 (1/@EXP(123*0.666)){down}~
789 (1/@EXP(123*0.750)){down}~
790 (1/@EXP(123*0.833)){down}~
791 (1/@EXP(123*0.916)){down}~
792 (1/@EXP(123*1.0))~
793 {goto}S108~
794 +P108*Q108*R108~
795 /C~.{down(11)}~
796 {goto}S121~
797 @SUM(S108..S119){down}~
798 +S121/12~
799 /XR~
```

### Macro Library

Line	Name	Macro
1	\0	{goto}A300~
2		{?}~
3		{goto}A320~
4		{?}~
5		{goto}A340~
6		{?}~
7		{goto}A350~
8		{MENUBRANCH Menu3}~
9		
10		
11	Menu3	Program Index
12		Continue Go To Index
13		{BRANCH \A}{BRANCH Index}~
14		
15		
16	Index	{goto}BA100~
17		{?}~
18		{goto}BA120~
19		{?}~
20		{goto}Ba140~
21		{?}~
22		{MENUBRANCH Menu3}~
23		
24		
25	\X	/PPOS/015~
26		MR%~MR220~
27		QRA100..I122~
28		GQ~
29		/PPRI100..S122~
30		GQ~
31		{quit}~