Title: Capital Budgeting: A Multiperiod IP Model

Course: EMGT 540/640
Term: Winter
Year: 1998
Author(s): E. Kalay, A. Narkiewicz, V. Pipugsmoot, S. Saengsin and C. Volz

Report No: P98005

Abstract: Presents a linear programming approach to optimize capital budget portfolio selection under conditions of certainty for a silicon wafer manufacturer. Explores some options for goal programming to meet financial targets.

Capital Budgeting: A Multiperiod IP Model

P Kalay A Narkiewicz V Pipugsmoot
S Saengsin C Volz

EMP-P9805

CAPITAL BUDGETING:
A MULTIPERIOD IP MODEL

TERM PROJECT

Submitted in Partial Fulfillment

of the Requirements for:

Operations Research in
Engineering Management

Timothy R. Anderson, Ph.D.

EMGT 540 / 640

WINTER TERM 1998

ENGINEERING MANAGEMENT PROGRAM

PORTLAND STATE UNIVERSITY

Submitted by:

P. Elgay Kalay

Andrew Narkiewicz

Vivat Pipugsmoot

Suphakit Saengsin

Craig Volz

3/11/98

TABLE OF CONTENTS

ABSTRACT

This paper presents a linear programming approach to optimize capital budget portfolio selection under conditions of certainty for a silicon wafer manufacturer. Mitsubishi Silicon America is a manufacturer of silicon wafers serving customers in the semiconductor industry. Due to the complexity and lack of analytical tools, historically the capital planning process has been based on maximizing production capacity. What is currently desired given today's market conditions is to maximize profits for the period 1998-2002. The model is designed to optimize after tax profits over a five year planning horizon. Some options for goal programming to meet financial targets will be explored.

EXECUTIVE SUMMARY

METHODS

A PC based linear programming model was used to optimize the selection of a capital projects portfolio for Mitsubishi Silicon America, a silicon wafer manufacturer. The model used a five year planning horizon, and evaluated 90 projects based on their net present value (NPV). The stated goal was to maximize the benefits (NPV) of the projects selected, given the budgetary constraints of capital rationing and positive quarterly cash flow.

RESULTS

Solution of the LP optimization model resulted in the following improvements:

- Achieved 98 percent of the total possible benefits (NPV) from all projects
- Reduced the number of projects by 25 percent (from 90 to 68).
- Reduced total capital expenditures by 23 percent.

RECOMMENDATIONS

1) Implement NPV evaluation and LP optimization as standard tools for capital planning decisions.
2) Investigate Hierarchical Decision Modeling (HDM) techniques to more closely link the capital project selection process with business objectives and goals. HDM is a technique used to quantify an individual project's contribution to the missions, goals, objectives, and strategies of the organization.

I - INTRODUCTION

Mitsubishi Silicon America is a manufacturer of silicon wafers serving customers in the semiconductor industry. The company and the semiconductor industry have experienced rapid growth in the past six years. This explosive growth fueled major capital investments in new equipment and manufacturing facilities. While the growth outlook remains positive, changes in the Asian economies and excess worldwide capacity resulting from the prior industry wide expansion has somewhat moderated the short term growth prospects. In this new climate of cautious growth, severe price pressures and product quality play a key role in future capital investment strategies.

The previous six year industry wide boom was characterized by high demand, insufficient capacity and high prices. During this period MSA's capital planning strategy was based on simply maximizing production capacity. In today's market with reduced demand, over capacity and lower prices the margin of error is greatly reduced, and the negative impact of less than optimal decisions is magnified. The previous strategy of maximizing production capacity no longer yields the desired results.

A freeze on capital investments, while possibly desirable in the short term, is clearly not a viable alternative in the dynamic "grow or die" semiconductor industry since no growth results in loss of market share. Indeed, a significant minimum level of growth is necessary in order to retain current market share. The capital investment strategy must address the development of new products and lay out an orderly strategy for future

capacity expansion. In today's more competitive market, product quality improvements and manufacturing cost reductions are critical to short term profitability. A new, more comprehensive model is needed to evaluate and select the optimal mix of projects that will enhance short term profitability and position MSA for future sales growth due to new products and increased capacity. This model should select the optimum portfolio of capital projects in order to maximize after tax profits over a five year planning horizon.

II - PROBLEM DEFINITION

Silicon wafer manufacturing is very capital intensive involving numerous processing steps. Only ultrapure water and chemicals are allowed to contact the wafer, and processing is done in a cleanroom environment. Although there are hundreds of part numbers for different individual customer specifications Mitsubishi Silicon America manufactures two main types of wafers in four different diameters ranging from 100 mm to 200 mm. The first type is a polished wafer, and the second is an epitaxial wafer.

The major processing steps include crystal growing, slicing, etching, polishing, and inspection. In crystal growing the raw polysilicon material is melted in a controlled atmosphere along with dopant material added to achieve the desired electrical properties. The crystal is grown by dipping a rotating seed crystal with the desired crystal orientation into the melt and slowly pulling it out while it rotates. In slicing the crystal ingots are sliced into wafers in specialized saws, and are then lapped for flatness. Etching removes the mechanical damage to the crystalline structure resulting from the slicing and lapping processes. After etching, the wafers are polished in a multi-step process. The wafers are then inspected for flatness, electrical properties, and visual defects and packaged for shipment. Another process called epitaxy, uses the polished wafer as a substrate and deposits a uniform layer of silicon oxide on the wafer surface in a high temperature reactor with a controlled atmosphere. Depending on the size and type, wafers are manufactured at one of three sites. As capital investment plans are formulated, it is important to balance capacities between the

the different processes in the various manufacturing facilities in order to remove production bottlenecks and maximize return on capital investment.

There are numerous inputs that must be considered in the capital budgeting process. The marketing and sales forecast includes overall silicon market conditions, annual sales projections, and pricing information. The marketing and sales forecast is used by production planning to develop a production plan supporting the current year's sales forecast based on existing capability and planned improvements. Manufacturing develops a detailed manufacturing plan. The capital budget is then developed to support the sales, production, and manufacturing plans. In current practice, this is typically an iterative process using spreadsheets as the principal analytical tool. Each input is outlined below.

Marketing and Sales Forecast

- Projected quarterly sales for each wafer type and size.
- Average selling price in dollars per square inch for each wafer type and size.
- Projected quarterly sales in thousands of wafers for each wafer type and size.
- Quarterly revenue forecast in dollars for each wafer type and size.

Production Forecast

- Current production capacity for each wafer type per week for each of three sites.
- Weekly production plan for number of wafers of each size and type to be produced at each site.
- Average production cost in dollars for each wafer type and size.

II - PROBLEM DEFINITION

Capital Projects Portfolio

- For each project: project interdependencies; capital expense cash flow; and capacity increase by wafer type and size.
- Quarterly capital budget.
- Current capital investment in millions of dollars for each manufacturing site.
- Current debt in millions of dollars for each manufacturing site.

III - LITERATURE REVIEW

Wafer Market

The semiconductor boom years of the early 1980's drew many entrants into the silicon market. It was not until 1993 that demand caught up with supply. MEMC, a leading wafer supplier reported 12 consecutive quarters of sold out capacity from mid 1993 to mid 1996. This strong demand for wafers led to another wave of expansion in response to the market beginning in 1994. Typically it takes one to two years to add capacity [9]. The latest expansions have resulted in the current worldwide over capacity of silicon wafers. Once again wafer manufacturers with excess capacity are waiting for market demand to grow.

Manufacturer's of wafer fab equipment expect the current market downturn for 1997-98 to be gentler than in the past. That was the good news emerging from Dataquest's Semicon West seminar, where analysts presided over a wide ranging discussion of forecasts and trends affecting the semiconductor market over the next three to five years. Among the topics discussed were capital spending forecasts, dynamics that could create demand cycles and projected worldwide semiconductor device consumption. The analyst's prediction that the current downturn will be shorter in duration and shallower came from Clark J. Fuhs [13]. Addressing the idea that the market could not continue to expand at the current high rate, he noted that history shows downturns are inevitable. However, the up curve in this cycle has lasted longer than in the past because the demand for semiconductors has become more diverse and is spread over a broader range of products. Fuhs concluded that the silicon cycle

has been modified because only one of the three factors necessary for a slump is present: 1) DRAM business cycle; 2) decline in PC unit shipments; and 3) slowdown in electronic equipment sales. The first factor, DRAM business cycle, is currently present, and new reports indicate that the second factor, declining PC shipments, is beginning to appear. In the past two downturns, the existence of all three factors triggered a buildup in semiconductor inventories. The DRAM cycle occurs as wafer fabs transition to the next bit level density, creating a glut of older chips. Most fabs today are producing 16-Mbit DRAMs. The DRAM cycle typically occurs every four to five years, although the last 4-Mbit cycle lasted seven years, contributing to the long boom period. Fuhs predicted that the worldwide wafer fab equipment market would slow, and then shrink in 1997, with expansion beginning again in mid 1999 [3].

Unit volume growth of pure silicon area has occurred every year over the past four decades, and will continue. DRAM bits have grown 75 percent compounded over the past fifteen years and will likely continue. There is more DRAM penetration in PCs today, and digital video disk (DVD) as well as advances in direct broadcast satellite, networks, and two-way paging are expected to sustain the DRAM demand. Given the short term uncertainties, silicon suppliers are proceeding cautiously in expanding capacity. Most suppliers are trying to keep investment rates at a slower rate than the market growth projections. Revenue per square inch has grown dramatically, but the current economic crisis in Asia has resulted in sharp price reductions. Announced

capacity expansions by major suppliers should increase supply at an 11 percent growth rate, while demand is expected to grow at 13 percent as the industry reaches $300 to $325 billion by the year 2000 [15].

Budget Planning

Capital budgeting is a four stage process: 1) Identify investment opportunities; 2) Develop the initial idea into a specific proposal; 3) Selection of projects; and 4) Monitoring to assess forecast accuracy. Financial theory for selecting capital projects is well established [17]. Many articles advance the argument that discounted cash flow (DCF) models capture the true economic value of long term investments. Surveys of current practice demonstrate that DCF models are the primary decision tool models used for conventional capital budgeting decisions [16] and for high technology investments [18].

Surveys of practicing managers indicate that many are not satisfied with these time value approaches because of the lack of a formal link between capital budgeting decisions and organizational strategy [16]. Many times there are non-financial and qualitative factors relating to capital investment decisions that are not considered within the limited framework of the DCF model. These factors involve evaluation of the capital investment alternatives in terms of their individual contributions to the strategies that the company has developed in order to meet business goals and objectives. While it is important to evaluate the financial return of projects, in some situations a broader

perspective may be needed. For example, a company may have the objective of becoming a technology leader. While this may be a critical decision for the company's future, the NVP for an investment in an R&D project may not be as great as for a project that increases production capacity. Other examples could include objectives to increase market share, possibly at the expense of profit margins; or to achieve certain environmental goals to demonstrate corporate citizenship and responsibility. This is really analogous to the difference between expected monetary value (EMV) and utility. DCF like EMV bases decision making strictly on monetary value, while utility can account for other factors such as risk and multiple criteria.

An approach which incorporates this broader perspective linking project selection to the mission, objectives, goals, and strategies of the organization is hierarchical decision modeling (HDM) [7] [20] [21]. The mission, goals, objectives, and strategies are explicitly stated. Then the relative contribution of each goal to the mission is determined by pairwise comparison. This process continues for the contribution of each strategy to the objectives, and so forth until the contribution of each project to the strategies has been defined. In this way the linkage between projects and strategies, objectives, goals, and mission is defined explicitly and quantifiably. Although beyond the scope of this project, HDM is a promising area for further study.

Contrasting practice with theory reveals a number of differences. This is most apparent in selection, which has been a primary focus of financial theory and is the most closely

examined aspect of business practice [6]. In contrast to theoretical assumptions, many projects are rejected during preselection stages for noneconomic considerations such as risk, alignment with business strategies, or because of corporate politics [14]. Also, since the role of the finance department is relatively minor at this stage, it is likely, given the problems most firms have with incremental costing, that some projects are mistakenly rejected because of misallocated costs [4] [13]. Evidence suggests that firms may not always use cash flows, and when they do many times components are overlooked in developing the cash flows. In selection, where evidence is most complete, contradictions abound. They include the following: 1) DCF is the rule rather than the exception, however business has chosen internal rate of return (IRR) over the preferred net present value method (NPV); 2) Payback period is still widely used; 3) Capital rationing is common place although at odds with financial market equilibrium theories. Linear programming, the theoretical prescription for optimization under capital constraints is used infrequently; 4) Firms use the cost of capital with differing definitions; and 5) Firms change the required payback period in lieu of risk analysis.

Linear Programming

Linear programming methods can be used to determine the optimum capital project portfolio under conditions of capital rationing [19]. The major steps include: 1) Formulate the problem specifying input parameters, decision variables, the objective function, and all relevant constraint equations; 2) Solve the problem using a computer

software application using the appropriate solver for the model; 3) Interpret the economic impact of the optimal solution; and 4) Perform a sensitivity analysis to obtain additional insights.

IV - ANALYSIS

Net Present Value

Net present value (NPV) offers an absolute measure of a project's worth compared to the relative measures provided by internal rate of return (IRR) and profitability index (PI) and is a much better indicator in order to maximize shareholder wealth. NPV is defined as:

$$\sum_{t=0}^{n} \frac{S_t}{(1+k)^t} - \sum_{t=0}^{n} \frac{A_t}{(1+k)^t}$$

$S_t \equiv$ cash inflow in period t

$A_t \equiv$ cash outflow in period t

$n \equiv$ useful life of the project

$k \equiv$ firm's required rate of return

It is a relatively straight forward procedure to determine the periodic cash outflows for each project. The cash inflows are more difficult to calculate. If the project in question adds additional capacity beyond market demand, or if a production bottleneck elsewhere is constraining the production capacity, then the portion of the project that contributes to excess capacity will not realize any benefits until another project eliminates the bottleneck, or market demand increases. The goal is to maximize the net present value of the capital project portfolio while satisfying the financial and logistical constraints. This goal can be summarized mathematically as follows:

IV - ANALYSIS

$$\text{maximize NPV} = \sum_{t=1}^{T} \sum_{i=1}^{N} b_i X_i \qquad \text{subject to } \sum_{i=1}^{N} C_{it} X_i \le K_t \quad t = 1, 2, \ldots, T$$

$X_i \equiv$ percent of project i that is accepted, $X_i \le 1$

$b_i \equiv$ net present value of project i over its useful life

$C_{it} \equiv$ cash outflow required by project i in period t

$K_t \equiv$ budget availability in period t

$N \equiv$ number of projects under evaluation

In our example, Mitsubishi Silicon America (MSA) wishes to evaluate 90 capital projects over a five year planning period. The objective function to be maximized is the net present value of the projects selected over the next five years. The objective function includes the additional profit resulting from the projects which is in addition to profits from existing operations. Project expenditures are included in the quarter in which they occur. Operational improvements resulting from the projects are also included in the quarter in which they occur, and continue in subsequent quarters. In the proposed model project cashflows are assumed at the beginning of the quarter, and project benefits begin to accrue in the beginning of the quarter following project completion. The interest rate used for the NPV analysis is 5 percent. Assumed conditions include capital rationing, and a further constraint that all quarterly cashflows must be positive. In order to determine the optimum selection of projects that maximizes NPV andsatisfies the constraints, the quarterly cash outflows and the NPV for each of the 90 projects will be determined for each of the 20 quarterly periods in the five year plan.

IV - ANALYSIS

Variable Project Start

Time shifting of projects will not be included in this model for several reasons. Many projects must be completed by fixed dates in order to meet sales commitments, development schedules, and other logistical constraints. It is a relatively simple matter to accommodate variable start times for a project. Simply define a new project that is the same as the original, except cashflows start in a different period with a different NPV. Theoretically, each one of the 90 projects could be expanded to create 20 new projects starting in each of the 20 quarters. The effort to compute the new NPV's is not too burdensome, however the number of additional constraints, and decision variables for 90 x 20 = 1800 projects is certainly beyond the capabilities of the student version of the LP software. A more practical approach would be to identify several projects that could shift within a specified time frame, and create new time shifted options for only those projects in that specific time window.

Project Relationships

There are many types of project dependencies. Some of the more common ones include: 1) Mutual exclusivity; 2) Prerequisite; and 3) Complementary. Mutually exclusive projects are defined as a set of projects where the acceptance of one project in the set precludes the acceptance of any other project in the set. Only one of the mutually exclusive projects may be selected. Prerequisite projects are two or more projects where the acceptance of one project is dependent on, or necessitates the

acceptance of another project or projects. Complementary projects have a synergistic relationship in that the combination results in a greater (or lesser) benefit than the sum of the individual benefits. One example of this was mentioned previously in the discussion on NPV. A project may provide a capacity increase that cannot be completely realized until another project eliminates a production constraining bottleneck. The combined benefit of a composite project merging the two separate projects would exceed the sum of the individual benefits of the two projects. As part of our model the project relationships will be defined for all 90 projects under evaluation.

Goal Programming

Under the scenario of capital rationing, and when operating revenues are used to fund capital expansion without incurring additional debt, it is necessary to maintain a positive cash flow for all periods. In addition to the *economic* or *hard constraints* of positive cash flow and available capital budget, it is desirable to make progress toward some *goals* or *soft constraints* in the form of the following financial ratios:

Debt : Annual Sales $\leq$ 2

Sales : Capital Investment $\geq$ 0.8

The goal constraints can be used to represent managerial policies and desired levels of various objectives. This can be accomplished using the technique of goal programming. In goal programming the hard constraints are treated the same as the constraints in a typical LP, requiring slack variables. The goal constraints are specified

as equalities containing two deviational variables d_i^+ and d_i^-, indicating the extent to which the desired goal is either overachieved or underachieved. One of the deviational variables will be zero and the other equal to the deviation from the goal level. If the goal is met exactly, then both deviational variables will equal zero. To define the objective function in a goal programming model the following must be specified:

1) Priority level of the goals to be optimized (ordinal)
2) Relative weight assigned to each goal (if same priority level)
3) Deviational goal to be penalized for each goal:

Achieve minimum level	minimize d^-
Do not exceed specified level	minimize d^+
Come as close as possible	minimize $(d^+ + d^-)$
Maximize goal level	minimize $(d^- - d^+)$
Minimize goal level	minimize $(d^+ - d^-)$

Typically goal programming is an iterative process. First the goals on priority one are optimized, then priority two, and so forth reducing the feasible region as each level of goal is optimized. The high priority goals should be stated in terms of achieving minimum levels or not exceeding maximum levels. If a higher priority goal is maximized or minimized, it will drive the solution to a single point in the feasible region and lower priority goals will not be considered. Maximization or minimization should be reserved for low priority levels, after the higher priority goals have been achieved. Although not part of this model, goal programming should be considered for future refinement of the model.

V - MODEL

Definitions

b_{it} ≡ the net cash inflow generated by project i in period t

C_{it} ≡ the cash outflow required for project i in period t

D_0 ≡ dollar amount of long-term debt outstanding at time zero

D_t ≡ dollar amount of long-term debt acquired in period t

A_0 ≡ dollar amount of capital assets at time zero

A_t ≡ dollar amount of capital assets acquired in period t

K_t ≡ the cash available for capital investment in period t

N ≡ number of projects under consideration

Decision Variables

Which of the 90 projects should be selected, and which should be rejected in order to stay within the capital budget available? The use of integer programming eliminates the possibility of accepting partial projects, and has the added benefit of simplifying the expression of the project dependency constraints. The decision variable X_i is defined below:

X_i ≡ acceptance of project i

$X_i = \{0,1\}$ $X_i = 1$ if project accepted, $X_i = 0$ if project rejected

Objective Function

Maximize the net present value of capital projects for the five year period 1998-2002.

$$\text{Max NVP} = \sum_{t=1}^{T} \sum_{i=1}^{N} b_{it} X_i \qquad \forall\ i = (1, .., 90)$$

V - MODEL

The objective function in algebraic form:

MAX - 0 X(2) + 599.402 X(3) + 129.5492 X(4) + 12.09756 X(5) + 147.2274 X(6)
- 0 X(7) + 129.0093 X(8) + 65.3647 X(9) + 512.0378 X(10) - 0 X(11) - 0 X(12)
- 0 X(13) + 241.3319 X(14) - 0 X(15) + 44.83365 X(16) + 55.04438 X(18)
+ 34.2509 X(19) - 0 X(20) + 256.6704 X(21) + 219.5717 X(22) + 183.4325 X(23)
- 0 X(24) - 0 X 25) - 0 X 26) - 0 X 27) - 0 X(28) + 219.5717 X(29) + 109.7859
X(30) + 384.2505 X(31) - 0 X(32) + 3.317073 X(33) - 0 X(34) + 1.073171 X(35)
+ .7804878 X(36) + .4390244 X(37) + .1463415 X(39) + 6.997679 X(41)
+ 6.997679 X(42) + 8.479951 X(43) - 0 X(44) - 0 X(45) + 1.268293 X(46)
+ .7317074 X(47) - 0 X(48) - 0 X(49) + 4.206636 X(50) + .2056784 X(51)
+ 7.011061 X(52) - 0 X(53) - 0 X(54) - 0 X(55) + .2926829 X(56) + 12.50381
X(57) + 9.622748 X(58) + 8.927321 X(59) + 8.231893 X(60) + 7.536464 X(61)
+ 6.877007 X(62) + 6.217549 X(63) - 0 X(64) - 0 X(65) + 1.95122 X(66)
+ .4878049 X(67) + .4878049 X(68) + .4878049 X(69) - 0 X(70) - 0 X(71)
+ 6.054415 X(72) + 6.054415 X(73) + 6.054415 X(74) + 6.054415 X(75)
+ 5.582783 X(76) + 5.111151 X(77) + 4.663914 X(78) + 4.216677 X(79)
+ 3.769439 X(80) + 3.322202 X(81) + 2.896961 X(82) + 2.471719 X(83)
+ 130.0827 X(84) + 121.3154 X(85) + 112.548 X(86) - 0 X(87) - 0 X(88)
+ 65 X(89) + 60 X(90)

Constraints

Hard

$\sum C_{it} X_i \leq K_t$ (CASHFLOW)

$\sum X_i \leq 1 \quad i \in M$ (MUTUALLY EXCLUSIVE PROJECTS)

$X_A \leq X_Z$ (PREREQUISITE PROJECTS)

$X_A + X_Z + X_{AZ} \leq 1$ (COMPLEMENTARY PROJECTS)

The algebraic expressions for the constraints are not included here due to space limitations, but can be found in Appendix A.

V - MODEL

Soft (Goals)

$\sum D_i / S \leq 2$ (DEBT : SALES RATIO)

$S / \sum A_i \geq 0.8$ (SALES : CAPITAL INVESTMENT RATIO)

If the model used the goal programming approach, we would set a minimum level of NPV to be achieved as priority level one (minimize d^-). The next iteration at priority level two would be to set the maximum upper limit on the debt to sales ratio (minimize d^+). In the final iteration at priority level three we would maximize the sales to capital investment ratio (minimize $d^- - d^+$).

VI - DATA

Data Import

Since the amount of data required for this model is large, a more convenient method than manually typing all the data into the LP program is desirable. Fortunately LINGO has the ability to interface with spreadsheets and can import and export data directly to and from the following spreadsheets:

- Excel 4.0 (worksheet only *.xls, no workbooks)
- Lotus 1-2-3 (*.wks, *.wk1, *.wk3, *.wk4)
- Symphony (*.wr1)
- Quattro Pro (*.wq1)

The @IMPORT function must be located in the DATA section of the model. The proper syntax is: @IMPORT (*drive:\path\filename, data range name*). The correct path must be specified, and it seems to work best if the data file is located in the LINGO directory. The corresponding range names must be defined within the spreadsheet. For more details please refer to the DATA section of the model in Appendix A.

Project Cashflows & NPV

The project quarterly cash outflows were entered in an Excel spreadsheet and the quarterly cash inflows were calculated, based on the incremental capacity increase in wafer production multiplied by the net profit per wafer. These calculations were performed for each of the 90 projects, over the 20 quarters, accounting for each of the (2) main wafer types and (4) sizes produced. Base and incremental production capac-

capacities were tabulated, and the NPV was calculated from the quarterly cashflows for each project. Copies of the project cashflow tables are on the following pages.

Project Relationships

The project inter-relationships were defined for each project and tabulated in the same Excel spreadsheet. However, the constraints were entered manually into the LINGO program. Copies of the project relationships tables are included following the cashflow tables.

Project Cash Flows

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	$741	0	34	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	$0	0	0	0	0	1	29	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	$599	0	0	0	0	0	0	0	8	5	5	5	5	5	5	5	5	5	3	0	0	0
4	$130	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0
5	$12	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	$147	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	$0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	$129	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	$65	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	$512	0	0	0	0	0	0	21	20	10	13	0	0	0	0	0	0	0	0	0	0	0
11	$0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	$0	0	1	0	0	0	0	0	0	0	9	39	39	39	0	0	0	0	0	0	0	0
13	$0	0	0	0	0	0	0	0	0	0	0	6	10	8	27	17	7	0	0	0	0	0
14	$241	0	0	0	0	0	0	0	0	0	0	0	0	44	15	0	15	15	0	0	0	0
15	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
16	$45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	34	0
17	$0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	$55	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	$34	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0
20	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	12	12	0	0
21	$257	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	$220	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
23	$183	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
24	$0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
25	$0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
26	$0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
27	$0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
28	$0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
29	$220	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
30	$110	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
31	$384	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
32	$0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
33	$3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
34	$0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
35	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
36	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
37	$0.4	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
38	$0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
39	$0.1	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
40	$0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	$8	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	$0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	$0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	$1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	$1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	39	20	20	0	0	0
49	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
50	$4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
51	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	0	0	0
52	$7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0
53	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	14	0

Project Cash Flows

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
54	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	6	0
55	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	21	0	24	0
56	$0.3	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	$13	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	$10	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	$9	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	$8	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
61	$8	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
62	$7	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
63	$6	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
64	$0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	$0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0
66	$2.0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	$0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	$0	0	0	0	0	0	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	$6	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
77	$5	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
78	$5	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
79	$4	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
80	$4	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
81	$3	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
82	$3	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
83	$2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
84	$130	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	$121	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	$113	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
87	$0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	$0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	$65	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	$60	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BUDGET ($)			$59.0	$61.4	$69.4	$78.2	$98.3	$94.0	$107.4	$113.9	$103.8	$111.2	$126.1	$131.0	$116.1	$123.7	$137.1	$143.0	$123.9	$132.3	$147.7	$154.5
PROJECT ($)			72	26	2	33	99	113	58	110	89	94	62	103	54	54	78	142	188	12	78	0

Project Relationships

PROJECT NO.	INDEPENDENT	MUTUALLY EXCLUSIVE	CONTINGENT	MANDATORY	COMPLEMENTARY
1	NO CONSTRAINTS				
2			(X2 >= X3 and X4)		
3			**X2 >= X3**		
4			**X2 >= X4**		
5	NO CONSTRAINTS				
6	NO CONSTRAINTS				
7			(X7 >= X8 and X9)		
8			**X7 >= X8**		
9			**X7 >= X9**		
10			**X10 = X11**		
11			**X11 = X3**		
12			(X12 >= X13 and X14 and X15)		
13			**X12 >= X13**		
14			**X13 >= X14**		
15			**X12 >= X15**		
16			**X15 >= X16**		
17				**X17 = 1**	
18			(X18 >= X19)		
19			**X18 >= X19**		
20			(X20 >= X50 and X51 and X52)		
21	NO CONSTRAINTS				
22	NO CONSTRAINTS				
23	NO CONSTRAINTS				
24			X24 = 1 IF X21+X22+X23 >= 2		
25			(X25 >= X26)		
26			**X25 >= X26**		
27			**X27 = X26**		
28			**X28 >= X26**		
29	NO CONSTRAINTS				
30	NO CONSTRAINTS				
31			(X32 >= X31)		
32			**X32 >= X31**		
33	NO CONSTRAINTS				
34			**X34 = 1 IF X26+X31 >= 1**		
35	NO CONSTRAINTS				
36	NO CONSTRAINTS				
37	NO CONSTRAINTS				
38				**X38 = 1**	
39	NO CONSTRAINTS				
40				**X40 = 1**	
41	NO CONSTRAINTS				
42	NO CONSTRAINTS				
43	NO CONSTRAINTS				
44	NO CONSTRAINTS				
45	NO CONSTRAINTS				
46			**X46 = 1 IF X41+X42 = 2**		

Project Relationships

PROJECT NO.	INDEPENDENT	MUTUALLY EXCLUSIVE	CONTINGENT	MANDATORY	COMPLEMENTARY
47	NO CONSTRAINTS				
48			X48 >= X49		
49			X49 >= X50		
50			X20 >= X50		
51			X20 >= X51		
52			X20 >= X52		
53			X53 >= X50		
54			X54 >= X51		
55			X55 >= X52		
56	NO CONSTRAINTS				
57	NO CONSTRAINTS				
58	NO CONSTRAINTS				
59	NO CONSTRAINTS				
60	NO CONSTRAINTS				
61	NO CONSTRAINTS				
62	NO CONSTRAINTS				
63	NO CONSTRAINTS				
64			X64 = 1 IF X57+ .. +X63 >= 2		
65			X65 = 1 IF X57+ .. +X63 >= 7		
66	NO CONSTRAINTS				
67	NO CONSTRAINTS				
68	NO CONSTRAINTS				
69	NO CONSTRAINTS				
70			X70 = 1 IF X57+ .. +X63 >= 2		
71			(X71 >= X72, .. , and X83)		
72			X71 >= X72		
73			X71 >= X73		
74			X71 >= X74		
75			X71 >= X75		
76			X71 >= X76		
77			X71 >= X77		
78			X71 >= X78		
79			X71 >= X79		
80			X71 >= X80		
81			X71 >= X81		
82			X71 >= X82		
80			X71 >= X83		
84	NO CONSTRAINTS				
85	NO CONSTRAINTS				
86	NO CONSTRAINTS				
87	NO CONSTRAINTS				
88	NO CONSTRAINTS				
89	NO CONSTRAINTS				
90	NO CONSTRAINTS				

VII - SOLUTION

Objective Function

After running the LINGO integer programming model the optimum solution was obtained. The value for the objective function, the sum of the NPV's for all selected projects, was **$ 4,653.37**. This is only slightly less than the total NPV of $ 4,735 for all possible projects.

Decision Variables

The following (22) projects, representing a combined NPV of $ 82, were rejected (i.e. the decision variable $X_i = 0$) based on the quarterly budget and project relationship constraints:

Reject: 43, 48, 49, 50, 53, 55, 56, 57, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, and 87

The remaining (68) projects accepted ($X_i = 1$) account for approximately 75 percent of the total number of projects, yet deliver over 98 percent of the total NPV. The projects accepted include:

Accept: 1 - 42, 44 - 47, 51, 52, 54, 58 - 71, 84 - 86, and 88 - 90

The projects accepted and rejected are summarized in spreadsheet format on the following two pages. For details of the LINGO solution please refer to Appendix B.

Accepted Projects

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	$741	0	34	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	$0	0	0	0	0	1	23	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	$599	0	0	0	0	0	0	0	8	5	5	5	5	5	5	5	5	5	3	0	0	0
4	$130	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0
5	$12	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	$147	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	$0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	$129	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	$65	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	$512	0	0	0	0	0	0	21	20	10	13	0	0	0	0	0	0	0	0	0	0	0
11	$0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	$0	0	1	0	0	0	0	0	0	0	9	18	18	18	0	0	0	0	0	0	0	0
13	$0	0	0	0	0	0	0	0	0	0	0	6	10	8	27	17	7	0	0	0	0	0
14	$241	0	0	0	0	0	0	0	0	0	0	0	0	44	15	0	15	15	0	0	0	0
15	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
16	$45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	34	0
17	$0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	$55	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	$34	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0
20	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	12	12	0	0
21	$257	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	$220	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
23	$183	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
24	$0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
25	$0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
26	$0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
27	$0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
28	$0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
29	$220	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
30	$110	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
31	$384	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
32	$0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
33	$3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
34	$0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
35	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
36	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
37	$0.4	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
38	$0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
39	$0.1	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
40	$0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	$0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	$0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	$1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	$1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	0	0	0
52	$7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0
54	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	6	0
58	$10	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	$9	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	$8	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
61	$8	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
62	$7	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
63	$6	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
64	$0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	$0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0
66	$2.0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	$0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	$0	0	0	0	0	0	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	$130	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	$121	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	$113	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
88	$0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	$65	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	$60	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BUDGET ($)			$59.0	$61.4	$69.4	$78.2	$98.3	$94.0	$107.4	$113.9	$103.8	$111.2	$126.1	$131.0	$116.1	$123.7	$137.1	$143.0	$123.9	$132.3	$147.7	$154.5
PROJECT ($)			58	26	2	33	97	85	52	103	82	87	55	96	47	22	39	74	120	12	40	0

Rejected Projects

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
43	$8	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	39	20	20	0	0	0
49	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
50	$4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
53	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	14	0
55	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	21	0	24	0
56	$0.3	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	$13	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	$6	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
77	$5	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
78	$5	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
79	$4	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
80	$4	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
81	$3	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
82	$3	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
83	$2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
87	$0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BUDGET ($)			$59.0	$61.4	$69.4	$78.2	$85.1	$94.0	$107.4	$113.9	$103.8	$111.2	$126.1	$131.0	$116.1	$123.7	$137.1	$143.0	$123.9	$132.3	$147.7	$154.5
PROJECT ($)			14	0	0	0	2	28	7	7	7	7	7	7	7	31	39	69	69	0	38	0

VII - SOLUTION

Budget Constraints

Below are the tabulated results of the capital budget for each quarter and the actual capital expenditures in that quarter for the optimized project portfolio. The budget constraints have been satisfied for all periods. This same information is shown previously in the Accepted Projects spreadsheet.

Quarter	Budget	Actual
Q1	$ 59.0	$ 58
Q2	61.4	26
Q3	69.4	2
Q4	78.2	33
Q5	98.3	97
Q6	94.0	85
Q7	107.4	52
Q8	113.9	103
Q9	103.8	82
Q10	111.2	87
Q11	126.1	55
Q12	131.0	96
Q13	116.1	47
Q14	123.7	22
Q15	137.1	39
Q16	143.0	74
Q17	123.9	120
Q18	132.3	12
Q19	147.7	40
Q20	154.5	0

VIII - CONCLUSION & RECOMMENDATIONS

Project Selection

The recommendation based on our analysis is for MSA to implement the optimal solution by proceeding with the (68) projects, thereby satisfying the capital budget constraints while maximizing the financial return from capital investment expenditures. The rejected projects should be put on hold, and reformulated or reevaluated as business conditions change.

Capital Planning Process

Realizing that most business decision environments are dynamic and subject to change, MSA should consider incorporating some form of NPV evaluation and optimization as part of their capital planning process. In the rapidly changing semiconductor industry, capital investment plans undergo continual change as new opportunities and challenges are encountered. A well documented, PC based model could provide valuable information for decision makers, as well as reduce the time required to revise the capital plan, or to evaluate multiple scenarios.

Model Refinements

There are several areas that suggest potential improvements for this model. The first, time shifting of projects has been discussed, and an approach outlined. Another refinement would be to carry forward the unused capital budget from prior quarters to be applied in later periods. This would help smooth the periodic cashflows and permit more projects to be accomplished. This could be accomplished by defining a variable

that represents the unused capital budget and then define the budget available in any period as the budget for that period plus any surplus carried forward. Goal programming has also been discussed as a way of including financial and managerial targets in the model. Goal programming combined with sensitivity analysis offers the potential for gaining many valuable insights into the impacts of various priorities and weightings on capital investment decisions.

Future Study

Some promising areas for future study include: 1) Non-linear programming methods in order to determine the NPV's for the individual projects; 2) Project risk assessment techniques; 3) Mathematical programming under conditions of risk; and 4) Hierarchical Decision Modeling. All of these areas have potential for improving decision making tools to better deal with the complexities of multi-criteria and risks associated with real world problems.

IX - REFERENCES

[1] A. Marks, *Business Journal - Portland*, vol. 13, no. 22, July 1996.

[2] R. Arrarwal, "Corporate use of sophisticated capital budgeting techniques: A strategic perspective and a critique of survey results", *Interfaces*, vol. 10, no. 2 April 1980.

[3] B. Hodess, Managing Director Montgomery Securities, "Will polysilicon supply slow semiconductor growth?", http://www.fsa.org, Aug. 1996

[4] R. Brealey, and S. Myers, *Principles of Corporate Finance*. New York: McGraw-Hill, 1984.

[5] E. Carter, "The behavioral theory of the firm and top-level corporate decisions", *Administrative Science Quarterly*, vol. 16, no. 4, Dec. 1971.

[6] G. Christy, "Capital budgeting: Current practices and their efficiency", Eugene: University of Oregon, 1966.

[7] M. Libertore, T. Monahan, and D. Stout, "Analytic hierarchy process for capital budgeting", *The Engineering Economist*, vol. 38, no. 1, Fall 1992.

[8] J. Emshoff, "Experience-generalized decision making: The next generation of management models", *Interfaces*, vol. 8, no. 4, Aug. 1978.

[9] Mitsubishi Materials Silicon, "About 12 inch silicon wafers", http://www.egg.or.jp/msil/english/msilhist5-e.html, Jan. 1996.

[10] S. Haka, L. Gordon, and G. Pinches "Sophisticated capital budgeting selection techniques and firm performance", *Accounting Review*, Oct. 1985.

[11] D. Istvan, "Capital expenditure decisions: How they are made in large corporations", *Bureau of Business Research*, Bloomington: Indiana University.

[12] T. Klammer, B. Koch, and N. Wilner, "Capital budgeting practices: A survey of corporate use", *Journal of Management Accounting Research*, 1991.

[13] S. Myers, "Notes on an expert system for capital budgeting", *Financial Management*, 1988.

IX - REFERENCES

[14] S. Myers, "Finance theory and finance strategy", *Interfaces*, vol. 14, no. 1, Jan. - Feb. 1984.

[15] R. Bruner, "Some fab plans taken off hold", *Electronic News*, vol. 43, no. 2177, July 1991.

[16] A. Sullivan, and K. Smith, "Capital budgeting practices for factory automation projects", *Working Paper #90-11-1*, Center for the Management of Manufacturing Enterprises, Krannert School of Management, Purdue University, Nov. 1990.

[17] J. Weston, and T. Copeland, "Managerial Finance", Hinsdale, II: Dryden Press, 1989.

[18] T. Klammer, B. Koch, and N. Wilner, "Justification of high technology capital investments", *The Engineering Economist*, vol. 39, no. 2, Winter 1993.

[19] J. Clark, T. Hindelang, and R. Pritchard, *Capital Budgeting: Planning and control of capital expenditures*, New Jersey: Prentice-Hall, 1984.

[20] D. Cleland, D. Kocaoglu, *Engineering Management*, New York: McGraw-Hill, 1981.

[21] D. Kocaoglu, "A participative approach to program evaluation", *IEEE Transactions on Engineering Management*, vol. EM-30, no. 3, Aug. 1983.

X - APPENDIX A

LINGO MODEL

```
MODEL:
! MITSUBISHI SILICON AMERICA - Capital Project Selection;

SETS:
! Set of 90 projects. Each project has the following attributes
CASH1 = cash outflow in quarter 1,
CASH2 = cash outflow in quarter 2,
... etc,
CASH20 = cash outflow in quarter 20,
NPV = net present value of the cash inflows for each of the 90 projects,
X(j) = Binary decision variable for project acceptance,
X(j) = 1 if project selected, X(j) = 0 if project rejected;

PROJ/1..90/:
CASH1, CASH2, CASH3, CASH4, CASH5, CASH6, CASH7, CASH8, CASH9, CASH10,
CASH11, CASH12, CASH13, CASH14, CASH15, CASH16, CASH17, CASH18, CASH19,
CASH20,
NPV, X;

ENDSETS

DATA:
! Import the project cash flows, and NPV's from Excel spreadsheet 540DATA.XLS
proper syntax, attribute = @IMPORT ( drive:\path\filename, data range name);

  CASH1 = @IMPORT ( C:\LINGO\540DATA.XLS, C_1);
  CASH2 = @IMPORT ( C:\LINGO\540DATA.XLS, C_2);
  CASH3 = @IMPORT ( C:\LINGO\540DATA.XLS, C_3);
  CASH4 = @IMPORT ( C:\LINGO\540DATA.XLS, C_4);
  CASH5 = @IMPORT ( C:\LINGO\540DATA.XLS, C_5);
  CASH6 = @IMPORT ( C:\LINGO\540DATA.XLS, C_6);
  CASH7 = @IMPORT ( C:\LINGO\540DATA.XLS, C_7);
  CASH8 = @IMPORT ( C:\LINGO\540DATA.XLS, C_8);
  CASH9 = @IMPORT ( C:\LINGO\540DATA.XLS, C_9);
CASH10 = @IMPORT ( C:\LINGO\540DATA.XLS, C_10);
CASH11 = @IMPORT ( C:\LINGO\540DATA.XLS, C_11);
CASH12 = @IMPORT ( C:\LINGO\540DATA.XLS, C_12);
CASH13 = @IMPORT ( C:\LINGO\540DATA.XLS, C_13);
CASH14 = @IMPORT ( C:\LINGO\540DATA.XLS, C_14);
CASH15 = @IMPORT ( C:\LINGO\540DATA.XLS, C_15);
CASH16 = @IMPORT ( C:\LINGO\540DATA.XLS, C_16);
CASH17 = @IMPORT ( C:\LINGO\540DATA.XLS, C_17);
CASH18 = @IMPORT ( C:\LINGO\540DATA.XLS, C_18);
CASH19 = @IMPORT ( C:\LINGO\540DATA.XLS, C_19);
CASH20 = @IMPORT ( C:\LINGO\540DATA.XLS, C_20);
NPV = @IMPORT ( C:\LINGO\540DATA.XLS, NPV);
```

X - APPENDIX A

LINGO MODEL

```
! Import the budget available for each quarter;
 AVAIL1 = @IMPORT ( C:\LINGO\540DATA.XLS, A_1);
 AVAIL2 = @IMPORT ( C:\LINGO\540DATA.XLS, A_2);
 AVAIL3 = @IMPORT ( C:\LINGO\540DATA.XLS, A_3);
 AVAIL4 = @IMPORT ( C:\LINGO\540DATA.XLS, A_4);
 AVAIL5 = @IMPORT ( C:\LINGO\540DATA.XLS, A_5);
 AVAIL6 = @IMPORT ( C:\LINGO\540DATA.XLS, A_6);
 AVAIL7 = @IMPORT ( C:\LINGO\540DATA.XLS, A_7);
 AVAIL8 = @IMPORT ( C:\LINGO\540DATA.XLS, A_8);
 AVAIL9 = @IMPORT ( C:\LINGO\540DATA.XLS, A_9);
AVAIL10 = @IMPORT ( C:\LINGO\540DATA.XLS, A_10);
AVAIL11 = @IMPORT ( C:\LINGO\540DATA.XLS, A_11);
AVAIL12 = @IMPORT ( C:\LINGO\540DATA.XLS, A_12);
AVAIL13 = @IMPORT ( C:\LINGO\540DATA.XLS, A_13);
AVAIL14 = @IMPORT ( C:\LINGO\540DATA.XLS, A_14);
AVAIL15 = @IMPORT ( C:\LINGO\540DATA.XLS, A_15);
AVAIL16 = @IMPORT ( C:\LINGO\540DATA.XLS, A_16);
AVAIL17 = @IMPORT ( C:\LINGO\540DATA.XLS, A_17);
AVAIL18 = @IMPORT ( C:\LINGO\540DATA.XLS, A_18);
AVAIL19 = @IMPORT ( C:\LINGO\540DATA.XLS, A_19);
AVAIL20 = @IMPORT ( C:\LINGO\540DATA.XLS, A_20);

ENDDATA

! OBJECTIVE FN - Maximize NPV for all projects accepted. Total NPV equals
sum of NPV(j) multiplied by the decision variable X(j) for all projects 1-90;

MAX = @SUM(PROJ: NPV * X);

! CONSTRAINTS - QUARTERLY CASHFLOW, The sum of all project cash flows in any
quarter C(i) can not exceed the capital budget available K(i) in that quarter,
X(j) x C(i) <= K(i);

@SUM( PROJ: CASH1 * X) <= AVAIL1;
@SUM( PROJ: CASH2 * X) <= AVAIL2;
@SUM( PROJ: CASH3 * X) <= AVAIL3;
@SUM( PROJ: CASH4 * X) <= AVAIL4;
@SUM( PROJ: CASH5 * X) <= AVAIL5;
@SUM( PROJ: CASH6 * X) <= AVAIL6;
@SUM( PROJ: CASH7 * X) <= AVAIL7;
@SUM( PROJ: CASH8 * X) <= AVAIL8;
@SUM( PROJ: CASH9 * X) <= AVAIL9;
@SUM( PROJ: CASH10 * X) <= AVAIL10;
@SUM( PROJ: CASH11 * X) <= AVAIL11;
@SUM( PROJ: CASH12 * X) <= AVAIL12;
@SUM( PROJ: CASH13 * X) <= AVAIL13;
@SUM( PROJ: CASH14 * X) <= AVAIL14;
@SUM( PROJ: CASH15 * X) <= AVAIL15;
@SUM( PROJ: CASH16 * X) <= AVAIL16;
@SUM( PROJ: CASH17 * X) <= AVAIL17;
@SUM( PROJ: CASH18 * X) <= AVAIL18;
@SUM( PROJ: CASH19 * X) <= AVAIL19;
@SUM( PROJ: CASH20 * X) <= AVAIL20;
```

X - APPENDIX A

LINGO MODEL

```
! CONSTRAINTS - PROJECT INTERDEPENDENCIES
Mandatory projects;
X(1)  = 1;
X(17) = 1;
X(38) = 1;
X(40) = 1;
! Prerequisite projects;
X(2) >= X(3);
X(2) >= X(4);
X(7) >= X(8);
X(11) >= X(10);
X(11) = X(3);
X(12) >= X(13);
X(13) >= X(14);
X(12) >= X(15);
X(15) >= X(16);
X(18) >= X(19);
X(25) >= X(26);
X(27) = X(26);
X(28) >= X(26);
X(32) >= X(31);
X(34) = X(31);
X(48) >= X(49);
X(49) >= X(50);
X(20) >= X(50);
X(20) >= X(51);
X(20) >= X(52);
X(53) >= X(50);
X(54) >= X(51);
X(71) >= X(72);
X(71) >= X(73);
X(71) >= X(74);
X(71) >= X(75);
X(71) >= X(76);
X(71) >= X(77);
X(71) >= X(78);
X(71) >= X(79);
X(71) >= X(80);
X(71) >= X(81);
X(71) >= X(82);
X(71) >= X(83);

! CONSTRAINT - BINARY DECISION VARIABLE;
@FOR( PROJ: @BIN( X));
END
```

X - APPENDIX A

LINGO MODEL

```
Rows=    55 Vars=    92 No. integer vars=    86 ( all are linear)
 Nonzeros=  1895 Constraint nonz=   207(   74 are +- 1) Density=0.370
 Smallest and largest elements in absolute value=  0.146341      599.402
 No. < :  20 No. =:   3 No. > :  31, Obj=MAX, GUBs <=  22
 Single cols=   6


MAX   - 0 X( 2) + 599.402 X( 3) + 129.5492 X( 4) + 12.09756 X( 5)
    + 147.2274 X( 6) - 0 X( 7) + 129.0093 X( 8) + 65.3647 X( 9)
    + 512.0378 X( 10) - 0 X( 11) - 0 X( 12) - 0 X( 13)
    + 241.3319 X( 14) - 0 X( 15) + 44.83365 X( 16) + 55.04438 X( 18)
    + 34.2509 X( 19) - 0 X( 20) + 256.6704 X( 21) + 219.5717 X( 22)
    + 183.4325 X( 23) - 0 X( 24) - 0 X( 25) - 0 X( 26) - 0 X( 27)
    - 0 X( 28) + 219.5717 X( 29) + 109.7859 X( 30) + 384.2505 X( 31)
    - 0 X( 32) + 3.317073 X( 33) - 0 X( 34) + 1.073171 X( 35)
    + .7804878 X( 36) + .4390244 X( 37) + .1463415 X( 39)
    + 6.997679 X( 41) + 6.997679 X( 42) + 8.479951 X( 43) - 0 X( 44)
    - 0 X( 45) + 1.268293 X( 46) + .7317074 X( 47) - 0 X( 48)
    - 0 X( 49) + 4.206636 X( 50) + .2056784 X( 51) + 7.011061 X( 52)
    - 0 X( 53) - 0 X( 54) - 0 X( 55) + .2926829 X( 56)
    + 12.50381 X( 57) + 9.622748 X( 58) + 8.927321 X( 59)
    + 8.231893 X( 60) + 7.536464 X( 61) + 6.877007 X( 62)
    + 6.217549 X( 63) - 0 X( 64) - 0 X( 65) + 1.95122 X( 66)
    + .4878049 X( 67) + .4878049 X( 68) + .4878049 X( 69) - 0 X( 70)
    - 0 X( 71) + 6.054415 X( 72) + 6.054415 X( 73) + 6.054415 X( 74)
    + 6.054415 X( 75) + 5.582783 X( 76) + 5.111151 X( 77)
    + 4.663914 X( 78) + 4.216677 X( 79) + 3.769439 X( 80)
    + 3.322202 X( 81) + 2.896961 X( 82) + 2.471719 X( 83)
    + 130.0827 X( 84) + 121.3154 X( 85) + 112.548 X( 86) - 0 X( 87)
    - 0 X( 88) + 65 X( 89) + 60 X( 90)
SUBJECT TO
2]  0 X( 2) + 0 X( 3) + 0 X( 4) + 6.04878 X( 5) + 0 X( 6)
    + 5.853659 X( 7) + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11)
    + .6829269 X( 12) + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16)
    + 0 X( 18) + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23)
    + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29)
    + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35)
    + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42)
    + 7.02439 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47)
    + 0 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53)
    + 0 X( 54) + 0 X( 55) + .1463415 X( 56) + 6.829268 X( 57)
    + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63)
    + 1.707317 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68)
    + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74)
    + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80)
    + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86)
    + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90) <=  15.70704
3]  0 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 9.756098 X( 6)
    + 6.04878 X( 7) + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11)
    + 0 X( 12) + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43)
```

X - APPENDIX A

LINGO MODEL

```
    + 1.853659 X( 44) + 0 X( 45) + 0 X( 46) + .7317074 X( 47)
    + 0 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53)
    + 0 X( 54) + 0 X( 55) + .1463415 X( 56) + 0 X( 57) + 0 X( 58)
    + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64)
    + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70)
    + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76)
    + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82)
    + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88)
    + 0 X( 89) + 0 X( 90) <=   54.18406
4]  0 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19) + 0 X( 20)
    + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24) + 0 X( 25) + 0 X( 26)
    + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30) + 0 X( 31) + 0 X( 32)
    + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36) + 0 X( 37) + 0 X( 39)
    + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44) + .9756098 X( 45)
    + 1.268293 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50)
    + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56)
    + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62)
    + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68)
    + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74)
    + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80)
    + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86)
    + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90) <=   69.38853
5]  1.219512 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 12.19512 X( 8) + 5.365854 X( 9) + 0 X( 10) + 0 X( 11)
    + 0 X( 12) + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 6.97561 X( 41) + 6.97561 X( 42)
    + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48)
    + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54)
    + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60)
    + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66)
    + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72)
    + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78)
    + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84)
    + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=   78.16841
6]  28.53658 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 0 X( 15) + 0 X( 16) + 17.07317 X( 18) + 0 X( 19)
    + 0 X( 20) + 7.756098 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50)
    + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56)
    + 0 X( 57) + 6.829268 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 1.95122 X( 66)
    + .4878049 X( 67) + .4878049 X( 68) + .4878049 X( 69)
    + 1.463415 X( 70) + 24.39024 X( 71) + 0 X( 72) + 0 X( 73)
    + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
```

X - APPENDIX A

LINGO MODEL

```
    + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83) + 5.073171 X( 84)
    + 0 X( 85) + 0 X( 86) + 1.658537 X( 87) + 0 X( 88)
    + 2.439024 X( 89) + 0 X( 90) <=  98.32298
 7] 12.09756 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 21.46342 X( 10) + 10.73171 X( 11)
    + 0 X( 12) + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50)
    + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56)
    + 0 X( 57) + 0 X( 58) + 6.829268 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67)
    + 0 X( 68) + 0 X( 69) + 0 X( 70) + 24.39024 X( 71)
    + 6.97561 X( 72) + 6.97561 X( 73) + 6.97561 X( 74)
    + 6.97561 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84)
    + 5.073171 X( 85) + 0 X( 86) + 0 X( 87) + 1.658537 X( 88)
    + 0 X( 89) + 2.439024 X( 90) <=  94.01739
 8] 0 X( 2) + 8.04878 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 20.4878 X( 10) + 0 X( 11) + 0 X( 12)
    + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19)
    + 0 X( 20) + 0 X( 21) + 7.707317 X( 22) + 0 X( 23)
    + 3.365854 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28)
    + 0 X( 29) + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34)
    + 0 X( 35) + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42)
    + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48)
    + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54)
    + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59)
    + 6.829268 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64)
    + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70)
    + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75)
    + 6.97561 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80)
    + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85)
    + 5.073171 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=  107.3519
 9] 0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 9.756098 X( 10) + 0 X( 11) + 0 X( 12)
    + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19)
    + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 13.7561 X( 25) + 25.17073 X( 26) + 3.268293 X( 27)
    + 5.853659 X( 28) + 3.170732 X( 29) + 5.073171 X( 30)
    + 11.41463 X( 31) + 5.853659 X( 32) + 3.317073 X( 33)
    + 1.219512 X( 34) + 1.073171 X( 35) + .7804878 X( 36)
    + .4390244 X( 37) + .1463415 X( 39) + 0 X( 41) + 0 X( 42)
    + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48)
    + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54)
    + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60)
    + 6.829268 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65)
    + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71)
    + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76)
    + 6.97561 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81)
    + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87)
```

X - APPENDIX A

LINGO MODEL

```
    + 0 X( 88) + 0 X( 89) + 0 X( 90) <=   113.4862
10]  0 X( 2) + 5.365854 X( 3) + 16.09756 X( 4) + 0 X( 5) + 0 X( 6)
    + 0 X( 7) + 0 X( 8) + 0 X( 9) + 12.92683 X( 10) + 0 X( 11)
    + 9.073171 X( 12) + 0 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16)
    + 0 X( 18) + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22)
    + 7.756098 X( 23) + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27)
    + 0 X( 28) + 0 X( 29) + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33)
    + 0 X( 34) + 0 X( 35) + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41)
    + 0 X( 42) + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47)
    + 0 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53)
    + 0 X( 54) + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59)
    + 0 X( 60) + 0 X( 61) + 6.829268 X( 62) + 0 X( 63) + 0 X( 64)
    + 24.39024 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69)
    + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75)
    + 0 X( 76) + 0 X( 77) + 6.97561 X( 78) + 0 X( 79) + 0 X( 80)
    + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86)
    + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90) <=   103.7787
11]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 39.02439 X( 12)
    + 6.04878 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 29.26829 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23)
    + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29)
    + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35)
    + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43)
    + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49)
    + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55)
    + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 6.829268 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66)
    + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72)
    + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78)
    + 6.97561 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83)
    + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89)
    + 0 X( 90) <=   111.1881
12]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 39.02439 X( 12)
    + 10.2439 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50)
    + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56)
    + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62)
    + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68)
    + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74)
    + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 6.97561 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84)
    + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=   126.0859
13]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 39.02439 X( 12)
    + 7.756098 X( 13) + 43.90244 X( 14) + 0 X( 15) + 0 X( 16)
    + 0 X( 18) + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23)
```

X - APPENDIX A

LINGO MODEL

```
    + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29)
    + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35)
    + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43)
    + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49)
    + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55)
    + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67)
    + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73)
    + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 0 X( 80) + 6.97561 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84)
    + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=  131.0467
14]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12)
    + 26.78049 X( 13) + 14.63415 X( 14) + 0 X( 15) + 0 X( 16)
    + 0 X( 18) + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23)
    + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29)
    + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35)
    + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43)
    + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49)
    + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55)
    + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67)
    + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73)
    + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 0 X( 80) + 0 X( 81) + 6.97561 X( 82) + 0 X( 83) + 0 X( 84)
    + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=  116.0576
15]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12)
    + 16.87805 X( 13) + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18)
    + 0 X( 19) + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 24.39024 X( 48) + 0 X( 49)
    + 0 X( 50) + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55)
    + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67)
    + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73)
    + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 0 X( 80) + 0 X( 81) + 0 X( 82) + 6.97561 X( 83) + 0 X( 84)
    + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90)
    <=  123.6873
16]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12)
    + 6.829268 X( 13) + 14.63415 X( 14) + 0 X( 15) + 0 X( 16)
    + 0 X( 18) + 0 X( 19) + 12.19512 X( 20) + 0 X( 21) + 0 X( 22)
    + 0 X( 23) + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28)
    + 0 X( 29) + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34)
    + 0 X( 35) + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42)
    + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47)
    + 39.02439 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52)
    + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58)
```

X - APPENDIX A

LINGO MODEL

```
    + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64)
    + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70)
    + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76)
    + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82)
    + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88)
    + 0 X( 89) + 0 X( 90) - AVAIL15 <=  0
17]  0 X( 2) + 5.365854 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 14.63415 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19)
    + 12.19512 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 19.5122 X( 48)
    + 8.780488 X( 49) + 8.780488 X( 50) + 11.60976 X( 51)
    + 20.14634 X( 52) + 10.2439 X( 53) + 9.902439 X( 54)
    + 21.21951 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59)
    + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65)
    + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71)
    + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77)
    + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83)
    + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89)
    + 0 X( 90) - AVAIL16 <=  0
18]  0 X( 2) + 2.682927 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 29.26829 X( 15) + 34.14634 X( 16) + 0 X( 18)
    + 0 X( 19) + 12.19512 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23)
    + 0 X( 24) + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29)
    + 0 X( 30) + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35)
    + 0 X( 36) + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43)
    + 0 X( 44) + 0 X( 45) + 0 X( 46) + 0 X( 47) + 19.5122 X( 48)
    + 8.780488 X( 49) + 8.780488 X( 50) + 11.60976 X( 51)
    + 20.14634 X( 52) + 10.2439 X( 53) + 9.902439 X( 54)
    + 21.21951 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59)
    + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65)
    + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71)
    + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77)
    + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83)
    + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89)
    + 0 X( 90) - AVAIL17 <=  0
19]  0 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19)
    + 12.19512 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24)
    + 0 X( 25) + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30)
    + 0 X( 31) + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36)
    + 0 X( 37) + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44)
    + 0 X( 45) + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50)
    + 0 X( 51) + 0 X( 52) + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56)
    + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62)
    + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68)
    + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74)
    + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80)
    + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86)
```

X - APPENDIX A

LINGO MODEL

```
    + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90) - AVAIL18 <=   0
20]  0 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 0 X( 15) + 34.14634 X( 16) + 0 X( 18) + 0 X( 19)
    + 0 X( 20) + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24) + 0 X( 25)
    + 0 X( 26) + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30) + 0 X( 31)
    + 0 X( 32) + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36) + 0 X( 37)
    + 0 X( 39) + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44) + 0 X( 45)
    + 0 X( 46) + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51)
    + 0 X( 52) + 13.65854 X( 53) + 5.609756 X( 54) + 24.14634 X( 55)
    + 0 X( 56) + 0 X( 57) + 0 X( 58) + 0 X( 59) + 0 X( 60) + 0 X( 61)
    + 0 X( 62) + 0 X( 63) + 0 X( 64) + 0 X( 65) + 0 X( 66) + 0 X( 67)
    + 0 X( 68) + 0 X( 69) + 0 X( 70) + 0 X( 71) + 0 X( 72) + 0 X( 73)
    + 0 X( 74) + 0 X( 75) + 0 X( 76) + 0 X( 77) + 0 X( 78) + 0 X( 79)
    + 0 X( 80) + 0 X( 81) + 0 X( 82) + 0 X( 83) + 0 X( 84) + 0 X( 85)
    + 0 X( 86) + 0 X( 87) + 0 X( 88) + 0 X( 89) + 0 X( 90) - AVAIL19
    <=   0
21]  0 X( 2) + 0 X( 3) + 0 X( 4) + 0 X( 5) + 0 X( 6) + 0 X( 7)
    + 0 X( 8) + 0 X( 9) + 0 X( 10) + 0 X( 11) + 0 X( 12) + 0 X( 13)
    + 0 X( 14) + 0 X( 15) + 0 X( 16) + 0 X( 18) + 0 X( 19) + 0 X( 20)
    + 0 X( 21) + 0 X( 22) + 0 X( 23) + 0 X( 24) + 0 X( 25) + 0 X( 26)
    + 0 X( 27) + 0 X( 28) + 0 X( 29) + 0 X( 30) + 0 X( 31) + 0 X( 32)
    + 0 X( 33) + 0 X( 34) + 0 X( 35) + 0 X( 36) + 0 X( 37) + 0 X( 39)
    + 0 X( 41) + 0 X( 42) + 0 X( 43) + 0 X( 44) + 0 X( 45) + 0 X( 46)
    + 0 X( 47) + 0 X( 48) + 0 X( 49) + 0 X( 50) + 0 X( 51) + 0 X( 52)
    + 0 X( 53) + 0 X( 54) + 0 X( 55) + 0 X( 56) + 0 X( 57) + 0 X( 58)
    + 0 X( 59) + 0 X( 60) + 0 X( 61) + 0 X( 62) + 0 X( 63) + 0 X( 64)
    + 0 X( 65) + 0 X( 66) + 0 X( 67) + 0 X( 68) + 0 X( 69) + 0 X( 70)
    + 0 X( 71) + 0 X( 72) + 0 X( 73) + 0 X( 74) + 0 X( 75) + 0 X( 76)
    + 0 X( 77) + 0 X( 78) + 0 X( 79) + 0 X( 80) + 0 X( 81) + 0 X( 82)
    + 0 X( 83) + 0 X( 84) + 0 X( 85) + 0 X( 86) + 0 X( 87) + 0 X( 88)
    + 0 X( 89) + 0 X( 90) - AVAIL20 <=   0
26]  X( 2) - X( 3) >=   0
27]  X( 2) - X( 4) >=   0
28]  X( 7) - X( 8) >=   0
29]- X( 10) + X( 11) >=   0
30]- X( 3) + X( 11) =    0
31]  X( 12) - X( 13) >=   0
32]  X( 13) - X( 14) >=   0
33]  X( 12) - X( 15) >=   0
34]  X( 15) - X( 16) >=   0
35]  X( 18) - X( 19) >=   0
36]  X( 25) - X( 26) >=   0
37]- X( 26) + X( 27) =    0
38]- X( 26) + X( 28) >=   0
39]- X( 31) + X( 32) >=   0
40]- X( 31) + X( 34) =    0
41]  X( 48) - X( 49) >=   0
42]  X( 49) - X( 50) >=   0
43]  X( 20) - X( 50) >=   0
44]  X( 20) - X( 51) >=   0
45]  X( 20) - X( 52) >=   0
46]- X( 50) + X( 53) >=   0
47]- X( 51) + X( 54) >=   0
```

X - APPENDIX A

LINGO MODEL

```
48]  X( 71) - X( 72) >=   0
49]  X( 71) - X( 73) >=   0
50]  X( 71) - X( 74) >=   0
51]  X( 71) - X( 75) >=   0
52]  X( 71) - X( 76) >=   0
53]  X( 71) - X( 77) >=   0
54]  X( 71) - X( 78) >=   0
55]  X( 71) - X( 79) >=   0
56]  X( 71) - X( 80) >=   0
57]  X( 71) - X( 81) >=   0
58]  X( 71) - X( 82) >=   0
59]  X( 71) - X( 83) >=   0
END
INTE X( 2)
INTE X( 3)
INTE X( 4)
INTE X( 5)
INTE X( 6)
INTE X( 7)
INTE X( 8)
INTE X( 9)
INTE X( 10)
INTE X( 11)
INTE X( 12)
INTE X( 13)
INTE X( 14)
INTE X( 15)
INTE X( 16)
INTE X( 18)
INTE X( 19)
INTE X( 20)
INTE X( 21)
INTE X( 22)
INTE X( 23)
INTE X( 24)
INTE X( 25)
INTE X( 26)
INTE X( 27)
INTE X( 28)
INTE X( 29)
INTE X( 30)
INTE X( 31)
INTE X( 32)
INTE X( 33)
INTE X( 34)
INTE X( 35)
INTE X( 36)
INTE X( 37)
INTE X( 39)
INTE X( 41)
INTE X( 42)
INTE X( 43)
INTE X( 44)
INTE X( 45)
```

X - APPENDIX A

LINGO MODEL

```
INTE X( 46)
INTE X( 47)
INTE X( 48)
INTE X( 49)
INTE X( 50)
INTE X( 51)
INTE X( 52)
INTE X( 53)
INTE X( 54)
INTE X( 55)
INTE X( 56)
INTE X( 57)
INTE X( 58)
INTE X( 59)
INTE X( 60)
INTE X( 61)
INTE X( 62)
INTE X( 63)
INTE X( 64)
INTE X( 65)
INTE X( 66)
INTE X( 67)
INTE X( 68)
INTE X( 69)
INTE X( 70)
INTE X( 71)
INTE X( 72)
INTE X( 73)
INTE X( 74)
INTE X( 75)
INTE X( 76)
INTE X( 77)
INTE X( 78)
INTE X( 79)
INTE X( 80)
INTE X( 81)
INTE X( 82)
INTE X( 83)
INTE X( 84)
INTE X( 85)
INTE X( 86)
INTE X( 87)
INTE X( 88)
INTE X( 89)
INTE X( 90)
```

X - APPENDIX B

LINGO SOLUTION

CASH16(54)	9.902439	0.0000000E+00
CASH16(55)	21.21951	0.0000000E+00
CASH16(56)	0.0000000E+00	0.0000000E+00
CASH16(57)	0.0000000E+00	0.0000000E+00
CASH16(58)	0.0000000E+00	0.0000000E+00
CASH16(59)	0.0000000E+00	0.0000000E+00
CASH16(60)	0.0000000E+00	0.0000000E+00
CASH16(61)	0.0000000E+00	0.0000000E+00
CASH16(62)	0.0000000E+00	0.0000000E+00
CASH16(63)	0.0000000E+00	0.0000000E+00
CASH16(64)	0.0000000E+00	0.0000000E+00
CASH16(65)	0.0000000E+00	0.0000000E+00
CASH16(66)	0.0000000E+00	0.0000000E+00
CASH16(67)	0.0000000E+00	0.0000000E+00
CASH16(68)	0.0000000E+00	0.0000000E+00
CASH16(69)	0.0000000E+00	0.0000000E+00
CASH16(70)	0.0000000E+00	0.0000000E+00
CASH16(71)	0.0000000E+00	0.0000000E+00
CASH16(72)	0.0000000E+00	0.0000000E+00
CASH16(73)	0.0000000E+00	0.0000000E+00
CASH16(74)	0.0000000E+00	0.0000000E+00
CASH16(75)	0.0000000E+00	0.0000000E+00
CASH16(76)	0.0000000E+00	0.0000000E+00
CASH16(77)	0.0000000E+00	0.0000000E+00
CASH16(78)	0.0000000E+00	0.0000000E+00
CASH16(79)	0.0000000E+00	0.0000000E+00
CASH16(80)	0.0000000E+00	0.0000000E+00
CASH16(81)	0.0000000E+00	0.0000000E+00
CASH16(82)	0.0000000E+00	0.0000000E+00
CASH16(83)	0.0000000E+00	0.0000000E+00
CASH16(84)	0.0000000E+00	0.0000000E+00
CASH16(85)	0.0000000E+00	0.0000000E+00
CASH16(86)	0.0000000E+00	0.0000000E+00
CASH16(87)	0.0000000E+00	0.0000000E+00
CASH16(88)	0.0000000E+00	0.0000000E+00
CASH16(89)	0.0000000E+00	0.0000000E+00
CASH16(90)	0.0000000E+00	0.0000000E+00
CASH17(1)	0.0000000E+00	0.0000000E+00
CASH17(2)	0.0000000E+00	0.0000000E+00
CASH17(3)	2.682927	0.0000000E+00
CASH17(4)	0.0000000E+00	0.0000000E+00
CASH17(5)	0.0000000E+00	0.0000000E+00
CASH17(6)	0.0000000E+00	0.0000000E+00
CASH17(7)	0.0000000E+00	0.0000000E+00
CASH17(8)	0.0000000E+00	0.0000000E+00
CASH17(9)	0.0000000E+00	0.0000000E+00
CASH17(10)	0.0000000E+00	0.0000000E+00
CASH17(11)	0.0000000E+00	0.0000000E+00
CASH17(12)	0.0000000E+00	0.0000000E+00
CASH17(13)	0.0000000E+00	0.0000000E+00
CASH17(14)	0.0000000E+00	0.0000000E+00
CASH17(15)	29.26829	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH17(16)	34.14634	0.0000000E+00
CASH17(17)	0.0000000E+00	0.0000000E+00
CASH17(18)	0.0000000E+00	0.0000000E+00
CASH17(19)	0.0000000E+00	0.0000000E+00
CASH17(20)	12.19512	0.0000000E+00
CASH17(21)	0.0000000E+00	0.0000000E+00
CASH17(22)	0.0000000E+00	0.0000000E+00
CASH17(23)	0.0000000E+00	0.0000000E+00
CASH17(24)	0.0000000E+00	0.0000000E+00
CASH17(25)	0.0000000E+00	0.0000000E+00
CASH17(26)	0.0000000E+00	0.0000000E+00
CASH17(27)	0.0000000E+00	0.0000000E+00
CASH17(28)	0.0000000E+00	0.0000000E+00
CASH17(29)	0.0000000E+00	0.0000000E+00
CASH17(30)	0.0000000E+00	0.0000000E+00
CASH17(31)	0.0000000E+00	0.0000000E+00
CASH17(32)	0.0000000E+00	0.0000000E+00
CASH17(33)	0.0000000E+00	0.0000000E+00
CASH17(34)	0.0000000E+00	0.0000000E+00
CASH17(35)	0.0000000E+00	0.0000000E+00
CASH17(36)	0.0000000E+00	0.0000000E+00
CASH17(37)	0.0000000E+00	0.0000000E+00
CASH17(38)	0.0000000E+00	0.0000000E+00
CASH17(39)	0.0000000E+00	0.0000000E+00
CASH17(40)	0.0000000E+00	0.0000000E+00
CASH17(41)	0.0000000E+00	0.0000000E+00
CASH17(42)	0.0000000E+00	0.0000000E+00
CASH17(43)	0.0000000E+00	0.0000000E+00
CASH17(44)	0.0000000E+00	0.0000000E+00
CASH17(45)	0.0000000E+00	0.0000000E+00
CASH17(46)	0.0000000E+00	0.0000000E+00
CASH17(47)	0.0000000E+00	0.0000000E+00
CASH17(48)	19.51220	0.0000000E+00
CASH17(49)	8.780488	0.0000000E+00
CASH17(50)	8.780488	0.0000000E+00
CASH17(51)	11.60976	0.0000000E+00
CASH17(52)	20.14634	0.0000000E+00
CASH17(53)	10.24390	0.0000000E+00
CASH17(54)	9.902439	0.0000000E+00
CASH17(55)	21.21951	0.0000000E+00
CASH17(56)	0.0000000E+00	0.0000000E+00
CASH17(57)	0.0000000E+00	0.0000000E+00
CASH17(58)	0.0000000E+00	0.0000000E+00
CASH17(59)	0.0000000E+00	0.0000000E+00
CASH17(60)	0.0000000E+00	0.0000000E+00
CASH17(61)	0.0000000E+00	0.0000000E+00
CASH17(62)	0.0000000E+00	0.0000000E+00
CASH17(63)	0.0000000E+00	0.0000000E+00
CASH17(64)	0.0000000E+00	0.0000000E+00
CASH17(65)	0.0000000E+00	0.0000000E+00
CASH17(66)	0.0000000E+00	0.0000000E+00
CASH17(67)	0.0000000E+00	0.0000000E+00
CASH17(68)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH17(69)	0.0000000E+00	0.0000000E+00
CASH17(70)	0.0000000E+00	0.0000000E+00
CASH17(71)	0.0000000E+00	0.0000000E+00
CASH17(72)	0.0000000E+00	0.0000000E+00
CASH17(73)	0.0000000E+00	0.0000000E+00
CASH17(74)	0.0000000E+00	0.0000000E+00
CASH17(75)	0.0000000E+00	0.0000000E+00
CASH17(76)	0.0000000E+00	0.0000000E+00
CASH17(77)	0.0000000E+00	0.0000000E+00
CASH17(78)	0.0000000E+00	0.0000000E+00
CASH17(79)	0.0000000E+00	0.0000000E+00
CASH17(80)	0.0000000E+00	0.0000000E+00
CASH17(81)	0.0000000E+00	0.0000000E+00
CASH17(82)	0.0000000E+00	0.0000000E+00
CASH17(83)	0.0000000E+00	0.0000000E+00
CASH17(84)	0.0000000E+00	0.0000000E+00
CASH17(85)	0.0000000E+00	0.0000000E+00
CASH17(86)	0.0000000E+00	0.0000000E+00
CASH17(87)	0.0000000E+00	0.0000000E+00
CASH17(88)	0.0000000E+00	0.0000000E+00
CASH17(89)	0.0000000E+00	0.0000000E+00
CASH17(90)	0.0000000E+00	0.0000000E+00
CASH18(1)	0.0000000E+00	0.0000000E+00
CASH18(2)	0.0000000E+00	0.0000000E+00
CASH18(3)	0.0000000E+00	0.0000000E+00
CASH18(4)	0.0000000E+00	0.0000000E+00
CASH18(5)	0.0000000E+00	0.0000000E+00
CASH18(6)	0.0000000E+00	0.0000000E+00
CASH18(7)	0.0000000E+00	0.0000000E+00
CASH18(8)	0.0000000E+00	0.0000000E+00
CASH18(9)	0.0000000E+00	0.0000000E+00
CASH18(10)	0.0000000E+00	0.0000000E+00
CASH18(11)	0.0000000E+00	0.0000000E+00
CASH18(12)	0.0000000E+00	0.0000000E+00
CASH18(13)	0.0000000E+00	0.0000000E+00
CASH18(14)	0.0000000E+00	0.0000000E+00
CASH18(15)	0.0000000E+00	0.0000000E+00
CASH18(16)	0.0000000E+00	0.0000000E+00
CASH18(17)	0.0000000E+00	0.0000000E+00
CASH18(18)	0.0000000E+00	0.0000000E+00
CASH18(19)	0.0000000E+00	0.0000000E+00
CASH18(20)	12.19512	0.0000000E+00
CASH18(21)	0.0000000E+00	0.0000000E+00
CASH18(22)	0.0000000E+00	0.0000000E+00
CASH18(23)	0.0000000E+00	0.0000000E+00
CASH18(24)	0.0000000E+00	0.0000000E+00
CASH18(25)	0.0000000E+00	0.0000000E+00
CASH18(26)	0.0000000E+00	0.0000000E+00
CASH18(27)	0.0000000E+00	0.0000000E+00
CASH18(28)	0.0000000E+00	0.0000000E+00
CASH18(29)	0.0000000E+00	0.0000000E+00
CASH18(30)	0.0000000E+00	0.0000000E+00
CASH18(31)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH18(32)	0.0000000E+00	0.0000000E+00
CASH18(33)	0.0000000E+00	0.0000000E+00
CASH18(34)	0.0000000E+00	0.0000000E+00
CASH18(35)	0.0000000E+00	0.0000000E+00
CASH18(36)	0.0000000E+00	0.0000000E+00
CASH18(37)	0.0000000E+00	0.0000000E+00
CASH18(38)	0.0000000E+00	0.0000000E+00
CASH18(39)	0.0000000E+00	0.0000000E+00
CASH18(40)	0.0000000E+00	0.0000000E+00
CASH18(41)	0.0000000E+00	0.0000000E+00
CASH18(42)	0.0000000E+00	0.0000000E+00
CASH18(43)	0.0000000E+00	0.0000000E+00
CASH18(44)	0.0000000E+00	0.0000000E+00
CASH18(45)	0.0000000E+00	0.0000000E+00
CASH18(46)	0.0000000E+00	0.0000000E+00
CASH18(47)	0.0000000E+00	0.0000000E+00
CASH18(48)	0.0000000E+00	0.0000000E+00
CASH18(49)	0.0000000E+00	0.0000000E+00
CASH18(50)	0.0000000E+00	0.0000000E+00
CASH18(51)	0.0000000E+00	0.0000000E+00
CASH18(52)	0.0000000E+00	0.0000000E+00
CASH18(53)	0.0000000E+00	0.0000000E+00
CASH18(54)	0.0000000E+00	0.0000000E+00
CASH18(55)	0.0000000E+00	0.0000000E+00
CASH18(56)	0.0000000E+00	0.0000000E+00
CASH18(57)	0.0000000E+00	0.0000000E+00
CASH18(58)	0.0000000E+00	0.0000000E+00
CASH18(59)	0.0000000E+00	0.0000000E+00
CASH18(60)	0.0000000E+00	0.0000000E+00
CASH18(61)	0.0000000E+00	0.0000000E+00
CASH18(62)	0.0000000E+00	0.0000000E+00
CASH18(63)	0.0000000E+00	0.0000000E+00
CASH18(64)	0.0000000E+00	0.0000000E+00
CASH18(65)	0.0000000E+00	0.0000000E+00
CASH18(66)	0.0000000E+00	0.0000000E+00
CASH18(67)	0.0000000E+00	0.0000000E+00
CASH18(68)	0.0000000E+00	0.0000000E+00
CASH18(69)	0.0000000E+00	0.0000000E+00
CASH18(70)	0.0000000E+00	0.0000000E+00
CASH18(71)	0.0000000E+00	0.0000000E+00
CASH18(72)	0.0000000E+00	0.0000000E+00
CASH18(73)	0.0000000E+00	0.0000000E+00
CASH18(74)	0.0000000E+00	0.0000000E+00
CASH18(75)	0.0000000E+00	0.0000000E+00
CASH18(76)	0.0000000E+00	0.0000000E+00
CASH18(77)	0.0000000E+00	0.0000000E+00
CASH18(78)	0.0000000E+00	0.0000000E+00
CASH18(79)	0.0000000E+00	0.0000000E+00
CASH18(80)	0.0000000E+00	0.0000000E+00
CASH18(81)	0.0000000E+00	0.0000000E+00
CASH18(82)	0.0000000E+00	0.0000000E+00
CASH18(83)	0.0000000E+00	0.0000000E+00
CASH18(84)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH18(85)	0.0000000E+00	0.0000000E+00
CASH18(86)	0.0000000E+00	0.0000000E+00
CASH18(87)	0.0000000E+00	0.0000000E+00
CASH18(88)	0.0000000E+00	0.0000000E+00
CASH18(89)	0.0000000E+00	0.0000000E+00
CASH18(90)	0.0000000E+00	0.0000000E+00
CASH19(1)	0.0000000E+00	0.0000000E+00
CASH19(2)	0.0000000E+00	0.0000000E+00
CASH19(3)	0.0000000E+00	0.0000000E+00
CASH19(4)	0.0000000E+00	0.0000000E+00
CASH19(5)	0.0000000E+00	0.0000000E+00
CASH19(6)	0.0000000E+00	0.0000000E+00
CASH19(7)	0.0000000E+00	0.0000000E+00
CASH19(8)	0.0000000E+00	0.0000000E+00
CASH19(9)	0.0000000E+00	0.0000000E+00
CASH19(10)	0.0000000E+00	0.0000000E+00
CASH19(11)	0.0000000E+00	0.0000000E+00
CASH19(12)	0.0000000E+00	0.0000000E+00
CASH19(13)	0.0000000E+00	0.0000000E+00
CASH19(14)	0.0000000E+00	0.0000000E+00
CASH19(15)	0.0000000E+00	0.0000000E+00
CASH19(16)	34.14634	0.0000000E+00
CASH19(17)	0.0000000E+00	0.0000000E+00
CASH19(18)	0.0000000E+00	0.0000000E+00
CASH19(19)	0.0000000E+00	0.0000000E+00
CASH19(20)	0.0000000E+00	0.0000000E+00
CASH19(21)	0.0000000E+00	0.0000000E+00
CASH19(22)	0.0000000E+00	0.0000000E+00
CASH19(23)	0.0000000E+00	0.0000000E+00
CASH19(24)	0.0000000E+00	0.0000000E+00
CASH19(25)	0.0000000E+00	0.0000000E+00
CASH19(26)	0.0000000E+00	0.0000000E+00
CASH19(27)	0.0000000E+00	0.0000000E+00
CASH19(28)	0.0000000E+00	0.0000000E+00
CASH19(29)	0.0000000E+00	0.0000000E+00
CASH19(30)	0.0000000E+00	0.0000000E+00
CASH19(31)	0.0000000E+00	0.0000000E+00
CASH19(32)	0.0000000E+00	0.0000000E+00
CASH19(33)	0.0000000E+00	0.0000000E+00
CASH19(34)	0.0000000E+00	0.0000000E+00
CASH19(35)	0.0000000E+00	0.0000000E+00
CASH19(36)	0.0000000E+00	0.0000000E+00
CASH19(37)	0.0000000E+00	0.0000000E+00
CASH19(38)	0.0000000E+00	0.0000000E+00
CASH19(39)	0.0000000E+00	0.0000000E+00
CASH19(40)	0.0000000E+00	0.0000000E+00
CASH19(41)	0.0000000E+00	0.0000000E+00
CASH19(42)	0.0000000E+00	0.0000000E+00
CASH19(43)	0.0000000E+00	0.0000000E+00
CASH19(44)	0.0000000E+00	0.0000000E+00
CASH19(45)	0.0000000E+00	0.0000000E+00
CASH19(46)	0.0000000E+00	0.0000000E+00
CASH19(47)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH19(48)	0.0000000E+00	0.0000000E+00
CASH19(49)	0.0000000E+00	0.0000000E+00
CASH19(50)	0.0000000E+00	0.0000000E+00
CASH19(51)	0.0000000E+00	0.0000000E+00
CASH19(52)	0.0000000E+00	0.0000000E+00
CASH19(53)	13.65854	0.0000000E+00
CASH19(54)	5.609756	0.0000000E+00
CASH19(55)	24.14634	0.0000000E+00
CASH19(56)	0.0000000E+00	0.0000000E+00
CASH19(57)	0.0000000E+00	0.0000000E+00
CASH19(58)	0.0000000E+00	0.0000000E+00
CASH19(59)	0.0000000E+00	0.0000000E+00
CASH19(60)	0.0000000E+00	0.0000000E+00
CASH19(61)	0.0000000E+00	0.0000000E+00
CASH19(62)	0.0000000E+00	0.0000000E+00
CASH19(63)	0.0000000E+00	0.0000000E+00
CASH19(64)	0.0000000E+00	0.0000000E+00
CASH19(65)	0.0000000E+00	0.0000000E+00
CASH19(66)	0.0000000E+00	0.0000000E+00
CASH19(67)	0.0000000E+00	0.0000000E+00
CASH19(68)	0.0000000E+00	0.0000000E+00
CASH19(69)	0.0000000E+00	0.0000000E+00
CASH19(70)	0.0000000E+00	0.0000000E+00
CASH19(71)	0.0000000E+00	0.0000000E+00
CASH19(72)	0.0000000E+00	0.0000000E+00
CASH19(73)	0.0000000E+00	0.0000000E+00
CASH19(74)	0.0000000E+00	0.0000000E+00
CASH19(75)	0.0000000E+00	0.0000000E+00
CASH19(76)	0.0000000E+00	0.0000000E+00
CASH19(77)	0.0000000E+00	0.0000000E+00
CASH19(78)	0.0000000E+00	0.0000000E+00
CASH19(79)	0.0000000E+00	0.0000000E+00
CASH19(80)	0.0000000E+00	0.0000000E+00
CASH19(81)	0.0000000E+00	0.0000000E+00
CASH19(82)	0.0000000E+00	0.0000000E+00
CASH19(83)	0.0000000E+00	0.0000000E+00
CASH19(84)	0.0000000E+00	0.0000000E+00
CASH19(85)	0.0000000E+00	0.0000000E+00
CASH19(86)	0.0000000E+00	0.0000000E+00
CASH19(87)	0.0000000E+00	0.0000000E+00
CASH19(88)	0.0000000E+00	0.0000000E+00
CASH19(89)	0.0000000E+00	0.0000000E+00
CASH19(90)	0.0000000E+00	0.0000000E+00
CASH20(1)	0.0000000E+00	0.0000000E+00
CASH20(2)	0.0000000E+00	0.0000000E+00
CASH20(3)	0.0000000E+00	0.0000000E+00
CASH20(4)	0.0000000E+00	0.0000000E+00
CASH20(5)	0.0000000E+00	0.0000000E+00
CASH20(6)	0.0000000E+00	0.0000000E+00
CASH20(7)	0.0000000E+00	0.0000000E+00
CASH20(8)	0.0000000E+00	0.0000000E+00
CASH20(9)	0.0000000E+00	0.0000000E+00
CASH20(10)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH20(11)	0.0000000E+00	0.0000000E+00
CASH20(12)	0.0000000E+00	0.0000000E+00
CASH20(13)	0.0000000E+00	0.0000000E+00
CASH20(14)	0.0000000E+00	0.0000000E+00
CASH20(15)	0.0000000E+00	0.0000000E+00
CASH20(16)	0.0000000E+00	0.0000000E+00
CASH20(17)	0.0000000E+00	0.0000000E+00
CASH20(18)	0.0000000E+00	0.0000000E+00
CASH20(19)	0.0000000E+00	0.0000000E+00
CASH20(20)	0.0000000E+00	0.0000000E+00
CASH20(21)	0.0000000E+00	0.0000000E+00
CASH20(22)	0.0000000E+00	0.0000000E+00
CASH20(23)	0.0000000E+00	0.0000000E+00
CASH20(24)	0.0000000E+00	0.0000000E+00
CASH20(25)	0.0000000E+00	0.0000000E+00
CASH20(26)	0.0000000E+00	0.0000000E+00
CASH20(27)	0.0000000E+00	0.0000000E+00
CASH20(28)	0.0000000E+00	0.0000000E+00
CASH20(29)	0.0000000E+00	0.0000000E+00
CASH20(30)	0.0000000E+00	0.0000000E+00
CASH20(31)	0.0000000E+00	0.0000000E+00
CASH20(32)	0.0000000E+00	0.0000000E+00
CASH20(33)	0.0000000E+00	0.0000000E+00
CASH20(34)	0.0000000E+00	0.0000000E+00
CASH20(35)	0.0000000E+00	0.0000000E+00
CASH20(36)	0.0000000E+00	0.0000000E+00
CASH20(37)	0.0000000E+00	0.0000000E+00
CASH20(38)	0.0000000E+00	0.0000000E+00
CASH20(39)	0.0000000E+00	0.0000000E+00
CASH20(40)	0.0000000E+00	0.0000000E+00
CASH20(41)	0.0000000E+00	0.0000000E+00
CASH20(42)	0.0000000E+00	0.0000000E+00
CASH20(43)	0.0000000E+00	0.0000000E+00
CASH20(44)	0.0000000E+00	0.0000000E+00
CASH20(45)	0.0000000E+00	0.0000000E+00
CASH20(46)	0.0000000E+00	0.0000000E+00
CASH20(47)	0.0000000E+00	0.0000000E+00
CASH20(48)	0.0000000E+00	0.0000000E+00
CASH20(49)	0.0000000E+00	0.0000000E+00
CASH20(50)	0.0000000E+00	0.0000000E+00
CASH20(51)	0.0000000E+00	0.0000000E+00
CASH20(52)	0.0000000E+00	0.0000000E+00
CASH20(53)	0.0000000E+00	0.0000000E+00
CASH20(54)	0.0000000E+00	0.0000000E+00
CASH20(55)	0.0000000E+00	0.0000000E+00
CASH20(56)	0.0000000E+00	0.0000000E+00
CASH20(57)	0.0000000E+00	0.0000000E+00
CASH20(58)	0.0000000E+00	0.0000000E+00
CASH20(59)	0.0000000E+00	0.0000000E+00
CASH20(60)	0.0000000E+00	0.0000000E+00
CASH20(61)	0.0000000E+00	0.0000000E+00
CASH20(62)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

CASH20(63)	0.0000000E+00	0.0000000E+00
CASH20(64)	0.0000000E+00	0.0000000E+00
CASH20(65)	0.0000000E+00	0.0000000E+00
CASH20(66)	0.0000000E+00	0.0000000E+00
CASH20(67)	0.0000000E+00	0.0000000E+00
CASH20(68)	0.0000000E+00	0.0000000E+00
CASH20(69)	0.0000000E+00	0.0000000E+00
CASH20(70)	0.0000000E+00	0.0000000E+00
CASH20(71)	0.0000000E+00	0.0000000E+00
CASH20(72)	0.0000000E+00	0.0000000E+00
CASH20(73)	0.0000000E+00	0.0000000E+00
CASH20(74)	0.0000000E+00	0.0000000E+00
CASH20(75)	0.0000000E+00	0.0000000E+00
CASH20(76)	0.0000000E+00	0.0000000E+00
CASH20(77)	0.0000000E+00	0.0000000E+00
CASH20(78)	0.0000000E+00	0.0000000E+00
CASH20(79)	0.0000000E+00	0.0000000E+00
CASH20(80)	0.0000000E+00	0.0000000E+00
CASH20(81)	0.0000000E+00	0.0000000E+00
CASH20(82)	0.0000000E+00	0.0000000E+00
CASH20(83)	0.0000000E+00	0.0000000E+00
CASH20(84)	0.0000000E+00	0.0000000E+00
CASH20(85)	0.0000000E+00	0.0000000E+00
CASH20(86)	0.0000000E+00	0.0000000E+00
CASH20(87)	0.0000000E+00	0.0000000E+00
CASH20(88)	0.0000000E+00	0.0000000E+00
CASH20(89)	0.0000000E+00	0.0000000E+00
CASH20(90)	0.0000000E+00	0.0000000E+00
NPV(1)	741.1916	0.0000000E+00
NPV(2)	0.0000000E+00	0.0000000E+00
NPV(3)	599.4020	0.0000000E+00
NPV(4)	129.5492	0.0000000E+00
NPV(5)	12.09756	0.0000000E+00
NPV(6)	147.2274	0.0000000E+00
NPV(7)	0.0000000E+00	0.0000000E+00
NPV(8)	129.0093	0.0000000E+00
NPV(9)	65.36470	0.0000000E+00
NPV(10)	512.0378	0.0000000E+00
NPV(11)	0.0000000E+00	0.0000000E+00
NPV(12)	0.0000000E+00	0.0000000E+00
NPV(13)	0.0000000E+00	0.0000000E+00
NPV(14)	241.3319	0.0000000E+00
NPV(15)	0.0000000E+00	0.0000000E+00
NPV(16)	44.83365	0.0000000E+00
NPV(17)	0.0000000E+00	0.0000000E+00
NPV(18)	55.04439	0.0000000E+00
NPV(19)	34.25090	0.0000000E+00
NPV(20)	0.0000000E+00	0.0000000E+00
NPV(21)	256.6704	0.0000000E+00
NPV(22)	219.5717	0.0000000E+00
NPV(23)	183.4325	0.0000000E+00
NPV(24)	0.0000000E+00	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

NPV(25)	0.0000000E+00	0.0000000E+00
NPV(26)	0.0000000E+00	0.0000000E+00
NPV(27)	0.0000000E+00	0.0000000E+00
NPV(28)	0.0000000E+00	0.0000000E+00
NPV(29)	219.5717	0.0000000E+00
NPV(30)	109.7859	0.0000000E+00
NPV(31)	384.2505	0.0000000E+00
NPV(32)	0.0000000E+00	0.0000000E+00
NPV(33)	3.317073	0.0000000E+00
NPV(34)	0.0000000E+00	0.0000000E+00
NPV(35)	1.073171	0.0000000E+00
NPV(36)	0.7804878	0.0000000E+00
NPV(37)	0.4390244	0.0000000E+00
NPV(38)	0.0000000E+00	0.0000000E+00
NPV(39)	0.1463415	0.0000000E+00
NPV(40)	0.0000000E+00	0.0000000E+00
NPV(41)	6.997679	0.0000000E+00
NPV(42)	6.997679	0.0000000E+00
NPV(43)	8.479951	0.0000000E+00
NPV(44)	0.0000000E+00	0.0000000E+00
NPV(45)	0.0000000E+00	0.0000000E+00
NPV(46)	1.268293	0.0000000E+00
NPV(47)	0.7317073	0.0000000E+00
NPV(48)	0.0000000E+00	0.0000000E+00
NPV(49)	0.0000000E+00	0.0000000E+00
NPV(50)	4.206637	0.0000000E+00
NPV(51)	0.2056784	0.0000000E+00
NPV(52)	7.011061	0.0000000E+00
NPV(53)	0.0000000E+00	0.0000000E+00
NPV(54)	0.0000000E+00	0.0000000E+00
NPV(55)	0.0000000E+00	0.0000000E+00
NPV(56)	0.2926829	0.0000000E+00
NPV(57)	12.50381	0.0000000E+00
NPV(58)	9.622748	0.0000000E+00
NPV(59)	8.927320	0.0000000E+00
NPV(60)	8.231892	0.0000000E+00
NPV(61)	7.536464	0.0000000E+00
NPV(62)	6.877007	0.0000000E+00
NPV(63)	6.217549	0.0000000E+00
NPV(64)	0.0000000E+00	0.0000000E+00
NPV(65)	0.0000000E+00	0.0000000E+00
NPV(66)	1.951220	0.0000000E+00
NPV(67)	0.4878049	0.0000000E+00
NPV(68)	0.4878049	0.0000000E+00
NPV(69)	0.4878049	0.0000000E+00
NPV(70)	0.0000000E+00	0.0000000E+00
NPV(71)	0.0000000E+00	0.0000000E+00
NPV(72)	6.054415	0.0000000E+00
NPV(73)	6.054415	0.0000000E+00
NPV(74)	6.054415	0.0000000E+00
NPV(75)	6.054415	0.0000000E+00
NPV(76)	5.582783	0.0000000E+00

X - APPENDIX B

LINGO SOLUTION

NPV(77)	5.111151	0.0000000E+00
NPV(78)	4.663914	0.0000000E+00
NPV(79)	4.216677	0.0000000E+00
NPV(80)	3.769440	0.0000000E+00
NPV(81)	3.322202	0.0000000E+00
NPV(82)	2.896960	0.0000000E+00
NPV(83)	2.471719	0.0000000E+00
NPV(84)	130.0828	0.0000000E+00
NPV(85)	121.3154	0.0000000E+00
NPV(86)	112.5480	0.0000000E+00
NPV(87)	0.0000000E+00	0.0000000E+00
NPV(88)	0.0000000E+00	0.0000000E+00
NPV(89)	65.00000	0.0000000E+00
NPV(90)	60.00000	0.0000000E+00
X(1)	1.000000	0.0000000E+00
X(2)	1.000000	-1184.736
X(3)	1.000000	0.0000000E+00
X(4)	1.000000	0.0000000E+00
X(5)	1.000000	0.0000000E+00
X(6)	1.000000	-147.2274
X(7)	1.000000	-116.5055
X(8)	1.000000	0.0000000E+00
X(9)	1.000000	-65.36470
X(10)	1.000000	0.0000000E+00
X(11)	1.000000	0.0000000E+00
X(12)	1.000000	-32.73609
X(13)	1.000000	0.0000000E+00
X(14)	1.000000	-241.3319
X(15)	1.000000	0.0000000E+00
X(16)	1.000000	0.0000000E+00
X(17)	1.000000	0.0000000E+00
X(18)	1.000000	-33.04278
X(19)	1.000000	0.0000000E+00
X(20)	1.000000	0.0000000E+00
X(21)	1.000000	-200.4179
X(22)	1.000000	-219.5717
X(23)	1.000000	-183.4325
X(24)	1.000000	0.0000000E+00
X(25)	1.000000	0.0000000E+00
X(26)	1.000000	0.0000000E+00
X(27)	1.000000	0.0000000E+00
X(28)	1.000000	0.0000000E+00
X(29)	1.000000	-219.5717
X(30)	1.000000	-109.7859
X(31)	1.000000	-384.2505
X(32)	1.000000	0.0000000E+00
X(33)	1.000000	-3.317073
X(34)	1.000000	0.0000000E+00
X(35)	1.000000	-1.073171
X(36)	1.000000	-0.7804878
X(37)	1.000000	-0.4390244
X(38)	1.000000	0.0000000E+00
X(39)	1.000000	-0.1463415

X - APPENDIX B

LINGO SOLUTION

X(40)	1.000000	0.0000000E+00
X(41)	1.000000	-6.997679
X(42)	1.000000	-6.997679
X(43)	0.0000000E+00	4.023856
X(44)	1.000000	0.0000000E+00
X(45)	1.000000	0.0000000E+00
X(46)	1.000000	-1.268293
X(47)	1.000000	-0.7317073
X(48)	0.0000000E+00	-4.206636
X(49)	0.0000000E+00	0.0000000E+00
X(50)	0.0000000E+00	0.0000000E+00
X(51)	1.000000	-0.2056784
X(52)	1.000000	-7.011061
X(53)	0.0000000E+00	0.0000000E+00
X(54)	1.000000	0.0000000E+00
X(55)	0.0000000E+00	0.0000000E+00
X(56)	0.0000000E+00	11.80488
X(57)	0.0000000E+00	0.0000000E+00
X(58)	1.000000	-9.622748
X(59)	1.000000	-8.927320
X(60)	1.000000	-8.231893
X(61)	1.000000	-7.536464
X(62)	1.000000	-6.877007
X(63)	1.000000	-6.217549
X(64)	0.0000000E+00	0.0000000E+00
X(65)	1.000000	0.0000000E+00
X(66)	1.000000	-1.951220
X(67)	1.000000	-0.4878049
X(68)	1.000000	-0.4878049
X(69)	1.000000	-0.4878049
X(70)	1.000000	0.0000000E+00
X(71)	0.0000000E+00	0.0000000E+00
X(72)	0.0000000E+00	0.0000000E+00
X(73)	0.0000000E+00	0.0000000E+00
X(74)	0.0000000E+00	0.0000000E+00
X(75)	0.0000000E+00	0.0000000E+00
X(76)	0.0000000E+00	0.0000000E+00
X(77)	0.0000000E+00	0.0000000E+00
X(78)	0.0000000E+00	0.0000000E+00
X(79)	0.0000000E+00	0.0000000E+00
X(80)	0.0000000E+00	0.0000000E+00
X(81)	0.0000000E+00	0.0000000E+00
X(82)	0.0000000E+00	0.0000000E+00
X(83)	0.0000000E+00	0.0000000E+00
X(84)	1.000000	-73.83025
X(85)	1.000000	-121.3154
X(86)	1.000000	-112.5480
X(87)	0.0000000E+00	0.0000000E+00
X(88)	1.000000	0.0000000E+00
X(89)	1.000000	-8.747494
X(90)	1.000000	-60.00000

X - APPENDIX B

LINGO SOLUTION

Row	Slack or Surplus	Dual Price
1	4653.365	1.000000
2	0.1770431E-01	0.0000000E+00
3	35.79381	0.0000000E+00
4	67.14463	0.0000000E+00
5	45.43670	0.0000000E+00
6	12.50183	0.0000000E+00
7	33.72470	0.0000000E+00
8	55.83974	0.0000000E+00
9	0.8518849	0.0000000E+00
10	0.0000000E+00	0.0000000E+00
11	24.65152	0.0000000E+00
12	71.45177	0.0000000E+00
13	34.99788	0.0000000E+00
14	69.27710	0.0000000E+00
15	101.4434	0.0000000E+00
16	98.03806	0.0000000E+00
17	69.11207	0.0000000E+00
18	3.980525	0.0000000E+00
19	120.1432	0.0000000E+00
20	107.9537	0.0000000E+00
21	154.5281	0.0000000E+00
22	0.0000000E+00	741.1916
23	0.0000000E+00	0.0000000E+00
24	0.0000000E+00	0.0000000E+00
25	0.0000000E+00	0.0000000E+00
26	0.0000000E+00	-1111.440
27	0.0000000E+00	-129.5492
28	0.0000000E+00	-129.0093
29	0.0000000E+00	-512.0378
30	0.0000000E+00	512.0378
31	0.0000000E+00	0.0000000E+00
32	0.0000000E+00	0.0000000E+00
33	0.0000000E+00	-44.83365
34	0.0000000E+00	-44.83365
35	0.0000000E+00	-34.25090
36	0.0000000E+00	0.0000000E+00
37	0.0000000E+00	0.0000000E+00
38	0.0000000E+00	0.0000000E+00
39	0.0000000E+00	0.0000000E+00
40	0.0000000E+00	0.0000000E+00
41	0.0000000E+00	-4.206636
42	0.0000000E+00	-4.206636
43	1.000000	0.0000000E+00
44	0.0000000E+00	0.0000000E+00
45	0.0000000E+00	0.0000000E+00
46	0.0000000E+00	0.0000000E+00
47	0.0000000E+00	0.0000000E+00
48	0.0000000E+00	-6.054415
49	0.0000000E+00	-6.054415
50	0.0000000E+00	-6.054415
51	0.0000000E+00	-6.054415
52	0.0000000E+00	-5.582783

X - APPENDIX B

LINGO SOLUTION

Row	Slack or Surplus	Dual Price
53	0.0000000E+00	-5.111151
54	0.0000000E+00	-4.663914
55	0.0000000E+00	-4.216677
56	0.0000000E+00	-3.769439
57	0.0000000E+00	-3.322202
58	0.0000000E+00	-2.896960
59	0.0000000E+00	-2.471719

Project Cash Flows

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	$741	0	34	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	$0	0	0	0	0	1	29	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	$599	0	0	0	0	0	0	0	8	5	5	5	5	5	5	5	5	5	3	0	0	0
4	$130	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0
5	$12	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	$147	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	$0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	$129	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	$65	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	$512	0	0	0	0	0	0	21	20	10	13	0	0	0	0	0	0	0	0	0	0	0
11	$0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	$0	0	1	0	0	0	0	0	0	0	9	39	39	39	0	0	0	0	0	0	0	0
13	$0	0	0	0	0	0	0	0	0	0	0	6	10	8	27	17	7	0	0	0	0	0
14	$241	0	0	0	0	0	0	0	0	0	0	0	0	44	15	0	15	15	0	0	0	0
15	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0
16	$45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	34	0
17	$0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	$55	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	$34	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0
20	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	12	12	0	0
21	$257	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	$220	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
23	$183	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
24	$0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
25	$0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
26	$0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
27	$0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
28	$0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
29	$220	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
30	$110	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
31	$384	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
32	$0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
33	$3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
34	$0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
35	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
36	$1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
37	$0.4	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
38	$0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
39	$0.1	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
40	$0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	$7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	$8	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	$0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	$0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	$1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	$1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	39	20	20	0	0	0
49	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
50	$4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0
51	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	0	0	0
52	$7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0
53	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	14	0

Project Cash Flows

PROJECT		97		1998				1999				2000				2001				2002			
NO.	NPV	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
54	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	6	0
55	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	21	0	24	0
56	$0.3	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	$13	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	$10	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	$9	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	$8	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
61	$8	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
62	$7	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
63	$6	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
64	$0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	$0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0
66	$2.0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	$0.5	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	$0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	$0	0	0	0	0	0	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	$6	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	$6	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
77	$5	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
78	$5	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
79	$4	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
80	$4	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
81	$3	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
82	$3	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
83	$2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
84	$130	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	$121	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	$113	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
87	$0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	$0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	$65	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	$60	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Project Relationships

PROJECT NO.	INDEPENDENT	MUTUALLY EXCLUSIVE	CONTINGENT	MANDATORY	COMPLEMENTARY
1	NO CONSTRAINTS				
2			(X2 >= X3 and X4)		
3			**X2 >= X3**		
4			**X2 >= X4**		
5	NO CONSTRAINTS				
6	NO CONSTRAINTS				
7			(X7 >= X8 and X9)		
8			**X7 >= X8**		
9			**X7 >= X9**		
10			**X10 = X11**		
11			**X11 = X3**		
12			(X12 >= X13 and X14 and X15)		
13			**X12 >= X13**		
14			**X13 >= X14**		
15			**X12 >= X15**		
16			**X15 >= X16**		
17				**X17 = 1**	
18			(X18 >= X19)		
19			**X18 >= X19**		
20			(X20 >= X50 and X51 and X52)		
21	NO CONSTRAINTS				
22	NO CONSTRAINTS				
23	NO CONSTRAINTS				
24			X24 = 1 IF X21+X22+X23 >= 2		
25			(X25 >= X26)		
26			**X25 >= X26**		
27			**X27 = X26**		
28			**X28 >= X26**		
29	NO CONSTRAINTS				
30	NO CONSTRAINTS				
31			(X32 >= X31)		
32			**X32 >= X31**		
33	NO CONSTRAINTS				
34			**X34 = 1 IF X26+X31 >= 1**		
35	NO CONSTRAINTS				
36	NO CONSTRAINTS				
37	NO CONSTRAINTS				
38				**X38 = 1**	
39	NO CONSTRAINTS				
40				**X40 = 1**	
41	NO CONSTRAINTS				
42	NO CONSTRAINTS				
43	NO CONSTRAINTS				
44	NO CONSTRAINTS				
45	NO CONSTRAINTS				
46			**X46 = 1 IF X41+X42 = 2**		

Project Relationships

PROJECT NO.	INDEPENDENT	MUTUALLY EXCLUSIVE	CONTINGENT	MANDATORY	COMPLEMENTARY
47	NO CONSTRAINTS				
48			X48 >= X49		
49			X49 >= X50		
50			X20 >= X50		
51			X20 >= X51		
52			X20 >= X52		
53			X53 >= X50		
54			X54 >= X51		
55			X55 >= X52		
56	NO CONSTRAINTS				
57	NO CONSTRAINTS				
58	NO CONSTRAINTS				
59	NO CONSTRAINTS				
60	NO CONSTRAINTS				
61	NO CONSTRAINTS				
62	NO CONSTRAINTS				
63	NO CONSTRAINTS				
64			X64 = 1 IF X57+ .. +X63 >= 2		
65			X65 = 1 IF X57+ .. +X63 >= 7		
66	NO CONSTRAINTS				
67	NO CONSTRAINTS				
68	NO CONSTRAINTS				
69	NO CONSTRAINTS				
70			X70 = 1 IF X57+ .. +X63 >= 2		
71			(X71 >= X72, .. , and X83)		
72			X71 >= X72		
73			X71 >= X73		
74			X71 >= X74		
75			X71 >= X75		
76			X71 >= X76		
77			X71 >= X77		
78			X71 >= X78		
79			X71 >= X79		
80			X71 >= X80		
81			X71 >= X81		
82			X71 >= X82		
80			X71 >= X83		
84	NO CONSTRAINTS				
85	NO CONSTRAINTS				
86	NO CONSTRAINTS				
87	NO CONSTRAINTS				
88	NO CONSTRAINTS				
89	NO CONSTRAINTS				
90	NO CONSTRAINTS				