OPTIMAL PROJECT SELECTION AND BUDGET ALLOCATION FOR THE SELECTED PROJECT

By

Nuhamin Taye

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COMPUTATIONAL SCIENCE PROGRAM

The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance a thesis entitled "**Optimal Project Selection and Budget Allocation for the Selected Project**" by **Nuhamin Taye** in partial fulfillment of the requirements for the degree of **Master of Science**.

Dated: June 2011

Supervisor: ______________________
Berhanu Guta (PHD)

Readers: ______________________
Semu Mitiku (PHD)

____
Berhanu Bekele (PHD)

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COMPUTATIONAL SCIENCE PROGRAM

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Author: **Nuhamin Taye**

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To My Family

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Abstract

Project Selection is the process of evaluating individual projects, to choose the right project based on an analysis so that the objectives of the company will be achieved. It involves a thorough analysis including the most important financial aspect to determine the most optimum project among all the alternatives. LINGO optimization tool has been adopted to determine the optimal project. The model presented in the paper shows a special tool for project selection based on influences that govern the project selection process. Finally, an optimal budget is allocated to the selected project using a dynamic programming. The result showed that optimal project selection and optimal budget allocation should be used by organization to maximize their return.

Acknowledgements

Thanks be to God for his indescribable gift and help all the years throughout my life.

My next and most earnest gratitude must go to my adviser Dr.Berhanu Guta for his continuous support and guidance throughout the various stages of this thesis. Without his personal involvement and intervention at critical stages, it would have been very challenging to complete the thesis according to the initially set plan. He provided critical and useful feadbacks and suggestions on how to approach the research problem systematically and tactfully. He showed me how researches will be produced and how an advisor interacts with his student(s), and he is really a role model for academic professionals, so I thank him all the time.

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Chapter 1

Introduction

During good times and bad, selecting the proper projects to undertake is an extremely important activity for organizations. Selecting the right projects (or wrong ones) can be the difference between success and failure for most organizations. The process of selecting projects and managing the project portfolio, formally called Project Portfolio Management, can help organizations get a grasp on their projects and the risk & benefits associated with those projects. Project Portfolio management and selection has become an important part of most organization's project management activities. By managing their project portfolio's correctly, organizations can gather information about all projects, prioritize those projects and manage the selected projects throughout the project life cycle. This remainder of this paper provides an overview on project selection and describes a prototype system that can be used to optimize the selection of projects. The project selection prototype uses optimization techniques to select the optimal number of projects based on given criteria.

1.1 *Background*

Organizations usually have to select from a large set of new projects according to various evaluation criteria, like costs, profit, return on investment, etc. This problem is widely known as project portfolio selection (PPS) and allocating budget for the selected project

.

The problem of choosing an optimal set of project subject to some constraints such as available budget for investment, production, marketing, personnel, administrative, and optimizing a measurement function like maximizing the returns of selected projects is an essential and practical problem. Formally it's a decision making problem which results in selecting some projects and rejecting others subject to organization resources and targets. Selecting proper projects to undertake are an extremely important activity for organizations. The continuous flow of projects that compete for resources, funding and priority status can help organizations get a grasp on their projects and benefits associated with that Project selection and budget allocation for constructing project portfolios is an essential decision problem faced by many organizations. A key motivation for forming an investment portfolio is risk diversification. Selection of an optimum portfolio when an organization is involved in a set of projects with a predetermined net present value and initial investment cost has both practical and theoretical importance which has made it attractive to the researchers in last decades. This selection should contain a set of projects in order to meet a high level profit margin. The problem of selecting and budget allocating for the selecting project an optimal set of project subject to some constraints such as available budget for investment and optimizing a Measurement function like maximizing the returns of selected projects is an essential and practical problem. Given a targeted achievable rate of return, the problem of formation of an efficient portfolio is to select, from a set of available budget, the portfolio that achieves the maximizing expected rate of return and simultaneously minimizes the portfolio risk. In any thriving organization, the number of potential projects will far outweigh the capital budget available. Therefore, selections of those projects that have the greatest value to an organization are extremely important to ensure that the organization to give support to the operations and grows in the selected strategic direction. Formally it's a decision making problem which results in selecting some projects and rejecting others subject to organization resources and targets. Generally, this is interpreted as capital budgeting which is a common paradigm with enough flexibility for standing in many areas. A great amount of research works have been reported in the literature of this area. According to this discusses a framework for project selection decision analysis often; this decision problem involves multiple objectives. Project proposals are evaluated with regard to multiple criteria which reflect these objectives, wherefore portfolio performance is also described in multiple criteria as an aggregate of the individual projects. Typically, only a subset of the project proposals can be funded with the available resources, and no feasible portfolio maximizes all criteria simultaneously. Project Portfolio management and project portfolio selection has become an important part of most organization's for its activities. By managing their project portfolio's correctly, organizations can gather selecting the right projects (or wrong ones) can be the difference between success and failure for most organizations. Selecting the information about all projects, prioritize those projects and manage the selected projects throughout the project life cycle, capital budgeting and project selection have also attracted a large variety of research efforts due to its adaptability to real case conditions. Project portfolio management deals with the continuous flow of projects; it entails choosing the right projects and the associated capacity allocation Therefore, the purpose of this paper is to provide an overview on project selection and describes a prototype system that can be used to optimize the selection of projects. In Multiple Criteria Capital Budgeting, projects can be investment opportunities, such as R&D proposals, maintenance sites, nature reserve candidates or real estates. The objective is optimum portfolio selection with lowest cost and maximum profit from available investment situations in an ambiguous environment.

1.2 *Objective*

1.2.1 *General Objectives*

The general objectives of this study are:

- to optimally select projects from large number of alternative projects that are with resource (capital) and time constraint and

- to allocate budget for the selected projects.

1.2.2 *Specific Objective*

The specific objectives of this study are to:

- Identify appropriate tools which can help an organization select the optimal project
- give a particular example that illustrates how to select a project from several alternatives
- select a project from alternative projects with time and capital constriant
- identify tools that enables us to allocate budget for the selected project
- allocate budget for the selected project using the identified tools

1.3 *Scope*

This study is concerned with optimal project selection with fixed capital and time constraint. It is assumed that all projects have the same priority level and does not take project risk into account. That is, we consider optimum portfolio selection with lowest cost and maximum profit from available investment situations in an unambiguous environment which contains investment analysis using an optimization tool called LINGO 13.0. The problem of choosing an optimal set of project subject to some constraints such as available budget for investment and optimizing a measurement function like maximizing the returns of selected projects is an essential and practical problem. Formally it's a decision making problem which results in selecting some projects and rejecting others subject to organization resources and targets.

1.4 *Methodology*

To formulate and solve budgeting problem as the sequence of decision process, it can be utilized the technique of dynamic programming as developed by Bellman. Bellman optimality principle states that optimal policy with regard to the state resulting from partial optimal decisions. Dynamic Programming (DP) is a mathematical technique that is applicable in allocation, cargo loading, replacement, sequencing, scheduling and inventory to solve such kinds of problems. Estimation of costs to the potential project, choosing the most beneficial projects top-down until the total cost exceeds the budget. Generally, this is interpreted as capital budgeting which is a common paradigm with enough flexibility for standing in many areas. A great amount of research works have been reported in the literature of this area; however, we used a lingo optimization software that was developed using the above stated technique to attack the problem.

Variable Types in LINGO

- All variables in a LINGO model are considered to be non-negative and non-continuous unless otherwise specified LINGOs four variable domain functions can be used to override the default domain for given variables .variable types in LINGO are the folowing :@GIN any positive integer value ;@BIN a binary value (ie, 0 or 1) ;@FREE any positive or negative real value and @BND any value within the specified bounds.

LINGO Solution Report Window

- Slack or Surplus Zero :if a constraint is completely satisfied as an equality ;Positive shows how many more units of the variable could be added to the optimal solution before the constraint becomes an equality and Constraint has been violated if negative.

- Reduced Cost: how much the objective function would degrade if one unit of a variable (not included in the current solution) were to be included.

- Dual Price :How much the objective function would improve if the constraining value is increased by one unit.

An Optimization model consists of 3 parts

- Objective Function: Asingle formula that describes exactly what the model should optimize.

- Variables:Quantities that can be changed to produce the optimal value of the objective function Variable names are not case-sensitive and must be egin with a letter (A-Z).

- Constraints:formulas that define the limits on the values of the variables.

Chapter 2

Review of Related Literature

A major part of the literature in this area is dedicated to the selection and sequencing of activities in order to maximize NPV (De *et al.*, 1993; Gupta *et al.*, 1992; Kyparisis *et al.*, 1996). This problem is extended to the selection of R&D activities from a set of alternatives by Granot and Zuckerman (1991). More detailed planning is performed by Kis (2005), and by Kolisch and Meyer (2006) for pharmaceutical research projects In order to manage project portfolio's, organizations must have a method of prioritizing and selecting projects . This selection process can be as simple as a ranking method or more complex criteria like return on investment, strategic value or some other criteria. In order to manage project portfolio's, organizations must have a method of prioritizing and selecting projects . This selection process can be as simple as a ranking method or more complex criteria like return on investment, strategic value or some other criteria. Choosing the proper selection criteria is beyond the scope of this paper, but many of these criteria allow for linear programming models for decision support systems to be utilized. The challenge for many organizations lies within the act of prioritizing and selecting projects in their portfolio . There has been considerable research and reporting on selecting projects based on ranking, strategic value, risk levels and other factors . The problem with many of these methods is that they rely more on human decisions, which can lead to project bias and favoritism rather than an optimal selection of projects. The project selection problem facing organizations cannot be completely overcome using optimization techniques, but the effect that human bias has can be minimized during some steps of the selection process. This can be accomplished using decision support tools to provide optimal project portfolio selection using inputs such as budget, risk level, strategic value, number of projects or other requirements [13]. Project selection is very much an 'in' or 'out' process since a project is either selected or not. This "yes or no" selection process lends itself well to using a binary linear programming method [15]. A review of existing research shows the use of a zero-one integer linear programming model developed by Ghasemzadeh and Archer to assist in the project selection process [9]. This zero-one model provides for accurate and optimal solutions for project portfolio selections due to the discrete nature of the inputs and outputs [16]. A great amount of research works have been reported in the literature of this area. As mentioned before, fuzzy/crisp capital budgeting and project selection have also attracted a large variety of research efforts due to its adaptability to real case conditions. Chance Programming Models for Capital Budgeting in Fuzzy Environments [19], Mean-variance model for fuzzy capital budgeting [15], Optimal project selection with random fuzzy parameters [16], Chance constrained programming models for capital budgeting with NPV as fuzzy parameters [13], Credibility-based chance-constrained integer programming models for capital budgeting with fuzzy parameters [6], A goal-seeking approach to capital budgeting [24], An research and development options selection model for investment decisions [8], Multiple criteria decision making combined with finance: A categorized bibliographic study [?], Capital budgeting and compensation with asymmetric information and moral hazard [3], A comprehensive 0-1 goal programming model for project selection [22], Optimal project selection when borrowing and lending rates differ [23], Capital budgeting under uncertainty: An extended goal programming approach [26], A general form for the capital projects sequencing problem [27], An empirical study of capital budgeting practices for strategic investments in CIM technologies [24], Capital budgeting model with flexible budget [8], Dependent-Chance Programming Models for

Capital Budgeting in Fuzzy Environments [20], Credibility based chance-constrained integer programming models for capital budgeting with fuzzy parameters [9] and On some optimization problems under uncertainty [4] are some illustrative examples of research works in this area. Knapsack problem and its extensions, well-known NP hard problems [25], are fitted properly to the lots of optimization and engineering problem as well as capital budgeting and project selection They can be evaluated in terms of both quantitative criteria (e.g., net present value, sales, market share, road condition data, acreage, species variety) and qualitative criteria (e.g., quality of basic research, risk level, personnel capabilities, environmental impacts, societal impacts). Often, projects are interdependent (e.g., synergy or cannibalization effects). In addition to resource constraints, the problem can involve different kinds of strategic and logical constraints, and there can be a minimum or maximum threshold on certain criteria (see, e.g., Archer and Ghasemzadeh, 1996; 1999; Stummer and Heidenberger, 2003) Choosing the proper selection criteria is beyond the scope of this paper, but many of these criteria allow for linear programming models for decision support systems to be utilized. The challenge for many organizations lies within the act of prioritizing and selecting projects in their portfolio [14]. There has been considerable research and reporting on selecting projects based on ranking, strategic value, risk levels and other factors [7]. The Project Selection using Decision Optimization Tools 4 Page 4 Copyright 2008 - Eric D. Brown problem with many of these methods is that they rely more on human decisions, which can lead to project bias and favoritism rather than an optimal selection of projects [29]. The portfolio management is one of the most challenging decision-making problems in the modern business (Cooper et al., 1997a). The project selection problem facing organizations cannot be completely overcome using optimization techniques, but the effect that human bias has can be minimized during some steps of the selection process. This can be accomplished using decision support tools to provide optimal project portfolio selection using inputs such as budget, risk level, strategic value, number of projects or other requirements [9]. Project selection is very much an 'in' or 'out' process since a project is either selected or not. This "yes or no" selection process lends itself well to using a binary linear programming method [16]. A review of existing research shows the use of a zero-one integer linear programming model developed by Ghasemzadeh and Archer to assist in the project selection process [23]. This zero-one model provides for accurate and optimal solutions for project portfolio selections due to the discrete nature of the inputs and outputs .When the focus is on obtaining optimal policies and transaction costs are not the primary issue, stochastic dynamic programming proves to be a very effective approach. Stochastic dynamic programming based on Bellman's (1957) dynamic programming principle has been used for the derivation of the theoretical results obtained for the HARA class of utility functions discussed above. Project selection is ultimately the responsibility of senior management, whose decision should be based on informative data (Burke, 1994). Although the financial point of view of project appraisal is the main basis for evaluation, there are various other considerations. Meredith and Mantel (1995) documented the areas of production considerations, marketing considerations, personnel considerations, and administrative considerations in addition to financial considerations. Early use of a dynamic programming formulation for solving investment problems can be found in Mossin (Mossin 1968) and Samuelson (Samuelson 1969) Dynamic programming was first introduced by Bellman (Bellman 1957) and provides, among other things, a solution methodology for solving dynamic problems with a graph structure. much to allocate to the project for the coming period is generally determined by one means or another from estimates of the following project parameters: project life, project cost, expected payoff if successfully and probability of success

Chapter 3

Problem Description

This section consists of two subsections, the 1^{st} deals with project selection using decision support optimization tools and the 2^{nd} is about budget allocation for the selected projects.

3.1 *A Real World Project Selection Problem*

The project selection problem described above exists within organizations. Consider an organization has recently started a project portfolio management initiative and is having difficulties with the project selection phase of project portfolio management. Specifically, the portfolio management team is having trouble in choosing the optimal project selection mixture. Rather than working to understand how to optimize the project selection process, the portfolio management team may have asked the organizational leadership for guidance on which projects are more important. Suppose the response from the leadership team has been to say that all projects have the same priority level. The organization's leadership has requested a report that outlines which projects will be selected and the methodology used to select these projects. In addition, consider that the Chief Information Officer (CIO) has asked for special consideration to be given to three high profile projects to ensure that they are selected. The Chief Executive Officer (CEO) has given his approval for these high profile projects to have a higher priority, but has asked for a project selection report with and without special consideration for these higher priority projects. Needless to say, the project portfolio management team is in a quandary. The project portfolio shows twenty-six projects that are considered 'high priority' (see Table 1). The portfolio does not take project risk into account as this has been considered prior to being listed as 'high priority'. Each project has a level of effort estimate, and thereby an estimate for cost to complete the project and each project has a statement of work and personnel associated with it. The organization has stated that the budget for all projects for the upcoming half-year is 750,000 birr, which must cover all internal and external costs associated with the projects. In addition, the amount of work that can be accomplished by the organization's personnel is to 7,750 hours for the half-year. The projects within the project portfolio are all scheduled to start and end within the upcoming six-month period and each has a different cost structure and level of effort. In addition, the leadership team has mandated that the project selection process provide a project mix that allows for the maximum number of projects to be undertaken within the budgetary constraints.

Project	Project Name	Resource Time (hrs)	Cost in Dollar
A	Social Networking	625	48,125.00
B	Content Management	975	118,950.00
C	Financial Reporting	350	37,800.00
D	Web Strategy	300	30,300.00
E	Document Management	575	55,775.00
F	Printing Solutions	250	23,500.
G	ON Demand Communications	750	78,750.00
H	Help Software Improvements	300	22,800.00
I	Server Upgrades	540	33,750.00
J	Share Point Implementation	1,205	102,425.00
K	Innovation Website	350	36,750.00
L	Market Website	125	11,875.00
M	Google Minimum Implementation	500	51,000.00
N	Web User Profile	870	104,400.00
O	Content Migration	575	55,200.00
P	Content Updates	430	36,120.00
Q	IT Infrastructure Upgrade	650	53,950.00
R	Email Upgrade	550	48,950.00
S	Photo System Improvement	325	29,250.00
T	People Soft Improvement	450	53,550.00
U	Ecommerce Upgrade	650	48,950.00
V	Finance System Upgrades	825	29,250.00
W	Health and Wellness Tracking	775	53,550.00
X	Broad Portal	900	66,300.00
Y	Website Redesign	875	69,300.00
Z	Communication Approval Process	175	59,675.00

3.2 *System Description*

To address the issues outlined above, a decision support system was built using a combination of excel and the LINGO optimization modeling software package. A zero-one integer linear programming model is used to select the optimal project portfolio. This model, based on Ghasemzadeh's work described in the Literature Review section above, attempts to maximize the number of projects undertaken while keeping total cost and number of hours below the constraint levels. The zero-one model can be described in mathematical terms as:

$$Z = \sum_{i=0}^{n} a_i x_i \tag{3.2.1}$$

Where

- Z is the optimized value you are seeking
- i is the total number of items
- a_i is a weighting factor (for risk, priority, etc)
- X_i is 1 or 0 based on being included or not

For the system described in this paper, a_i is set to '1' because all projects are considered to be of the same importance; therefore weighting is equal for all projects. The power of the zero-one model comes from the constraints placed upon it while running the optimization. Without constraints, this model is nothing more than a summation of all X's (e.g., projects). For the implementation discussed in this paper, the constraints for the model are:

- Total Project Costs (C) $\leq \$750,000$
- Total Project Time in hour (H) $\leq 7,750$

These constraints can be described in mathematical terms as:

$$\sum_{i=0}^{n} C_i * x_i \leq \$750,000 \tag{3.2.2}$$

$$\sum_{i=0}^{n} H_i * x_i \leq \$7,750 \tag{3.2.3}$$

Where

- C_i is the cost for each Project
- H_i is the number of hours for each Project
- i is the total number of projects

Using the zero-one model and the constraints described above, a semi-automated method of selecting the optimal project mix can be created using excel and LINGO. The implementation is described in the following section.

3.3 *Implementation*

Excel has been used to gather the appropriate information about the projects in the portfolio. The excel spreadsheet contains a list of all high priority projects along with their costs, level of effort estimates, other relevant project information and the cost and hour limits. An excel macro is run to provide an automated method of gathering the relevant pieces of information and storing the data into a text file for use with the LINGO optimization software platform. The data from excel appears in Table 2.

Table 2 - Data dump from excel for use in LINGO

COST = 750,000;

HOURS = 7,750;

625* A + 975* B + 350* C + 300* D + 575*E + 250* F + 750* G + 300* H + 450* I + 1205* J + 350*K + 125* L + 500* M + 870* N + 575*O + 430* P + 650* Q + 550*R + 325* S + 450*T + 650 *U + 825* V + 775*W + 900* X + 875* Y + 175* Z $\leq HOURS$;

$48125 * A + 118950 * B + 37800 * C + 30300 * D + 55775 * E + 23500 * F + 78750 * G + 22800 * H + 33750 * I + 104425 * J + 36750 * K + 11875 * L + 51000 * M + 104400 * N + 5200 * O + 36120 * P + 53950 * Q + 48950 * R + 29250 * S + 53550 * T + 66300 * U + 69300 * V + 59675 * W + 75600 * X + 83125 * Y + 21000 * Z \leq COST$;

The goal of the LINGO optimization is to maximize the number of projects Undertaken in the six-month period. Using LINGO language, this is written as:

$$Max = A + B + C + D + E + F + G + H + I + J + K + L + M + N + O$$
$$+P + Q + R + S + T + U + V + W + X + Y + Z; \quad (3.3.1)$$

The last step required before running the optimization is to ensure that LINGO understands that all projects "A" through"Z" can only be a value of '1' (yes) or '0' (no). This can be done in LINGO using the following terminology:

$$@bin(term) \quad (3.3.2)$$

The LINGO model, for the project selection system for all projects weighted equally is shown in Table 3.

Table 3 - LINGO Model #1

MAX=A+B+C+D+E+F+G+H+I+J+K+L+M+N+O

+P+Q+R+S+T+U+V+W+X+Y+Z;

COST =750,000;

HOURS = 7,750;

625*A + 975*B + 350*C + 300*D + 575*E + 250*F + 750*G + 300*H + 450*I + 1205*J + 350*K + 125*L + 500*M + 870*N + 575*O + 430*P + 650*Q + 550*R + 325*S + 450*T + 650*U + 825*V + 775*W + 900*X + 875*Y + 175*Z $\leq HOURS$;

$48125 * A + 118950 * B + 37800 * C + 30300 * D + 55775 * E + 23500 * F + 78750 * G + 22800 * H + 33750 * I + 104425 * J + 36750 * K + 11875 * L + 51000 * M + 104400 * N + 55200 * O + 36120 * P + 53950 * Q + 48950 * R + 29250 * S + 53550 * T + 66300 * U + 69300 * V + 59675 * W + 75600 * X + 83125 * Y + 21000 * Z \leq COST;$

$@bin(A); @bin(B); @bin(C); @bin(D); @bin(E); @bin(F); @bin(G); @bin(H); @bin(I); @bin(J); @bin(K$

$RESULTSFORLINGOMODEL\#1$

$Globaloptimalsolutionfound.$

$Objectivevalue : 18.00000$

$Objectivebound : 18.00000$

$Infeasibilities : 0.000000$

$Infeasibilities : 0.000000$

$Totalsolveriterations : 0$

Variable	Value	Reduced Cost
A	1.000000	-1.000000
B	0.000000	-1.000000
C	1.000000	-1.000000
D	1.000000	-1.000000
E	1.000000	-1.000000
F	1.000000	-1.000000
G	0.000000	-1.000000
H	1.000000	-1.000000
I	1.000000	-1.000000
J	0.000000	-1.000000
k	1.000000	-1.000000
l	1.000000	-1.000000
m	1.000000	-1.000000
n	0.000000	-1.000000
o	1.000000	-1.000000
p	1.000000	-1.000000
Q	1.000000	-1.000000
R	1.000000	-1.000000
S	1.000000	-1.000000
T	1.000000	-1.000000
U	1.000000	-1.000000
V	0.000000	-1.000000
W	0.000000	-1.000000
X	0.000000	-1.000000
Y	0.000000	-1.000000
Z	1.000000	-1.000000
COST	750000.0	0.000000
HOURS	7750.000	0.000000

Row	Slack or Surplus	Dual Price
1	18.00000	1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	120.0000	0.000000
5	34005.00	0.000000

$TheLINGOmodelforthethreeprojectsgivenspecialconsiderationisshownintable4.TakenoteofProjec$

$LINGOModel\#2-withspecialconsiderationgiventothreeprojects(B,E,F)$

$MAX = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O$

$+P+Q+R+S+T+U+V+W+X+Y+Z; COST = 750,000; HOURS = 7,750; B =$

$1; E = 1; F = 1; 625*A+975*B+350*C+300*D+575*E+250*F+750*G+300*H+$

$450*I+1205*J+350*K+125*L+500*M+870*N+575*O+430*P+650*Q+550*$

$R+325*S+450*T+650*U+825*V+775*W+900*X+875*Y+175*Z <= HOURS;$

$48125*A+118950*B+37800*C+30300*D+55775*E+23500*F+78750*G+$

$22800*H+33750*I+104425*J+36750*K+11875*L+51000*M+104400*N+$

$55200*O+36120*P+53950*Q+48950*R+29250*S+53550*T+66300*U+$

$69300*V+59675*W+75600*X+83125*Y+21000*Z <= COST;$

$@bin(A); @bin(C); @bin(D); @bin(G); @bin(H); @bin(I); @bin(J); @bin(K); @bin(L); @bin(M); @bin($

$RESULTSFORLINGOMODEL\#2$

$Globaloptimalsolutionfound.$

$Objectivevalue: 17.00000$

$Objectivebound: 17.00000$

$Infeasibilities : 0.000000$

$Infeasibilities : 0.000000$

$Totalsolveriterations : 0$

Variable	Value	Reduced Cost
A	1.000000	-1.000000
B	1.000000	-1.000000
C	1.000000	-1.000000
D	1.000000	-1.000000
E	1.000000	-1.000000
F	1.000000	-1.000000
G	0.000000	-1.000000
H	1.000000	-1.000000
I	1.000000	-1.000000
J	0.000000	-1.000000
k	1.000000	-1.000000
l	1.000000	-1.000000
m	1.000000	-1.000000
n	0.000000	-1.000000
o	0.000000	-1.000000
p	1.000000	-1.000000
Q	1.000000	-1.000000
R	1.000000	-1.000000
S	1.000000	-1.000000
T	1.000000	-1.000000
U	0.000000	-1.000000
V	0.000000	-1.000000
W	0.000000	-1.000000
X	0.000000	-1.000000
Y	0.000000	-1.000000
Z	1.000000	-1.000000
COST	750000.0	0.000000
HOURS	7750.000	0.000000

Row	Slack or Surplus	Dual Price
1	17.00000	1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	1.000000
5	0.000000	1.000000
6	0.000000	1.000000
7	370.0000	0.000000
8	36555.00	0.000000

Chapter 4

How to Allocating Budget for the Selected Project using Dynamic Programing

4.1 *Description of the Dynamic Programing*

Dynamic programming is a mathematical technique that is applicable in allocation, cargo loading, replacement investment to solve such kinds of problems and approach involves the optimization of multistage decision processes. It basically divides a given problem in to stages or sub problems and then solves the sub problems sequentially until the initial problem is finally solved . Break up a problem into a series of overlapping sub-problems, and build up solutions to larger and larger sub-problems. The dynamic programming approach can also be used to solve the problem of selecting and allocating budget for the selected project.In order to optimize the total return for all project in this case we consider.

- The return from all projects are measured in common unit
- The return from specific project is independent of the returns from the other projects
- The return function are non-decreasing
- The total return from all project is equal to the sum of the individual returns

In order to develop the dynamic programming function equation for the general budget allocation problem suppose $R(x_1, x_2, \ldots, x_n)$ =total return from allocating x_i units of budget to the i^{th} project $(i = 1, 2 \ldots, n)$

$g_i(x_i)$ = return from the i^{th} project when x_i unit of budget are allocated to that activity

X^* = maximum number of units of budget available to allocate to the n activities.

The allocation problem we want to solve is

$$\max[R(x_1, x_2 \ldots, x_n)] = \max[\sum_{k=1}^{n} f_k(x_k)]\text{S.t} \sum_{k=1}^{n} x_k = x^*, x_k \geq 0$$

A sequence of functional equation $\{f_i(x)\}$ is defined as

$$f_i(x) = \max_{x_k}[\sum_{k=1}^{n} f_k(x_k)] for x = 0, \Delta, 2\Delta, \ldots, x^* i = n, n-1, \ldots, 1\text{S.t} \sum_{k=1}^{n} x_k = x, x_k \geq 0$$

This is the optimal Return from projects $i, i+1, \ldots, n$, when x units of budget are available for allocation to these projects only. Note that for $i = 1$ and $x = x*$ this is identically the problem we set out to solve. However we have embedded the original problem in family of problems where the number of project under consideration, say M, is any positive integer less than or equal to N and the amount of budget is any amount, say x less than or equal to $x*$. This family of problems is solved sequentially until the original problem N, eventually is solved we start by assuming that the last project, project N, is the project available for allocation of budget. If $x = 0, \Delta, 2\Delta \ldots, x*$ units are available to allocate, we should allocate all x units to project N since the return from that project is non decreasing.This is represented by the functional equation

$$\begin{aligned} f_n(x) = \max_{x_n}[g_n(x_n)] = g_n(x) \\ x = 0, \Delta, 2\Delta, \ldots, x^* \\ \text{S.t} \\ x_n = x \end{aligned} \tag{4.1.1}$$

This is the optimal return from project n when x units of budget are available for allocation to that activity only. let $d_n(x) = x$ be the optimal amount of budget to allocate to the n^{th}

project when it is the only project, and x units of resource are available. The next step is to assume that activities n and $(n-1)$ are the only projects to which the budget can be allocated. If x units of the budget are available, how many units should be allocated to project $(n-1)$ to optimize the total return from project $(n-1)$ and n?. If we allocate x_{n-1} units to project $(n-1)$ and use the remaining $(x-x_{n-1})$ units of budget to get a maximum return from project n, then the total return from the two projects would be

$$g_{n-1}(x_{n-1}) + f_n(x - x_{n-1}) \tag{4.1.2}$$

Thus the optimal return from activate $(n-1)$ and n when x units of budget are available to allocate to these activities is obtained by choosing x_{n-1} such that the quantity in equation (4.1.4)is a maximum. That is,

$$f_{n-1}(x) = \max_{x_n=0,\Delta,2\Delta,\ldots,x \& x=0,\Delta,2\Delta,\ldots,x^*} [g_{n-1}(x_{n-1} + f_n(x - x_{n-1}] \tag{4.1.3}$$

is the total optimal return from project $(n-1)$ and n when x units of budget are available for allocation to these two projects only. let $d_{n-1}(x)$ be the optimal number of units to allocate to project $(n-1)$ when x units are available to allocate to projects $(n-1)$ and n only. Thus $d_{n-1}(x) =$ value of x_{n-1} that yields $f_{n-1}(x)$. We now assume that projects $(n-2)$, $(n-1)$ and n are the only project available and we want to know how many units of budget should be allocated to them to obtain an optimal return. We repeat the same type of thinking process as before with only two projects. when x units of budget are available, x_{n-2} units are allocated to project $(n-2)$ and the remaining $(x-x_{n-2})$ unites are used to obtain an optimal return from the remaining two projects. Thus,

$$g_{n-2}(x_{n-2}) + f_{n-1}(x - x_{n-2}) \tag{4.1.4}$$

Would be the total return. Note that $f_{n-1}(k)$ was just calculated in the previous step for $k = 0, \Delta, 2\Delta, \ldots, x^*$ so it is readily available. Hence, evaluate equation (4.1.6) 0for

$x_{n-2} = 0, \Delta, 2\Delta, \ldots, x$ and let $f_{n-2}(x)$ be the maximum value obtained. Then,

$$f_{n-2}(x) = \max_{x_{n-2}=0,\Delta,2\Delta,\ldots,x \& x=0,\Delta,2\Delta,\ldots,x^*} [g_{n-2}(x_{n-2}) + f_{n-1}(x - x_{n-2})]$$

is the total optimal return for example from large n project we only selected three project then x units are available to allocate to the three projects only. Define $d_{n-2}(x)$ to be the decision Variable that represents the optimal amount of resource to allocate to project $(n-2)$. Thus $d_{n-2}(x)$ = value of x_{n-2} that yields $f_{n-2}(x)$ the process is repeated for $i = n-3, n-4, \ldots, 1$, each time defining

$$f_i(x) = \max_{x_i=0,\Delta,2\Delta,\ldots,x \& x=0,\Delta,2\Delta,\ldots,x} [d_i(x_i) + f_{i+1}(x - x_i)] \tag{4.1.5}$$

$d_i(x)$ = value x_i yields $f_i(x)$ in this subproblem we assume that project $1, 2, \ldots, n$ are available and that x units of budget are available for allocation. This is the original problem we see out to solve for $x = x^*$. The problem can now be solved easily since all values of f_2 are available from previous computations. Necessarily, $f_1(x^*)$ is the optimal return from the n project when x^* units of resource are available. The optimal amount to the various activities is given by the decision variables $d_i(x)$. For example, when x^* Units of resource are available

$y_1 = d_1(x^*)$ units are allocated to project 1

$y_2 = d_2(x^* - y_1)$ units are allocated to project 2

$y_3 = d_3(x^* - \sum_{k=1}^{2} y_k)$ units are allocated to project 3

$\vdots$

$y_i = d_i(x^* - \sum_{k=1}^{i-1} y_k)$ units are allocated to project i

$\vdots$

$y_n = d_n(x^* - \sum_{k=1}^{n-1} y_k)$ units are allocated to project n

$$f_i(x) = \max_{x_k, \sum_{k=1}^{n} x-k=x} \sum_{k=1}^{n} g_k(x_k), i = n-1, n-2, \ldots, 1$$

then

$$f_i(x) = \max_{0 \le x_i \le x, \{x_{i+1}, x_{i+2}, \ldots, x_n\}, \sum_{k=i+1}^{n} x_k = x - x_i} \{\max[\sum_{k=1}^{n} g_k(x_k)]\}$$

$$= \max_{0 \le x_i \le x} \{g_i(x_i) + \max_{\{x_{i+1}, x_{i+2}, \ldots, x_n\}, \sum_{k=i+1}^{n} x_k = x - x_i} [\sum_{k=1}^{n} g_k(x_k)]\}$$

$$= \max_{0 \le x_i \le x} g_i(x_i) + f_{i+1}(x - x_i)$$

$$i = n-1, n-2, \ldots, 1$$

$$x = 0, \Delta, 2\Delta, \ldots, x^*$$

$$f_1(x^*) = \max_{x_k, \sum_{k=1}^{n} x-k=x} \sum_{k=1}^{n} g_k(x_k)] = \max[R(x_1, x_2, \ldots, x_n)] \quad (4.1.6)$$

This is a concise computer-oriented presentation of the backward dynamic programming approach to the solution of a general allocation problem with k units of resource available to invest in N investment programs, with the returns from each program given in tabular form.

4.2 *Dynamic Programming Principles*

4.2.1 *Principle of Optimality*

If a problem has optimal substructure an optimal solution to that problem contains optimal solutions to all subproblems. It means that usually optimal solution can be described recursively in terms of optimal solutions to subproblems. This principle of optimality is an extremely powerful concept and more meaningful to the dynamic programming.

4.2.2 *Overlapping Subproblems*

A recursive solution contains "small" (polynomial) number of distinct subproblems repeated many saving after computing a solution to a sub-problem, store it in a table. Subsequent calls check the table to avoid redoing work.

4.2.3 *Example of a Budget Allocation Problem*

coincider the general problem of allocating a fixed amount of resource (money) to the number of activities (investment program) in such a way that the total return is maximized. More specifically, suppose only 8 unit of money are available for allocation in unit amounts to three investment programs. The return function for each project is given below. The function $g_i(x)$ represents the return from investing x units of money in the i^{th} investment project ($i = 1, 2, 3$). The return from each project is independent of the allocation to the other program. For example,$g_2(5) = 70$ is the return for investing 5 units in project 2 regardless of how the remaining 3 units are allocated to other two project.

x	0	1	2	3	4	5	6	7	8
$g_1(x)$	0	5	15	40	80	90	95	98	100
$g_2(x)$	0	5	15	40	60	70	73	74	75
$g_3(x)$	0	4	26	40	45	50	51	52	53

Is problem general allocating budget problem that can be solved sequentially in stage each stage is a sub problem which, when solved, provides information in each stage. The solution to the sub problem at the final stage is the solution to the original problem. **Step1** Assume for a moment that project 3 is the only investment project available to invest in. Since $g_3(x)$, the return function for project 3 is an increasing function of amount invested x, we should invest the entire 8 units in project 3. The return on our investment is $f_3(8) = g_3(8) = 53$ and the amount invested to obtain this return is $d_3(8) = 8$, where $f_3(x)$ is the optimal return from project 3 when 8 units are invested in it.

Step 2 Now , let $f_3(x) = g_3(x), x = 0, 1, 2, \ldots, 7$ be the optimal return from project 3 when x units are invested in it, and let $d_3(x) = x$ $x = 0, 1, 2, \ldots, 7$ be the optimal amount to invest in project 3. This appears rather trivial, and it is nevertheless, it is essential to the optimal return from project 3 when it is the only project in order to develop the final programming solution.

Step 3 Assume now that project 2 and 3 are the only project available, and the entire 8 units are available to invest in these two project ,since both return function are increasing functions of the amount invested, the entire amount should be invested. The question, then is how many units should be allocated to each project? we already know the optimal return from project 3 for any amount invested in it so it is just a matter of examining each of the sums of the maximum return

x	0	1	2	3	4	5	6	7	8
f3(x)	0	4	26	40	45	50	51	52	53
d3(x)	0	1	2	3	4	5	6	7	8

$$f_2(8) = \max_{z=0,1,2,\dots} [g_2(z) + f_3(8-z)]$$

Then

$$g_2(0) + f_3(8) = 53$$

$$g_2(5) + f_3(3) = 110$$

$$g_2(1) + f_3(7) = 57$$

$$g_2(6) + f_3(2) = 99$$

$$g_2(2) + f_3(6) = 66$$

$$g_2(7) + f_3(1) = 78$$

$$g_2(3) + f_3(5) = 90$$

$$g_2(4) + f_3(4) = 105$$

$$g_2(8) + f_3(0) = 75 \tag{4.2.1}$$

The optimal amount to invest in program 2 is denoted by $d_2(8)$ and is necessarily the value of z

$f_2(8) = g_2(5) + f_3(3) = 110$ that yield $f_2(8)$ in this case $d_2(8) = 5$

Step 4 In step 3 assumption program 2 and 3 are the only programs available to invest in, but in this step assume that only x units are available to invest in these programs $(x = 0, 1, 2, \ldots, 7)$. Means for each value of x get the corresponding optimal return value for these project, so

$$f_2(x) = \max_{z=0,1,\ldots,7}[g_2(z) + f_3(x - z)]$$

The amount to invest in program 2 is $d_2(x) = \text{value} of z \text{yields}$. We would calculate $f_2(x)$ and $d_2(x)$ for $x = 0, 1, 2 \ldots, 7$. These values are ,

$$\begin{aligned} x = 0, f_2(0) &= \max_{z=0}[g_2(z) + f_3(0 - z)] \\ &= g_2(0) + f_3(0) = 0 \\ &\text{Therefor } d_2(0) = 0 \end{aligned}$$

$$\begin{aligned} x = 1, f_2(1) &= \max z = 0, 1[g_2(z) + f_3(1 - z) \\ &= \max \begin{bmatrix} g_2(0) + f_3(1) \\ g_2(1) + f_3(0) \end{bmatrix} \\ &= \max \begin{bmatrix} 0 + 4 \\ 5 + 0 \end{bmatrix} \\ &= 5, \ \text{Therefor } d_2(1) = 1 \end{aligned} \tag{4.2.2}$$

This means that if one unit of resource is available to invest in program 2 and 3, the optimal policy is to invest it in program 2 for a total return of 5.

$$\begin{aligned} x = 2, f_2(2) &= \max z = 0, 1, 2[g_2(z) + f_3(2 - z) \\ &= \max \begin{bmatrix} g_2(0) + f_3(2) \\ g_2(1) + f_3(1) \\ g_2(2) + f_3(0) \end{bmatrix} \\ &= \max \begin{bmatrix} 0 + 26 \\ 5 + 4 \\ 15 + 0 \end{bmatrix} \\ &= 26, \ \text{Therefor } d_2(2) = 0 \end{aligned} \tag{4.2.3}$$

If 2 units are available for project 2 and 3 the optimal policy is to invest 0 in project 2 and 2units project 3 for a total return of 26. Remember that we are solving a whole class of sub problems that will eventually lead to the original problem

$$x = 3, f_2(3) = \max z = 0,1,2,3[g_2(z) + f_3(3-z)$$
$$= \max \begin{bmatrix} g_2(0) + f_3(3) \\ g_2(1) + f_3(2) \\ g_2(2) + f_3(1) \\ g_2(3) + f_3(0) \end{bmatrix}$$
$$= \max \begin{bmatrix} 0 + 40 \\ 5 + 26 \\ 15 + 4 \\ 40 + 0 \end{bmatrix}$$
$$= 40, \text{ Therefor } d_2(3) = 0 \text{ or } 3 \tag{4.2.4}$$

If we invested in an optimal solution rather than all optimal solutions, we need only retain $d_2(3) = 0$ or $d_2(3) = 3$ and not both the values $f_2(x)$ and $d_2(x)$ for $x = 4, 5, 6$ are in similar fashion to the above. The results from step 1-4 we get

x	0	1	2	3	4	5	6	7	8
$f_3(x)$	0	4	26	40	45	50	51	52	53
$d_3(x)$	0	1	2	3	4	5	6	7	8
$f_2(x)$	0	5	26	40	60	70	86	100	110
$d_2(x)$	0	1	0	0	4	5	4	4	5

Step 5 The final stage is the same as the original problem. How should 8 units of money be invested in the three investment programming? In this step results of investing z units in program 1 and $8 - z$ units optimality in programs 2 and 3 for $z = 0, 1, \ldots, 8$ then is the maximum of the result.

$$g_1(0)+f_2(8) = 110 g_1(1)+f_2(7) = 105 g_1(2)+f_2(6) = 101 g_1(3)+f_2(5) = 110 g_1(4)+f_2(4) = 140 g_1(5)+f_2(3$$

Namely $f_1(8) = g_1(4) + f_2(4) = 140$. Therefor, $d_1(8) = 4$

Note that $f_1(8)$ is the optimal return when 8 units are invested optimally in the three projects and $d_1(8)$ is the optimal amount to invest in project 1. Since $d_1(8) = 4$, in this levels 4 units to invest optimally in project 2 and 3. Recall that $d_2(4) = 4$ represent the optimal amount to invest in project 2 when just project 2 and 3 are available. In this 0 units to invest in project 3. Thus the optimal allocation of money to the three investment project is $d_1(8) = 4$ units in project 1, $d_3(0) = 0$ units in project 3 and $d_2(4) = 4$ units in project 2 Results from steps 1-5

x	0	1	2	3	4	5	6	7	8
$f_3(x)$	0	4	26	40	45	50	51	52	53
$d_3(x)$	0	1	2	3	4	5	6	7	8
$f_2(x)$	0	5	26	40	60	70	86	100	110
$d_2(x)$	0	1	0	0	4	5	4	4	5
$f_1(x)$	0	5	26	40	80	90	106	120	140
$d_1(x)$	0	0	0	0	4	5	4	4	4

For a total maximum return of $f_2(8) = 140$ Note that we can check by examining the sum of the return functions when the corresponding optimal amounts are invested in them $g_1(4)+g_2(4)+g_3(0) = 80+60+0 = 140$, given the result for any initial amount available up through 8 units.

For the 18 or 17 projects selected above we can allocate the budget available to the selected projects in the same as we did in the above example.

4.3 *Algorithm for Budget Allocation in Dynamic Programing*

Problem-Tabular Return function, Assume k units of budget are available to invest in N investment programs. How many units should be invested in each project to maximize the total return? G(I,X)=the return for investing $(x-1)$ units of budget in project I; $I = 1, 2, \ldots, N$

$F(I,X)$ =the optimal return for investing $(x-I)$ units of budget in projects $I, I+1, \ldots, N$

$D(I,X)$ =the optimal number of units to invest in project I when only Project $I, I+1, \ldots, N$ are being considered and $(X-1)$ units are available to invest

$XSTAR(I)$ =optimal number of units to invest in program I when all Projects are being considered and K units of budget are available $(I = 1, 2, , N)$

We assume that K, N and $G(I,X)$ for $I = 1, 2, \ldots, N$ and $X = 1, 2, \ldots, k+1$ have been read in to the computer

STEP 1: Assume the last project is the only project. Initialize the optimal return and the optimal amount to invest for $0, 1, \ldots, k$ units of budget. For $X = 1, 2, \ldots, k+1$ $F(N,X) = (G,X)$ $D(N,X) = X - 1$

STEP 2: Assume the last two projects are the only projects. Set $I = N - 1$

STEP 3: Set the amount of budget to zero. Set $x = 1$

STEP 4: Calculate the optimal return from investing $x - 1$ units of budget in when $X - 1$ units of budget are available to invest in projects $I, I+1, , N$. Calculate

STEP 5: Check to see if current amount is at the maximum amount. If $X = K + 1$, go to step 6;otherwise, increase X by 1 and return to step 4.

STEP 6: Check to see if original problem has been solved. If $I = 1$, go to step 7; otherwise, decrease I by 1 and return to step 3.

STEP 7-11: Determine the optimal number of units to invest in each project and print the results STEP 7 Set , $XSTAR(1) = D(1, K+1)$ STEP 8 Set $I = 2$ STEP 9 Calculate STEP 10 Set $XSTAR(I) = D(I, K + 1 - sum)$ STEP 11 If $I = N$, print the result and stop; otherwise, increase I by 1 and return to step 9.

Chapter 5

Evaluation and Conclusion

5.1 *Evaluation*

The solutions provided by the LINGO optimization platform were quite interesting. The optimal project selection output maximizes the number of projects based solely on staying under the budget and hour constraint. Model #1shows 18 projects being undertaken with a budget of selected projects of $715,995 and 7,630 hours. Model # 2, with the three projects given special consideration, shows 17 projects selected with a budget of $713,445 and 7,380 hours. Reviewing the project selection mixture shows that these solutions appear to be the optimal solution.

5.2 *Conclusion*

The model and decision support system described in this thesis has provided a quick and easy method of project selection for an organization. The ability to select an optimal mix of projects when constrained by budget (or any other constraints) provides a significant improvement to the project selection process. There are some limitations to this project selection decision support model. The current implementation assumes that the list of projects have the same priority. The zero-one model does allow for a weighting to be applied to each project but this weighting factor must be selected prior to setting up the LINGO model. This might cause confusion with some users when creating the project portfolio for use in the selection decision support model. Future improvements are planned for this model to help make it more robust. The current model assumes that the money is spent during the time frame considered and all projects are started and ended within the same period. The priority of the projects will not change throughout the time period. Making changes in these areas would provide for a more robust model to asses in project selection. Optimal budget allocation is approached using dynamic programming. In the thesis we found that optimal project selection cannot bring the required result unless budget is allocated optimally to the selected projects.

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