Project Selection using Decision Support Optimization Tools

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About the Author

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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 [1].

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 lifecycle.

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.

Literature Review

In order to manage project portfolio's, organizations must have a method of prioritizing and selecting projects [2]. 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 [3]. There has been considerable research and reporting on selecting projects based on ranking, strategic value, risk levels and other factors [2-7]. 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 [8].

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 [10]. 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 [11]. This zero-one model provides for accurate and optimal solutions for project portfolio selections due to the discrete nature of the inputs and outputs [11].

Problem Description

The act of prioritizing projects can be daunting, especially when confronted with a large number of projects with multiple constraints on project resources. In an ideal world, with unlimited budget and personnel and the ability to take on any risk, the project selection process would be very straightforward.

As an example of the project selection problem, let's assume there are 26 projects with the same priority level listed on an organization's project portfolio. If there is no constraint (i.e., enough budget to do them all), the selection process is easy…the organization would undertake all 26 projects. In the real world though, there are always constraints such as budget, strategic value, personnel requirements and many more.

Back to the example: Assume that a budgetary constraint exists that prevents the organization from undertaking all projects. This constraint forces the organization's leadership to select a set number of projects so the overall budget isn't exceeded. How should this organization select the projects that are undertaken? What criteria (other than budget) should be used? Should forced ranking be used or would strategic value be a better option? How about project risk levels or Return on Investment? All of these criteria are correct and plausible choices and can be used to select projects in a one-constraint environment, but the project selection solution space is larger than most realize.

In the above example with one constraint, there are 2^{26} (67,108,864) possible project selection possibilities. Of course, most of these possibilities aren't optimal (e.g., select only one project even though the project cost is much less than the budget constraint) so they aren't necessarily viable solutions.

When there are two constraints placed on the project selection process, the project selection solution space gets to be so large as to not allow for optimal solutions without help from a computer system. Using optimization tools and techniques to assist with the selection process can provide a great deal of benefit to an organization. These tools can help an organization select the optimal project portfolio mixture to gain the maximum benefit from project resources (budgets, personnel, etc).

A Real World Project Selection Problem

The project selection problem described above exists with one of my clients. The client has recently started a project portfolio management initiative and is having difficulties with the project selection phase of portfolio management. Specifically, the portfolio management team is having trouble choosing the optimal project selection mixture. Rather then work to understand how to optimize the project selection process, the portfolio management team has begun to ask the organizational leadership for guidance on which projects are more important. The response form 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, 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, 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 limited 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.

Table 1 - *Project Portfolio (** denotes special consideration projects)*

Project	Project Name	Resource LOE (hrs)	Cost
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	Print Solutions **	250	$23,500.00
G	On Demand Communications	750	$78,750.00
H	Helpdesk software improvements	300	$22,800.00
I	Server upgrades	450	$33,750.00
J	SharePoint implementation	1,205	$102,425.00
K	Innovation website	350	$36,750.00
L	Marketing website	125	$11,875.00
M	Google mini 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	Phone system improvement	325	$29,250.00
T	PeopleSoft improvements	450	$53,550.00
U	Ecommerce upgrade	650	$66,300.00
V	Finance system upgrades	825	$69,300.00
W	Health & Wellness Tracking	775	$59,675.00
X	Board Portal	900	$75,600.00
Y	Website Redesign	875	$83,125.00
Z	Communication approval process	175	$21,000.00
	Totals	**14,805**	**$1,408,220**

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:

$$Z = \sum_{i=0}^{n} a_i X_i \qquad (1)$$

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) ≤ $750,000
- Total Project Hours (H) ≤ 7,750

These constraints can be described in mathematical terms as:

$$\sum_{i=0}^{n} C_i \leq \$750{,}000 \qquad (2)$$

$$\sum_{i=0}^{n} H_i \leq 7{,}750 \qquad (3)$$

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.

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 <= 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  <= 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:

$$MAX = A+B+C+D+E+F+G+H+I+J+K+L+M+N+O+P+Q+R+S+T+U+V+W+X+Y+Z; \qquad (4)$$

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:

$$@bin(term); \qquad (5)$$

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 <= 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(B); @bin(C); @bin(D); @bin(E); @bin(F); @bin(G); @bin(H); @bin(I);
@bin(J); @bin(K); @bin(L); @bin(M); @bin(N); @bin(O); @bin(P); @bin(Q); @bin(R);
@bin(S); @bin(T); @bin(U); @bin(V); @bin(W); @bin(X); @bin(Y); @bin(Z);
```

The LINGO model for the three projects given special consideration is shown in Table 4. Take note of Projects B, E and F being assigned a value of '1' to account for the fact that they are considered to be 'special' and must be included in the project selection mix.

Table 4 - LINGO Model #2 - with special consideration given to three projects (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(N); @bin(O);  @bin(P); @bin(Q); @bin®; @bin(S); @bin(T); @bin(U);
@bin(V); @bin(W); @bin(X); @bin(Y); @bin(Z);
```

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 #1 (shown in Appendix A) shows 18 projects being undertaken with a budget of selected projects of $715,995 and 7,630 hours. Model # 2 (shown in Appendix B), 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.

Conclusion

The model and decision support system described in this paper has provided a quick and easy method of project selection for my client. 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 (the a_i factor) 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. In addition, the model assumes that 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 assist in project selection.

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APPENDIX A – RESULTS FOR LINGO MODEL #1

Global optimal solution found.

Objective value:	18.00000
Objective bound:	18.00000
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	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

APPENDIX B – RESULTS FOR LINGO MODEL #2

Global optimal solution found.

Objective value:	17.00000
Objective bound:	17.00000
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0

Variable	Value	Reduced Cost
A	1.000000	-1.000000
B	1.000000	0.000000
C	1.000000	-1.000000
D	1.000000	-1.000000
E	1.000000	0.000000
F	1.000000	0.000000
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