Using Microcomputers To Improve Capital Decision Making

Richard L. Holmes, Rick E. Schroeder, and Laurie Frederick Harrington

Health care organizations have traditionally selected capital projects based on subjective measures such as medical staff priority, accreditation criteria, and regulations. In some cases, basic qualitative measures, such as payback period or profitability indices, have been used. The expected reduction in available capital that will result from changes in Medicare reimbursement and from managed care, as well as increased competition, will require health care decision makers to adopt more sophisticated methods of capital project evaluation in the future if they expect their organizations to remain viable. This article demonstrates, through the use of microcomputers and commonly used spreadsheet software, that the capital selection decision process can be improved and the optimal combination of projects, from a financial perspective, selected.
Key words: capital allocation, financial analysis, linear programming, risk assessment

Historically, hospitals have based their capital decisions on community and facility need, physician demand, accreditation requirements, and regulatory stipulations.\(^1\) However, with the expected reduction in Medicare reimbursement for capital; intense competition; the growth of investor-owned institutions; and, according to some authors, the fact that three of five capital investments do not produce the expected gain,\(^2\) more sophisticated methodologies are required to evaluate capital allocation decisions.

One survey of mostly not-for-profit hospitals found that only 30 percent of the respondents formally evaluated all their capital requests, and only 35 percent formally evaluated only about half of all their capital proposals.\(^3\) The primary methods utilized and the percentage of respondents who reported using each are shown in Table 1. The payback period, a relatively simplistic analysis, was the most commonly used method.\(^4\)

When comparing hospitals with industrial and service firms (which most frequently used the internal rate-of-return method), the researchers concluded that hospitals are less apt than other industries to use the more sophisticated capital evaluation tools. The survey showed that approximately 36 percent of hospitals account for risk, while 70 percent of industrial firms do so. The hospitals also reported that assessing risk was the most difficult task they encountered when evaluating capital proposals.\(^5\) These findings were validated in a series of surveys, which

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Table 1. Methods Used to Evaluate Capital Decisions

<table>
<thead>
<tr>
<th>Method</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting rate of return</td>
<td>12.9</td>
</tr>
<tr>
<td>Payback period</td>
<td>22.7</td>
</tr>
<tr>
<td>Discounted payback period</td>
<td>9.1</td>
</tr>
<tr>
<td>Net present value (NPV)</td>
<td>18.9</td>
</tr>
<tr>
<td>Internal rate of return (IRR)</td>
<td>19.7</td>
</tr>
<tr>
<td>Profitability index</td>
<td>15.9</td>
</tr>
<tr>
<td>Other method</td>
<td>0.8</td>
</tr>
<tr>
<td>No method</td>
<td>0</td>
</tr>
</tbody>
</table>

found that most hospitals use inexact methods of evaluation. Health care managers have shied away from an objective search for the optimal mix of projects because of the work involved. Each possible combination of projects must be evaluated to determine whether a firm’s potential total investment exceeds available capital. Even if only 15 projects are under consideration in a single budget year and each cannot be replicated or divided, there are still thousands of possible combinations of projects.6

While clinical factors and community need must be considered, it is evident that, due to the complexity of the process, the financial analysis as a complement to other considerations could use some improvement. There have been some articles recommending the use of Monte Carlo stimulation7 and the return-on-investment method in capital planning.8 However, the body of literature with examples, which would be helpful to the health care financial decision maker, is limited.

The purpose of this article is to provide the financial manager with a sound approach to capital decision making by incorporating a sophisticated quantitative tool into the evaluation of capital projects. This tool should enable decision makers to elevate the quantitative portion of the assessment process to a par level with subjective measures. The goal for the health care financial professional is to maximize revenues or minimize costs while producing the economic or social goods that define the mission of the organization. One means to accomplish this is through the use of linear programming methods, characterized by the establishment of an objective function that is to be maximized or minimized subject to a number of constraints.

This article presents an example in which profit maximization is the objective. The technique, however, is equally applicable to an organization seeking to maximize any quantifiable attribute. For example, in the case of a charitable organization, projects can be scored in terms of social value rendered, and the linear programming technique can then be used to maximize net present social value.

Manual accomplishment of this task is overwhelming, but microcomputer spreadsheet software includes capabilities to solve linear programming maximization problems. The following demonstration describes the resolution of a multiyear capital rationing problem using such software. The four basic steps involved are:

1. the analysis of each proposed project
2. the preparation of a spreadsheet with project and budget data
3. the development of a linear programming problem based on a model of the situation
4. the solution to the problem
Analysis of Proposed Projects

Four characteristics of each project must be identified. First, using discounted cash flow techniques and the firm’s weighted average cost of capital, the net present value (NPV) of each project is calculated. Just as with any research in which sound data are required for valid results of a statistical analysis, correctly calculating a realistic NPV of the expected projects is critical to the final outcome. A poorly calculated NPV will invalidate the results of the maximization problem. When establishing the NPV, a range of discount rates should be considered, and the discount rate varies from year to year as appropriate. This variation should provide a more realistic estimate of the actual NPV for a project that covers an extended period of time.9

Second, the startup investment of each project, if not already completed, is calculated. Third, the project should be evaluated for divisibility; that is, can the project be done on a limited scale, with a realization of a portion of the NPV? For example, an assisted living center that may be operated with half the proposed staff and half the projected patients is a divisible project; whereas a machine cannot be half-purchased and therefore is indivisible. Fourth, the project should be evaluated for replication; that is, could the project be repeated for the same gain in net present value? An example of a replicable project would be a satellite health clinic that could be replicated in several neighborhoods. Furthermore, for any project that is replicable, a maximum number of feasible replications should be established.10

The Spreadsheet

Excel 97 running on a Windows 95 platform was the software package used in this demonstration. Other spreadsheet software may work equally well. The spreadsheet (Fig 1) is prepared in sections: project information, budget constraints, discount rate (for a multiyear plan), decision matrix, and aggregate NPV. Each of these sections is described below.

Project information

- The project section uses one column for each project (A, B, C, etc.), with respective rows for NPV, initial investment required (Invested), indicator of divisibility (Y/N; divisible?), number of replications possible (“1” if not replicable; replicate?). Spreadsheet manipulation will be easier if the indivisible projects are entered in consecutive columns (see the last four items in Figure 1, Projects E though H). To simplify later operations, establish cell addresses or range names for each of the four rows of project data. (See Range Names in software instruction for assistance with this step.) For this discussion, the range names are assigned as shown in above in parentheses and in Figure 1.

Budget constraints

The budget constraint section uses one row for every year being budgeted. For each year there are two values in the columns: the constraint (available capital in that year), and the capital used in that solution. For this discussion, the names are assumed to be
<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
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<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
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<td>5</td>
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<td>$40,000</td>
<td>$82,000</td>
<td>$6,000</td>
<td>$55,322</td>
<td>$57,600</td>
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<td>6</td>
<td>Invested</td>
<td>$5,886</td>
<td>$4,988</td>
<td>$11,200</td>
<td>$4,900</td>
<td>$13,000</td>
<td>$24,322</td>
<td>$24,576</td>
<td>$2,000</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>Divisible?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Replicate?</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
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<td>12</td>
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<td>13</td>
<td>Constraints Actual</td>
<td>Decision Matrix (Decisions)</td>
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<td></td>
<td></td>
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<td>14</td>
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<td>$19,360</td>
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<td>3.88</td>
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<td>0.57</td>
<td>0.00</td>
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<td>0.00</td>
<td>5.00</td>
<td>Decision 3</td>
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<tr>
<td>17</td>
<td>Year 4</td>
<td>$35,000</td>
<td>$35,000</td>
<td>1.00</td>
<td>0.00</td>
<td>0.43</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Decision 4</td>
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<td>18</td>
<td>Replications</td>
<td>1.00</td>
<td>4.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>5.00</td>
<td></td>
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<tr>
<td>19</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>20</td>
<td>Discount Rate</td>
<td>6.50%</td>
<td>Aggregate</td>
<td>NPV</td>
<td>$617,072</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Figure 1.** Spreadsheet layout for maximization calculation.
“Capital Constraints” for the cells containing constraint values, and “Budget Actual” for the cells showing capital consumed.

**Discount rate**

The discount rate is needed for multiyear problems. It is not the same cost of capital rate that was used in calculating NPV figures, because inflation will affect projects deferred for a year, resulting in a greater NPV in that year. To correct for this, the discount rate used should be the firm’s average cost of capital less the expected rate of inflation for the coming year. Each firm’s discount rate will be different. A range name for this cell should be assigned. For this discussion, this cell’s name is “Discount Rate.”

**Decision matrix and aggregate NPV**

The decision matrix includes one column for every project and one row for every year. There must be the same number of years in the decision matrix as in the budget constraint section. For example, the top left cell in the matrix holds the first year. A zero means no part of a project is funded, whereas a “1” means the complete investment is included in the budget as the spreadsheet is completed. Divisible projects may have fractional decisions such as 0.5; meaning half of the investment is funded that year. Replicable projects may have numbers greater than 1, indicating a decision to fund more than one iteration of the project. The range (a row) of the decisions on projects for a single year should be named for each of the years. Here these names are “Decision 1” for the first year, “Decision 2” for the second year, etc. Name the entire decision matrix, “Decisions.” Decisions in the example are cells D14 through K17.

At this point it is good practice to check the name ranges to verify that there are named ranges for Aggregate NPV, Capital Constraints, Decision 1, Decision 2, Decision 3, Decision 4, Discount rate, Divisible?, Invested, NPV, Budget Actual, and Replicate?.

Because the relevant ranges were already named, a single result cell can hold a formula, which uses the spreadsheet’s capacity to multiply together corresponding items in two groups and add the totals together (the “=SUMPRODUCT” function in Excel). The cell’s entry is shown below:

```
=SUMPRODUCT (Decision 1, NPV) 
+SUMPRODUCT (Decision 2, NPV)/(1+Discount rate) 
+SUMPRODUCT (Decision 3, NPV)/(1+Discount rate)x2 
+...additional years if applicable
```

The primary result cell is named “Aggregate NPV.”

There are two other sets of results. The actual capital expended can now be calculated and placed in the budget section. The formula for the first year’s capital spending is:

```
=SUMPRODUCT (Decision 1, Invested)
```

Other years differ only in which decision number is specified in the formula. The total replications of projects may also be calculated, ensuring that nonreplicable projects were not planned more than once and that replicable projects did not exceed the maximum feasible replications. This total is calculated by adding one row under the decision matrix and in each of its cells placing =SUM (the cells immediately above it). This range of totals may be named “Replications.” The primary result will be the aggregate NPV of
Table 2. Constraints Applying to the Linear Programming Solution

<table>
<thead>
<tr>
<th>Constraint to be entered</th>
<th>Name</th>
<th>Comparison</th>
<th>Constraint</th>
<th>Effect of constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Decisions Replications</td>
<td>≥</td>
<td>0</td>
<td>Prohibits &quot;negative&quot; projects being done</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤</td>
<td>Replication limits for each year</td>
<td>Replications will not exceed maximum feasible</td>
</tr>
<tr>
<td></td>
<td>Budget Actual</td>
<td>≤</td>
<td>Capital constraints</td>
<td>Total investment in any year will not exceed the available capital</td>
</tr>
<tr>
<td></td>
<td>Select all decision cells</td>
<td>Integer</td>
<td>Divisible? (N)</td>
<td>Prohibits decisions to do only a fraction of a nondivisible project</td>
</tr>
<tr>
<td></td>
<td>under nondivisible projects</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

all selected projects. In essence, this is the sum of the NPV of projects selected initially, plus the sum of projects selected for the second year but discounted one year into present value, etc. Finally, set the numeric format of the cells in the decision matrix to two decimal places to prevent rounding inconsistencies.

After completing these steps, the basic spreadsheet will be ready to begin the optimization exercise. A "seed value" of 1 is inserted in any cell in the decision matrix. The amount in the Budget Actual cell should equal the invested amount for that project if the spreadsheet was built without error. The "1" must be left in at least one cell for the software to search for better decision solutions.

Preparation of the Linear Programming

The linear programming function in the spreadsheet can now be utilized in Excel by selecting "Tools" and then "Solver" from the Excel menu. The problem is then described in terms of the objective, the decisions to be made, and the constraints required by any linear programming calculation, as follows:

1. The objective is described by entering "Aggregate NPV" in the appropriate window of the solver, labeled "target cell," and checking the "max equal to" cell. Spreadsheets usually select a default setting to maximize this value, which is appropriate here. However, this same technique could be used to solve cost minimization by changing this to the "minimize" setting. Note: Be sure to have given your aggregate NPV a range name, "Aggregate NPV."

2. The program calculates the decisions by entering "Decisions" into the appropriate window, labeled "changing cells."

3. The constraints are made by selecting "Add" in the "Subject to the Constraints" instruction. This will produce a template calling for each constraint to be described as a comparison between two values (cell reference and constraint). In addition, the direction of inequality must be specified (de-
faulting to "less than or equal"). There is a special comparison choice of integer, which limits the named cell to only integer values. Table 2 and the instructions below show the constraints to be entered, and what they accomplish.

Constraints will have to be entered for the following:

- **Budget Actual** less than or equal to Capital Constraints (by year)
- Replications less than or equal to Replicate? (Set by each project)
- Divisible—integer solutions are forced for nondivisible projects by highlighting the entire decision matrix cells (in nondivisible project columns) for the constraint cell and selecting integer for the comparison
- Aggregate NPV greater than or equal to 0
- Decisions greater than or equal to 0

After all constraints have been entered, the "Solve" selection instructs the computer to seek the optimum solution. It is possible the solution will not emerge within the maximum number of tries allowed by the software. If the solution is reached, record it and direct the software to solve again; this will verify the aggregate NPV. If a solution is not reached ("Maximum iterations reached" or "Maximum time exceeded"), use the "Options" choice to increase the number of iterations or maximum time permitted.

### Interpretation of Resource Maximization Spreadsheet

The decision matrix displays the optimal set of projects. Each nonzero number in the matrix indicates that the project of that column should be funded in the budget year of that row. If the number is a fraction, the optimal solution takes a portion of a divisible project. If the number is greater than one, the optimal solutions replicates a project that is able to be replicated. Each row of the decision matrix gives the capital budget for a different planning year, but all decision rows together form the optimal set of projects and timing for the greatest aggregate NPV.

In this example, eight projects are being considered for implementation over a period of four fiscal years. Projects A, B, C, and D are divisible, indicating that they can be completed in phases over a period of multiple years. Projects E, F, G, and H are not divisible; they must each be completed within a fiscal period. In addition, note that projects B and H may be replicated. For example, project B may represent the development of a clinic. The organization desires to develop four clinics using the same implementation process for each.

The solution reveals the optimal combination of projects to be undertaken and the implementation schedule, year by year, to maximize the NPV of capital investments. During the first year, the organization should invest in the implementation of project B in three replications and begin on a fourth. Since this project is divisible, 88 percent of the fourth replication will be initiated. In the second year, resources should be allocated to completely implement project G. The third year is used to implement project E and five replications of project H, and to complete the fourth replication of project B. The first 57 percent of project C will be developed. Finally, in the fourth year in our example, project C is completed, and the rest of the capital budget funds projects A and F. Project
D is not selected for development.

Conclusion

This process can be performed in about the same amount of time as less sophisticated capital analysis methods. Considering the increasing pressures on the health care industry, this tool will assist the decision maker when difficult capital allocation questions must be addressed to ensure capital efficiency and financial viability.

REFERENCES
