# A Decision Support System for Resource Allocation

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*Abstract:* - This paper concerns the design of decision support systems (DSSs) which help financial managers in evaluating proposals for strategic and long-range planning. With the proposed two-phased DSS, projects are first selected from a given pool according to greedy heuristics based on the project's preferences as well as the project's efficiency. Then, integer programming with an approximation algorithm is used in the second phase to re-evaluate those proposed projects which met the first phase criteria.

*Key-Words:* Decision Support System, Resource Allocation, Analytic Hierarchy Process, Project Preference

## 1 Introduction

Investment decisions may be tactical or strategic. A tactical investment decision generally involves a relatively small amount of funds and does not constitute a major departure from what the firm has been doing in the past. Strategic investment decisions may involve large sums of money and may also result in a major departure from what the company has been doing in the past. Acceptance of a large strategic investment will involve a significant change in the company's expected profits and in the risks to which these profits will be subject [2]. A capital budgeting decision represents a long-term investment decision. As a result, many corporate managers continually apply formal capital budgeting procedures in order to achieve good financial management.

The proposed decision support system enables the financial manager to evaluate investment alternatives based on qualitative data rather than quantitative data in a systematic way and to make the most preferable investments that are possible within the constraints of limited capital. Thus, the capital rationing decision associated with strategic or major projects can be intimately linked to overall corporate planning and policy decisions.

## 2 A Two-phased Approach for Project Selection

In viewing the project selection activity as a decision-making process, we note that the intelligence phase is concerned with gathering relevant data about each candidate project and the criteria used to make a final decision; whereas the design phase relates the project characteristics to various criteria. Finally, the choice phase requires the use of an appraisal strategy to arrive at a final decision, i.e. a project portfolio [1]. A logical manner of handling this rationing is to rank-order projects, and to accept the highest-priority projects until the mandated budget level is reached, or the hurdle rate is reached, whichever constraint is imposed by management.

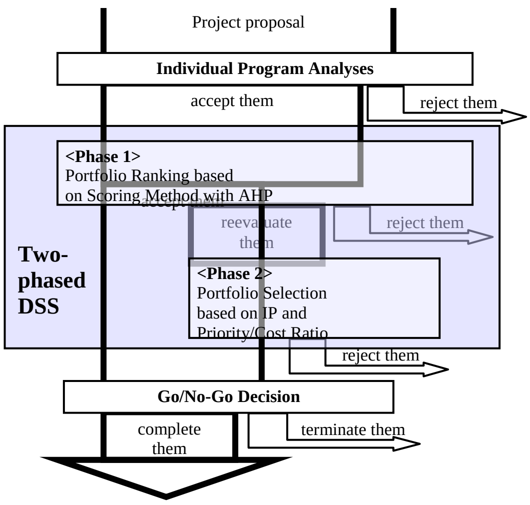


Figure 1. Project Selection Process

The project portfolio for investment planning is selected through the two phased evaluation of proposals in this research (See Fig. 1). This two-phased approach is a variation of the model suggested by Liberatore [4] . Liberatore uses integer programming (IP) in R&D project selection with the input generated from applying AHP for efficiency calculation. Each proposal has a score after the AHP is completed. The score represents the priority of the project. The alternative with the highest score is the one preferred. The proposals are ranked based on the score. Whether or not the manager should accept the proposal is determined by the greedy heuristics using its rank and the given budget.

## 3 Architecture of the Two-phased Decision Support System

The two-phased decision support system (TPDSS) follows three traditional major functions or conceptual components proposed by Sprague and Carlson [9]: the management of data, the management of models, and the management of dialogue between the user and the system. Each component of DSS, except the dialogue component, consists of a base (storage) and a management system. Fig. 2 depicts the three-way linkage among the data, model, and dialogue management of the two-phased DSS in general form.

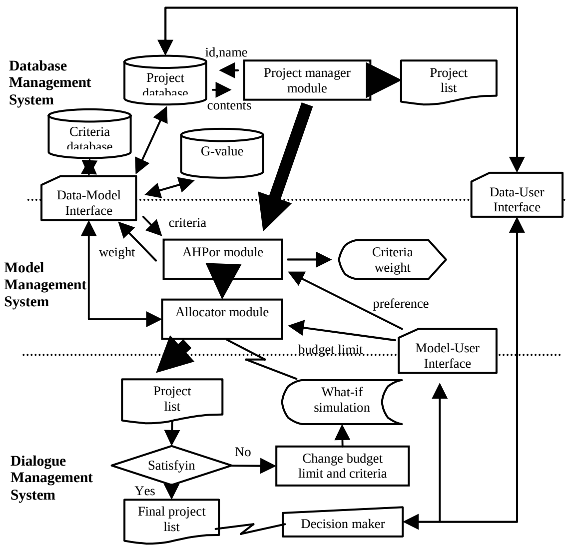


Figure 2. Conceptual Architecture of TPDSS

### 3.1 Modelbase and its Management

A DSS is the computer-based information system that supports semi-structured or unstructured decisions. Due to the complexity of these decisions, decision makers need the proper mathematical and/or analytical models to improve their performance. Therefore, the model subsystem is identified as one that distinguishes a traditional transaction-oriented data processing system from a DSS.

The analytic hierarchy processor (AHPor), statistic analyzer, budget constrainer, ranker, and integer programming formulator and solver (IPFSor) constitute the modelbase of TPDSS. The AHPor and IPFSor are the core of the modelbase.

The AHPor, which consists of a priority calculator and a consistency checker, determines the weights of criteria in the first phase evaluation. Golden and Wang [3] proposed a new measure of consistency, the G-value, which is a function of matrix size because Saaty's consistency ratio [8] was arbitrary and the 10 percent cut-off rule was too easy to satisfy for small matrices and too hard to satisfy for large matrices.

The general form of the model in phase one is:

$$S_j = W_1R_{1j} + ... + W_iR_{ij} + ... + W_nR_{nj}$$

where,

- $n$ = the number of the criterion
- $S_j$ = the score for the j-th alternative
- $W_i$ = the weight assigned to the i-th criterion
- $R_{ij}$ = the rating assigned to the i-th criterion, which reflects the performance of alternative j relative to maximum attainment of the criterion

A detailed description of the modeling component in phase two is as follows:

Let

- $n$ be the number of projects under consideration
- $T$ be the total budget remaining
- $B_i$ be the required budget of i-th project
- $R_i$ be the priority-to-cost ratio of i-th project
- $X_i$ 1 if i-th project is selected
  0 otherwise

We wish to maximize:

$$X_1R_1 + ... + X_iR_i + .... + X_nR_n$$

subject to:

(1) budgetary constraint:

$$X_1B_1 + ... + X_iB_i + .... + X_nB_n \leq T$$

(2) integer constraints:

$$X_i = 0, 1 \quad \text{for all } i.$$

The budget constrainer, IPFSor, and ranker constitute the allocator. IPFSor is triggered as soon as the first phase evaluation is completed. It maximizes the priority-to-cost ratio over the projects, subject to budgetary constraints. In this research, we implement a branch and bound algorithm proposed by Martello and Toth [5]. The algorithm starts by building the first integer solution. Then a depth-first branch and bound search is performed. The building phase, which finds the largest possible set of new consecutive elements to be introduced into the current solution, is followed by the saving phase, which updates the current solution found by the building phase, only if an upper bound does not exclude that the obtainable current solution could, through subsequent forward moves, improve on the current optimal solution; otherwise a backtracking move immediately follows. The budget constrainer with the statistic analyzer in TPDSS displays the percentage of each proposal according to the proper criteria in the scoring sheet. The manager will use this ratio as an indicator to balance the budget among competing proposals.

### 3.2 Database and its Management

Database design is typically divided into four phases: (1) requirements specification; (2) conceptual design; (3) logical design; and (4) physical design. The requirements specification phase is concerned with identifying the information needs of various users or groups. The conceptual design phase models the users' and applications' views of information. During the logical design, the conceptual schema is translated into the logical data model of the selected DBMS. Finally, physical database design transforms the logical data model into a form that is suitable for the specific hardware and DBMS that are to be used [3]. We use the entity-relationship model for the conceptual database design, and for the logical design, we convert the entity-relationship diagram to a relational database scheme.

The data management component of DSS maintains the factual basis. The database provides parameters for the model and stores the results of the model execution. Thus, the management of data, that is the ability to store, retrieve, and manipulate data, is fundamental to any service that a DSS provides. TPDSS uses various databases in the third normal form along with an appropriate index file to accelerate access to the databases. The databases for the comparison, the evaluation criterion, and the proposal are mandatory. The applicative environment requires various additional databases.

### 3.3 Dialog System

In whatever form, DSS usage involves a dialogue between the user and the DSS. Although the model can be treated as a black-box whose algorithm and solution procedures need not be understood by the decision-maker, it should generate and compare alternatives in fairly simple and transparent terms. In view of this, the dialogue management subsystem focuses attention on the user-model interface to enable the decision-maker to enumerate the project evaluation. Even if the DSS provides extremely powerful functions, it may not be used if the dialogue is found to be unacceptable. Therefore the success of the DSS depends heavily on the degree of user-friendliness. In other words, from the user's point of view, the dialogue system is the DSS itself. Accordingly, dialogue style, the nature of the interface between the system and the user, includes question/answer style, command mode, input/output form, menu-driven dialogue, and natural language including combinations of these [11].

A two-phased DSS accepts the menu-driven system as its dialogue management system. Menu selection systems are attractive because they can eliminate training and memorization of complex command sequences. When the menu items are written using familiar terminology, users can select an item easily and indicate their choice with one or two key presses or use of a pointing device. It guides the decision-maker through the evaluation by appropriate prompts and questions. When a choice or decision is needed, the TPDSS presents a menu of alternatives. This simplified interaction style reduces the possibility of keying errors and structures the task to guide the novice and intermittent user. With careful design and high-speed interaction, menu selection can become appealing to expert and frequent users as well.

## 4 Two-phased Decision Support System Operation

Investment managers may operate the system according to a regular periodic schedule to set the future investment plan, or they can re-evaluate the investment alternatives as often as the economic and social environment changes.

The operation of the system begins in Block 0 with the request of the new project proposal evaluation (See Fig. 3). The computer eliminates the previous evaluation results such as the weight of criteria and the priority matrix, and resets the value of approved flags in the proposal database. At the same time, the future planning horizon is shifted forward one time period (Block 1).

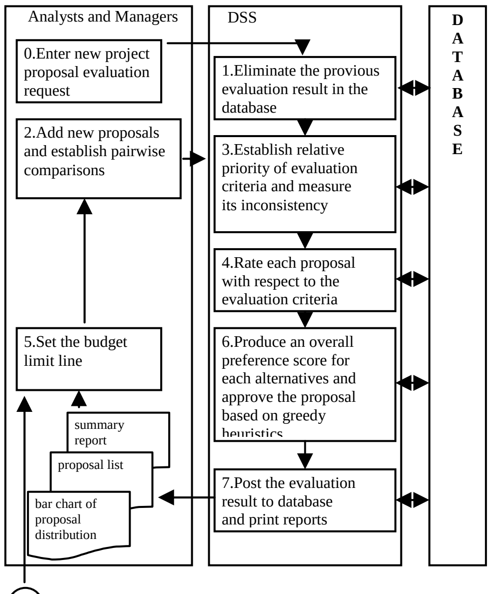


Figure 3. Two-Phased DSS Usage (to be continued)

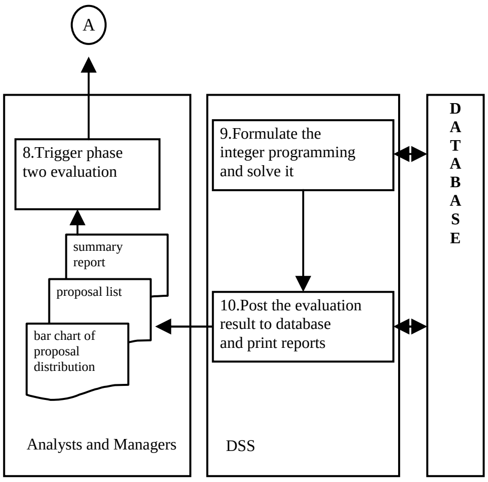


Figure 3. Two-Phased DSS Usage (continued)

Once the new proposals are added, pairwise comparisons to evaluate the multiple decision criteria are conducted. This allows managerial judgments to be included formally and systematically in the investment justification process (Block 2). The computer calculates the relative priorities of evaluation criteria and measures their consistency. This enables managers to focus on those aspects of the decision that need refinement or have the highest degree of uncertainty, namely, inconsistency (Block 3). Based on the weight in Block 3, each proposal is rated with respect to the evaluation criteria. The linear additive model is used to identify the alternatives which are more preferred (Block 4). When the manager sets the budget limit line (Block 5), the system provides an overall preference score for each alternative and then orders alternatives to approve the proposal based on greedy heuristics (Block 6). The output reports are printed after the evaluation results are posted to database (Block 7), and become the topic of discussion. Managers examine the initial set of reports, compare them with previous plans, and with goals and objectives. If they wish to submit some modification to the decision guideline, the program is re-entered at Block 2, and a new set of pairwise comparisons is prepared.

The re-evaluation does not consider the proposals which are ranked beyond the boundary because they are dominantly either better or worse. Triggering the phase two evaluation (Block 8) makes the computer formulate the integer programming to maximize the priority-cost ratio subject to the budget constraints (Block 9). Then, the solution of the integer programming is posted to the database, and the computer prints and graphs the reports (Block 10). The manager can simulate an investment package which meets various budget limit lines. Recycling from Blocks 2 through 10 ultimately produces an approved plan for the coming planning horizon which ensures the balanced allocation of limited financial resource among the competing proposals. This capability gives the manager the option to answer "what if" questions.

## 5 Conclusions

The primary aims in this research have been (1) to establish formal information system development methodologies to aid the financial manager in resource allocation; (2) to develop an integrated two-phased decision support system architecture based on the analytic hierarchy process and integer programming; and (3) to implement the proposed architecture. Even though this work is not intended to improve the theory of project allocation, several contributions can be expected from this study in the area of information system for resource allocation.

First, it demonstrates the decision support system as a valid decision aid for resource allocation problems. According to Rosenblatt and Jucker [7], resource allocation among competing projects is the everyday work of the financial manager. However, coalitions, interpersonal factors, bargaining and politics often play an important role in the selection or rejection of capital budgeting projects [2] because an appropriate information system is not available. Therefore a decision support system is mandatory to protect limited budgets and secure effective capital rationing.

Second, instead of using different commercial DSS tools as in [4], a two-phased decision support system has been proposed to integrate microcomputer-based software for project selection and resource allocation (See Fig. 4). The TPDSS uses Golden and Wang's G-value consistency index, which is an improvement over Saaty's random consistency index. The zero-one knapsack problem solver is implemented based on Martello and Toth's branch and bound algorithm. Using a project selection grid, the projects are ranked according to preference of investment as well as efficiency of investment. The TPDSS is intended to be general so that a specific decision support system can be modified according to its decision environment.

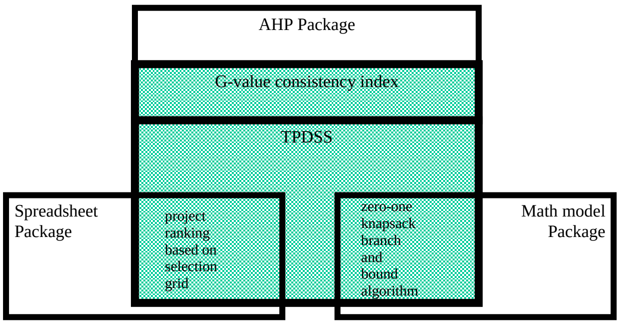


Figure 4. Features of TPDSS

There are also number of future improvements which could be made to the TPDSS to enhance its usefulness. To begin with, the proposed model lacks handling ability for the front-end and the back-end of the DSS. As depicted in Fig. 1, the project selection process consist of (1) individual program analysis, (2) portfolio selection, and (3) go/no-go decision. This leads to the development of an integrated system containing several heterogeneous subsystems to cover all the project selection process.

Second, further integration with other computer-based information systems such as an executive information system can be sought. Long-range planning related project selection has strategic aspects because the organization's future market and financial position depends in large measure on the project proposals which are selected today. Strategic and policy planning and decision-making has been considered the major task of executives.

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