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Title: EXTENDING THE PLANNING CAPABILITY OF ZERO-BASE AND FLEXIBLE BUDGETING THROUGH THE USE OF RPM NETWORKS AND OPTIMIZATION TECHNIQUES

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The viability of incorporating optimization within budgeting methodologies is examined.

Resource Planning and Management System and optimization are proposed as tools to enhance the planning and control functions of the budgeting process. Three hypotheses are proposed: (1) Integer Programming, Integer Goal Programming and Dynamic Programming can be substituted in place of traditional ranking techniques utilized in zero-base budgeting; (2) Linear Programming and RPM networks provide more objective and meaningful data to management in flexible budgeting; and (3) Linear Programming and RPM networks serve to integrate zero-base budgeting and flexible budgeting.

A simplified example including ten decision packages (23 decision variables) of zero-base budgeting is designed to test the theoretical validity of the first hypothesis.

The Cathode Ray Tube production plant in electronic industry is chosen as the prototype upon which to construct mathematical models to test the second and third hypotheses. Two major RPM network models were constructed. The first model focused upon the manufacturing of components used in the CRT production and detailed the daily operation to provide data for flexible budgeting. This model included 81 activity processes and 93 resource constraints. The second model depicted the management process for the entire plant and was used for flexible budgeting and to validate data for zero-base budgeting. This model included 521 activity processes and 523 resource constraints.

The following conclusions were drawn by the CRT management: (1) the graphical representation of the RPM networks was found effective in understanding the interrelationships between budgeting decisions, activity processes and resources involved; (2) optimization techniques were found helpful to the management in both zero-base and flexible budgeting; (3) further work is needed to fully integrate the operations research techniques as commonly accepted tools for decision making within the corporate budgeting structure.

Extending the Planning Capability of Zero-Base and Flexible Budgeting Through the Use of RPM Networks and Optimization Techniques

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EXTENDING THE PLANNING CAPABILITY OF ZERO-BASE AND FLEXIBLE BUDGETING THROUGH THE USE OF RPM NETWORKS AND OPTIMIZATION TECHNIQUES

I. INTRODUCTION

Budgeting has been defined as a "planning and control system" (Jones and Trentin, 1971, page 2). This concept is justified only to the extent that it serves to facilitate performance of the management process (Welsch, 1976, page 4). Hence, in order that budgeting systems be successfully implemented, they must provide adequate planning and control mechanisms consistent with policies and objectives of the organization. Two separate budgeting techniques have emerged in an attempt to fulfill the above needs of management: zero-base budgeting and flexible budgeting; the Resource Planning and Management System is proposed in this thesis to enhance the managerial characteristics of those budgeting techniques and to relate them in areas of interaction.

A. Zero-Base Budgeting

Zero-base budgeting is a practical managerial tool for evaluating expenses (Pyhrr, 1973). Its use is limited to activities and costs not directly associated with the manufacturing process; although zero-base budgeting is usually performed on a year-to-year basis, long-term considerations may be included in the decision process. Most manufacturing overhead activities and costs may be planned and controlled with this approach, but information to and from flexible budgeting is desirable for effective planning and control purposes (Pyhrr, 1973, pages 107-111).

The process of allocating resources under zero-base budgeting is based on priorities assigned to activities according to benefit-cost implications; this process does not guarantee (from the theoretical point of view) optimal allocation of resources.

B. Flexible Budgeting

A flexible budget is one that automatically adjusts for changes in production output (Zimmer and Gray, 1973). Flexible budgeting is associated with the manufacturing process, and it provides an adequate control mechanism for direct materials, direct labor and manufacturing overhead; however, it does not provide management with a tool that effectively gives information and support for planning decisions.

C. RPM Networks

The Resource, Planning and Management network has been defined by Eckholt (1976, page 2) as follows:

> . . . it is a graphical representation of flows of resources through various processes of transformation within a system. The network is intuitively obvious to anyone familiar

> with the operations described, but rigorous enough to be interpreted mathematically and processed by computer programs to yield theoretically correct solutions.

The RPM networks used in this thesis include linear relationships and deterministic values. These assumptions facilitate construction and understanding of the models, but also reflect crude approximations and may hide the effects of not including stochastic phenomena in the model (Eckholt, 1976, page 3).

D. Structure of the Thesis

This thesis describes zero-base and flexible budgeting as they are currently being implemented at Tektronix Inc.; optimization techniques are proposed to improve the allocation of resources in zero-base budgeting and the models are presented with both mathematical expressions and RPM networks.

RPM networks are proposed to extend the planning mechanism of flexible budgeting and to relate it to zero-base budgeting in areas where the two budgeting methods may interact (especially in production support activities). This approach is illustrated by presenting a model developed for Cathode Ray Tube production area in Tektronix Inc., and an evaluation of such a model given by the CRT management is included in Chapter VI.

Table 1.1 shows the areas for which zero-base and flexible budgeting may be used as well as the areas of applicability of RPM networks and optimization to both budgeting systems as proposed in this thesis. A brief explanation on the RPM methodology is included in the Appendix.

Table 1-1. Areas of applicability of zero-base and flexible budgeting, and their relationship to RPM networks and optimization techniques.

Activity / Approach	Direct Material	Direct Labor	Manufacturing Overhead	Activities and costs not directly associated with manufacturing	Reference in this Thesis
Zero-base budgeting.	Not applicable	Not applicable	Applicable in most areas; relationship to flexible budgets is desirable. (Pyhrr, 1973)	Provides adequate planning and control mechanism. (Pyhrr, 1970; Pyhrr, 1973; Davis , 1975; Stonich, 1976)	Described in Chapter II
Flexible budgeting.	Adequate control mechanism. It is not a planning tool in itself. (Jones, 1971; Welsch, 1971; Horngren, 1972; Zimmer and Gray, 1973)			Not generally used.	Described in Chapter IV
RPM and optimization.	Complement flexible budgeting by providing a planning tool.		May relate flexible and zero-base budgeting in some service and support areas; planning is thus based on optimal decisions.		Description and examples of application in Chapters III and V.

II. THE ZERO-BASE BUDGETING PROCESS

A. The Need for Zero-Base Budgeting

Zero-base budgeting was first implemented in the preparation of the 1970 budget for the Staff and Research Divisions of Texas Instruments (Pyhrr, 1973, page xi). Before that year, the budgeting process for activities and costs not directly associated with the manufacturing process was traditionally based upon the current budget as the starting point and focused attention on attempting to justify incremental budget requests (Davis, 1975, page 10).

The traditional approach had not met the fundamental requirements of an effective budgeting system, i. e., providing an adequate planning and control mechanism to fulfill the needs and objectives of the organization (Jones and Trentin, 1971, page 1). Stonich (1976, page 1) identified the following weaknesses of the traditional approach:

> a) The cost center manager does not do a good job for analyzing his operation. For example, he is not asked to examine alternatives; he does not determine his base activities; nor does he intertwine budgeting, planning and decision-making.
>
> b) The general manager is not able to allocate resources on the basis of costs and benefits because he does not have well-organized, appropriate data available to him.

Pyhrr (1973, page x) identified the lack of realistic goals, the lack of operating decisions affecting the amount of money and the fact that the budget dollars were not strictly allocated in accordance with changing responsibilities and work loads. Based on this identification, he developed the zero-base budgeting process.

Zero-base budgeting is best applied to service and support areas of the company. The reason for this is that at the manufacturing area, the level of activity is determined by the sales volume; and this level, in turn, determines the expenditures on labor, materials and overhead. On the other hand, the relations between costs and benefits for service and support areas are rarely linear or simple; thus, zero-base budgeting is ideally applied in areas where expenditures are not directly determined by the manufacturing operations, and where managers have discretion to choose between different levels of activity having different costs and benefits (Pyhrr, 1970, page 112).

Applications of zero-base budgeting in government are also possible because government is a service organization that provides benefits for the tax dollars spent (Pyhrr, 1973, page 24), and the level of activity is also determined by the service provided. In fact, zero-base budgeting was first applied to government activities in the State of Georgia for the Fiscal Year 1973. Since then, the process has been adopted by other governmental agencies (Pyhrr, 1973, page xi).

B. Description of Zero-Base Budgeting

1. Concepts and Definition

> Zero-base planning (budgeting) is a tool that helps the cost center managers to analyze their operations better, and it allows general managers to allocate resources more effectively through:
>
> Proper identification of "decision units"
> Rigorous analysis of each "decision unit"
> Allocation of critical resources to appropriate activities.
> Preparation of detailed budgets (Stonich, 1976, page 1).

Even though a detailed description of the zero-base budgeting process is not provided in this thesis, the basic steps are described below and further discussions on specific aspects will be presented later in this chapter. The terminology used in the remainder of this paper tries to integrate and unify various terminologies and concepts used by various authors that have written on this subject.

The following is a description of the basic steps in the zero-base budgeting process, as described by Pyhrr (1970, 1973):

Step 1 - Development of decision packages

Step 2 - Evaluation and ranking of decision packages

Step 3 - Allocation of resources accordingly.

Stonich (1976) proposed the following steps:

Step 1 - Proper identification of decision units.

Step 2 - Analysis of each decision unit.

Step 3 - Allocation of critical resources.

Step 4 - Preparation of detailed budgets.

Although both descriptions are built around the same philosophy, the one by Stonich appears more appropriate for our study because, through it, we can follow a more structured framework in describing each step of the process.

2. Identification of Decision Units

The first step in the zero-base budgeting process is the determination of the "decision unit" around which the decision packages are developed (Tektronix, 1975, page 4)

> . . . the "decision unit" is the discrete grouping of activities around which analysis is centered. Decision units may include special projects, programs, organizational activities, objects of expense, or services rendered (Stonich, 1976, page 1).

The decision package is the building block of the zero-base budgeting process. It provides management with a description and evaluation of each level of service so that management review and decision-making may be facilitated (Tektronix, 1975, page 4).

The determination of activities that will be a part of a decision package is a key point of the zero-base budgeting process. The selection of a decision unit is based on how meaningful the unit is for analysis to the manager. The selection could be constrained by legal or industry policies, personnel specialization, size of operation, time constraints and available alternatives (Pyhrr, 1973; Tektronix, 1975).

3. Analysis of Each Decision Unit

When formulating decision packages, a manager responsible for the package must go through an analysis process that can be summarized in the following categories:

a) Current operations and method are examined.

b) Alternative ways of performing activities are considered.

c) New activities and programs are explored.

d) Incremental cost-benefit analysis is performed after the method of operation is determined (Pyhrr, 1973; Stonich, 1976).

The last category needs further elaboration: The incremental analysis is started by determining, from a base of zero, which is the most important service need provided by the decision unit. This is the minimum increment of service. In all cases, the first increment will require lower expenditures than is currently provided. Then, additional increments of service and cost are developed with each successive increment containing services that are next in order of priority (Stonich, 1976, page 2).

The results of this analysis are written in a decision package form. The purpose of the decision package form is to communicate the analysis and recommendations made by each manager for his activities and operations to higher levels of management for review and ranking (Pyhrr, 1973, page 62).

The format and content of decision packages should be prepared according to the size and specific needs of the organization. At Tektronix, Inc. for example, the decision package forms contain:

1. Purpose/objective.
2. Description of actions.
3. Workload and performance measures.
4. Resources required and benefits.
5. Impact on other departments or to the company if not funded.
6. Alternative means of accomplishing objectives.
7. Various levels of effort.

Figure 2-1 shows a fictitious but realistic example of a decision package prepared at Tektronix. This package consists of 3 incremental levels of effort (2 pages each level).

4. Allocation of Resources and Preparation of Detailed Budgets

Zero-base budgeting allocates limited resources through the ranking process. The ranking process forces management to list all the packages identified in order of decreasing benefit to the company. In doing so, management is constructing its answer to the two fundamental questions of budgeting: "How much should be spent?" and

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 1 of 3	CRT Manufacturing		5/6/74	

(6) PURPOSE/OBJECTIVE 1. Transfer new devices from Storage Design Engineering to Storage CRT Manufacturing. 2. Insure that the design of devices meets the requirements of customer and the limitations of manufacturing. 3. Provide technical support to Storage CRT Manufacturing and to reduce manufacturing costs through improved designs and/or manuracturing processes.

(7) DESCRIPTION OF ACTIONS (OPERATIONS) FOR THIS LEVEL

Four Engineers and seven Technicians:

a. Coordinate and accomplish the transfer of new devices and processes from Storage CRT Design Engineering to Storage CRT Production, (Project list is attached).

b. Provide direct support to Storage CRT Production department to maintain process and test yields (two Technicians are supporting Reject Analysis).

c. Also one Engineer will provide management support as a dual function.

(8) WORKLOAD/PERFORMANCE MEASURES	Period 12 Estimated	Period 13 Proposed
Number of new tubes/processes worked on.	5	5
Average yields on tubes.	55%	No more than 20% slippage from Period 12 average.

(9) RESOURCES REQUIRED	Period 12 Estimated	Description	Period 13 Proposed
Positions	18	This Level	11
		Positions Cumulative	11
Expense	100.0	This Level	60.0
		Expense Cumulative	60.0
		% of - Estimated	60%
Investment		Operating Equipment	

Figure 2-1. Decision package.

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 1 of 3	CRT Manufacturing		5/6/74	

(10) BENEFITS

Provides minimum level of support necessary to introduce those new devices and processes which it appears will be ready in Period 13 and cannot reasonably be delayed.

Provides the minimum level of direct support necessary to insure continuous output without major interruptions or drastic reductions in yields.

(11) CHANGES/IMPROVEMENTS FROM CURRENT OPERATIONS

The level of direct support is reduced by 50% with an expected increase in response time and a reduction in average yields by approximately 15% to 20%. A reduction in STP test yield of 20% from 55% to 35% would increase the STP rejects by approximately $150,000. Cost reduction projects have been eliminated. This eliminates approximately $400,000 savings at a minimum.

(12) IMPACT ON OTHER DEPARTMENTS OF NOT FUNDING THIS PACKAGE LEVEL

Storage CRT Manufacturing would not be able to support the introduction of new devices.

Storage CRT Production departments would have to find alternative sources of direct support.

Failure to accomplish the limited objectives of the projects listed would result in significant cost overage in Storage CRT Manufacturing.

This would also require that production resources be expanded to accommodate a larger throughput for a given output because processing yields were either not maintained or improved.

(13) ALTERNATIVE MEANS OF ACCOMPLISHING THIS PACKAGE

Rely on Storage CRT Design Engineering to provide all or some of the support. This is done already to provide coverage for periods of peak activity and when special skills are required. Additional support would not decrease the resources required by Tektronix and would result in a low efficient division of labor. Also, Storage CRT Design Engineering is not presently staffed to provide continual engineering support to Storage CRT Manufacturing. The engineering support can only be utilized during a manufacturing crisis.

Figure 2-1. Continued.

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 2 of 3	CRT Manufacturing		5/6/74	

(6) PURPOSE/OBJECTIVE 1. Transfer new devices from Storage Designs Engineering to Storage CRT Manufacturing. 2. Insure that the design of devices meets the requirements of customer and the limitations of manufacturing. 3. Provide technical support to Storage CRT Manufacturing and to reduce manufacturing costs through improved designs and/or manufacturing processes.

(7) DESCRIPTION OF ACTIONS (OPERATIONS) FOR THIS LEVEL

Three engineers and four technicians provide direct support to production department. Initiate and carry out cost reduction and performance improvement projects. (A project list is attached.)

(8) WORKLOAD/PERFORMANCE MEASURES	Period 12 Estimated	Period 13 Proposed
Average yields on tubes not included in cost reduction projects		55% Overall
Projected annual savings of completed cost reduction projects		$400,000

(9) RESOURCES REQUIRED	Period 12 Estimated	Description	Period 13 Proposed
Positions	18	This Level	7
		Positions Cumulative	18
Expense	100.0	This Level	35.0
		Expense Cumulative	95.0
		% of - Estimated	95%
Capital Investment		Operating Equipment	

Figure 2-1. Continued.

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 2 of 3	CRT Manufacturing		5/6/74	

(10) BENEFITS

a) Insures that the primary cost reduction and performance projects are carried out.

b) Increases the average yield expected by decreasing the reaction time to solve production problems.

c) Yields a significant increase in manufacturing efficiency through cost reduction projects.

(11) CHANGES/IMPROVEMENTS FROM CURRENT OPERATIONS

None.

(12) IMPACT ON OTHER DEPARTMENT OF NOT FUNDING THIS PACKAGE LEVEL

An increase in production disruptions and a decrease in yields due to a lower level of support on production problems.

Expected efficiency improvements would not be fully achieved.

(13) ALTERNATIVE MEANS OF ACCOMPLISHING THIS PACKAGE

As per Level 1.

Figure 2-1. Continued.

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 3 of 3	CRT Manufacturing		5/6/74	

(6) PURPOSED/OBJECTIVE 1. Transfer new devices from Storage Design Engineering to Storage CRT Manufacturing. 2. Insure that the design of devices meets the requirements of customer and the limitations of manufacturing. 3. Provide technical support to Storage CRT Manufacturing and to reduce manufacturing costs through improved designs and/or manufacturing processes.

(7) DESCRIPTION OF ACTIONS (OPERATIONS) FOR THIS LEVEL

Three engineers and four technicians - initiate and carry out cost reduction and performance improvement projects. (A project list is attached.)

(8) WORKLOAD/PERFORMANCE MEASURES	Period 12 Estimated	Period 13 Proposed
Average yields on tubes not included in cost reduction projects.		3% Improvement
Projected annual savings of completed cost reduction projects.		$50,000

(9) RESOURCES REQUIRED	Period 12 Estimated	Description	Period 13 Proposed
Positions	18	This Level	7
		Positions Cumulative	25
Expense	100.0	This Level	20.0
		Expense Cumulative	115.0
		% of Estimated	115%
Capital Investment		Operating Equipment	

Figure 2-1. Continued.

(1) Package Name	(2) Department	(3) Prepared By	(4) Date	(5) Rank
Storage CRT Prod. Engineering 3 of 3	CRT Manufacturing		5/6/74	

---

(10) BENEFITS

An increase in the average yield due to increased direct support and additional cost reduction projects.

---

(11) CHANGES/IMPROVEMENTS FROM CURRENT OPERATIONS

Additional support is offered in the deposition and pumping area. This will aid in additional understanding and control of process variables and will result in approximately a $12,000 savings.

Assuming a 10% increase (from 80% to 90%) in P3 yield, this project should result in approximately a $125,000 savings.

---

(12) IMPACT ON OTHER DEPARTMENTS OF NOT FUNDING THIS PACKAGE LEVEL

The additional cost savings and yield improvements would not be realized.

---

(13) ALTERNATIVE MEANS OF ACCOMPLISHING THIS PACKAGE

As in Level 2.

Figure 2-1. Continued.

"Where should the resources be spent?" (Pyhrr, 1970, page 116).

The initial ranking occurs at the cost-center level where the packages are developed. Managers evaluate their own activities and rank them accordingly.

Then, the division head, or the next higher level manager reviews these rankings with the cost-center managers themselves, using their rankings as guides to produce a single ranking for all packages presented to him from below (Pyhrr, 1970, page 116).

When the final ranking has been made at the upper consolidation level of the organization, the decision packages are arranged in order of decreasing benefit to the firm. The cummulative cost of the packages is calculated and finally the projected expenditure level identifies the "cut-off" point. All packages above the point are adopted for the new budget and those falling below are not supported. Since in some cases a small additional expenditure may result in significant benefits, management should consider the consequences of approving additional packages ranked below the expenditure level, before accepting the "cut-off" point as definitive (Davis, 1975, page 13). Pyhrr (1970) recommends that cut-offs be set before consolidation begins at any level.

To illustrate, suppose that at one consolidation level, three decision packages are to be ranked (A, B and C) and that each package is formed by four incremental cost-benefit levels (A1,A2...).

After the analysis described above, the packages will be in order of priority. This process is shown in Figure 2-2 which illustrates that the minimum increments A1, B1 and C1 are ranked first, followed by C2, C3, A2 and so on. If the projected expenditure level is represented by the cut-off line in the figure, all packages will be approved except A3, A4 and B4 (Stonich, 1976).

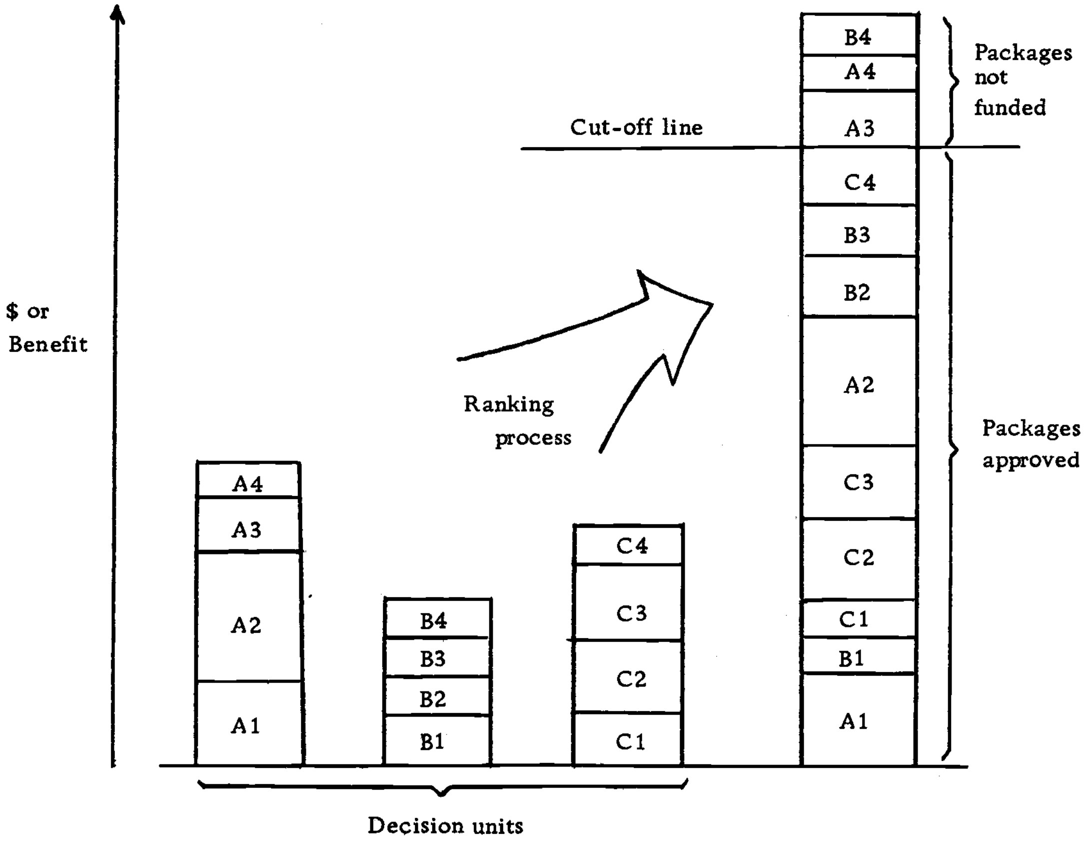


Figure 2-2. Allocation of resources through the ranking process in zero-base budgeting. Source: Stonich (1976, page 3).

After the allocation decisions have been made, the preparation of detailed budgets is a clerical function that can be aided by the ranking table prepared by management (Stonich, 1976, page 3).

It is important to note that the process is not as simple as it seems in the above overview. Evaluation and tradeoffs must be made at each organizational level where packages are ranked (Davis, 1975, page 13). However, implementation and ranking problems are also common problems in zero-base budgeting. The next section in this chapter deals with these particular problems.

5. General Problems in Zero-Base Budgeting

Two kinds of common problems are generally found through the zero-base budgeting process: Implementation Problems and Ranking Problems.

a) Implementation Problems: Stonich (1976, page 3) identified two basic implementation problems through his experience with 20 organizations:

1. Natural hesitancy of decision unit managers to participate.
2. Roadblocks to smooth administration of the process.

Based on his experiences, Stonich says that these problems can be overcome if the following conditions are met:

> The zero-base budgeting process must be individually designed for each organization. . . the organization structure, organization culture, and other planning

> and reporting processes must be studied before the appropriate zero-base budgeting system is designed. . . . The initial communication about zero-base budgeting must be well-conceived . . . second, a series of meetings should be devoted to (a) describing the process, (b) detailing responsibilities, (c) outlining benefits and (d) answering questions . . . it is imperative that managers be trained in the process . . . (Stonich, 1976, page 3).

b) Ranking Problems: According to Pyhrr (1973, pages 31-32) there are four common problems encountered during the ranking process. These problems, and the means for overcoming them are suggested as follows.

1. Determining who will do the ranking, to what level within each organization packages will be ranked, and what method or procedure will be used to review and rank the packages.

   This problem is overcome by grouping cost centers together according to the number of packages involved, and the time and effort required to review and rank them.

2. Evaluating dissimilar functions when higher levels of management are not familiar with the functions, especially when subjective judgment is required.

   The only way to overcome this problem is that managers become familiar with the activities ranked. Communication and understanding between different levels of management are improved when solving this problem (Davis, 1975, page 14).

3. Ranking packages considered high priorities.

   This problem can be avoided by:

   (a) Not concentrating on ranking high priority packages that are well within expected expenditure levels, but concentrating instead on discretionary functions and levels of effort.
   (b) Not spending too much time worrying over whether package 4, for example, is more important than package 5, but instead only assuring themselves that packages 4 and 5 are more important than package 15 . . . (Pyhrr, 1973, pages 31-32).

4. Handling large volumes of packages.

   The volume problem may become a critical one in the zero-base budgeting process. Pyhrr (1973, pages 79-87) proposes the following ways to solve this problem:

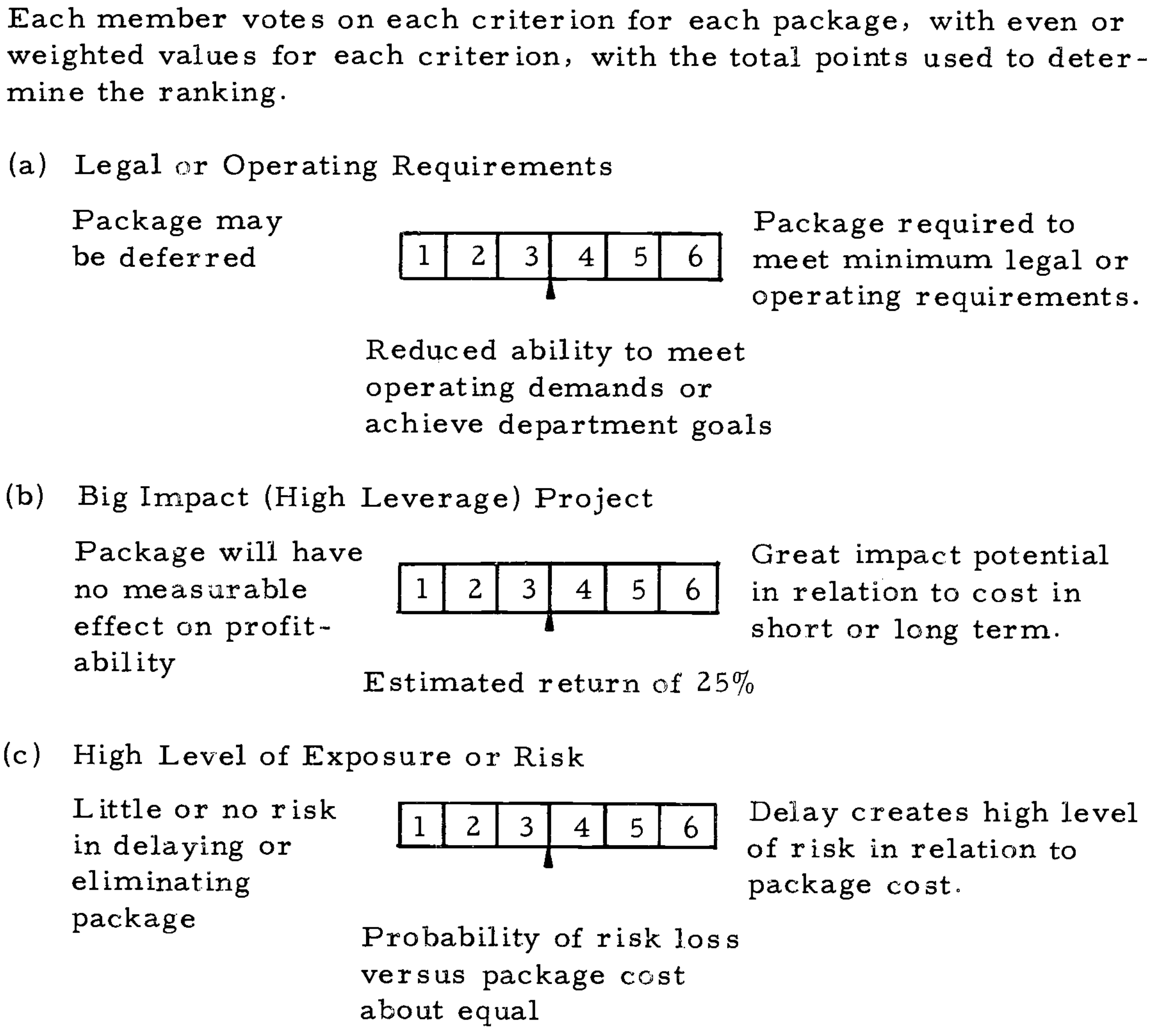
   1. Concentrating management's review on lower priority packages around which the funding levels or cut-off will be determined.
   2. Limiting the number of consolidation levels to which the packages will be merged.

Pyhrr (1973, pages 89-92) proposes also the use of "voting mechanisms" to help solving the volume problem by saying that when ranking, individuals or committees find easier to assign a "weight" or "vote" to each package as it is reviewed and then to establish the ranking based on the weighting or voting.

The value assigned to each package is considered a "weight" if assigned by an individual or a "vote" if assigned by a committee.

Figure 2-3 shows one example of criteria for evaluating overhead and service activities designed by Pyhrr (1973, page 92).

Management is forced by this method to subjectively evaluate each package on three criteria as opposed to one. Multiple criteria may require more time in the ranking process, but its use may also produce a better ranking.



Each member votes on each criterion for each package, with even or weighted values for each criterion, with the total points used to determine the ranking.

(a) Legal or Operating Requirements

Package may be deferred

Package required to meet minimum legal or operating requirements.

Reduced ability to meet operating demands or achieve department goals

(b) Big Impact (High Leverage) Project

Package will have no measurable effect on profitability

Great impact potential in relation to cost in short or long term.

Estimated return of 25%

(c) High Level of Exposure or Risk

Little or no risk in delaying or eliminating package

Delay creates high level of risk in relation to package cost.

Probability of risk loss versus package cost about equal

Figure 2-3. Multiple criteria for ranking purposes. Source: Pyhrr (1973, page 92).

6. Benefits of Zero-Base Budgeting

When zero-base budgeting is adequately implemented, the following advantages can be obtained (Pyhrr, 1973, pages 32-36; Davis, 1975, page 14).

1. Maximization of benefits per dollar spent.
2. The analysis of decision units forces managers to review current operations and new ways of doing things. The probability of improving the current method of operations is increased.
3. Communication and collaboration between managers are improved. Zero-base budgeting provides management with a tool that identifies, evaluates and communicates his activities and alternatives to higher levels of management. Duplication of efforts among organizational units is identified and elimination or centralization of functions is easily accepted by the affected organizational areas.
4. All this participation can promote the development of the management team and their subordinates. In addition to a deeper understanding of their own operations, managers may serve on committees that rank multiorganization decision packages, which produces increased and better knowledge of other activities and problems.

Thus far, we have described the general process of zero-base budgeting; we have also considered its benefits and problems as identified by the people who have had experience with the process. In the next chapter we will describe one problem that may arise in zero-base budgeting (at least theoretically) and which was not mentioned in this chapter. Optimization models will be proposed to overcome such a problem.

III. OPTIMIZATION TECHNIQUES FOR A PROPER ALLOCATION OF RESOURCES IN ZERO-BASE BUDGETING

A. The Need for Optimization Techniques

Voting mechanisms for ranking purposes are especially useful when the number of decision packages becomes large (Pyhrr, 1973, page 89). In this case, the members of a ranking committee assign priorities to decision packages by voting on one or more scales representing the objectives of the organization and decision packages are ranked in order of priority so that funding decisions may then be performed. The problem is that a simple ranking mechanism might not allocate resources optimally, particularly when the volume of decision packages is large and when more than one goal is under consideration.

Van Horne (1974, pages 86-87) has used an example that illustrates the problem described above. Although his example was not designed to illustrate zero-base budgeting, it does point out the weakness of ranking mechanisms. A modified version of Van Horne's example is presented below.

Example 3. 1. Suppose that four decision packages of one cost-benefit level each are presented to the ranking committee. These packages are to be judged only on the basis of profitability because they happen to be alternatives on capital investment and no other effects than the net present value are foreseen by the management. The investment opportunities are shown in Table 3-1.

Table 3-1. Alternatives on capital investment.

Proposal (Decision Package)	Profitability Index	Initial Outlay
C	1.15	$200,000
A	1.13	125,000
B	1.11	175,000
D	1.08	150,000

Suppose, now, that the cut-off level is $300,000. If the committee were ranking only on the basis of the profitability index, then only proposal C would be funded and a non-optimal solution would be obtained; the committee should accept proposals A and B despite the fact that the profitability indexes are lower for these two proposals, because the total net-present value of proposals A and B ($35,500) is higher than that of proposal C ($30,000); the reason is that more of the available budget is used.

The above example does not illustrate how zero-base budgeting works, it only shows that the ranking procedures used in zero-base budgeting might not result in an optimal solution when large volumes of packages are being ranked and when more than one scale is being used in the ranking process.

In attempting to solve this problem, we propose the use of optimization models as substitution for the traditional ranking process. These models will be described in the remainder of this chapter but before proceeding to explain them, we must point out that they were built upon the following assumption: The voting process must provide relative indicators of the contribution of the decision packages to the objectives under consideration, that is, the votes of the committee members must represent the contribution of the decision packages to each objective; these indicators are relative in the sense that definite scales are used for voting. Rather than assigning priorities to the decision packages, the committee members will indicate in scales the extent to which each decision package contributes to the achievement of one or more goals of the organization.

The above assumption is critical for the validity of the models; we may then refer to "optimal" solutions as long as this assumption is completely satisfied.

B. Integer Programming with Cumulative Cost-Benefits for the Decision Variables

The problem described in the prior section could be solved through the use of linear programming. However, the optimal solution would indicate non-integer values for the decision variables. This new problem may be solved by applying integer programming to our solution procedure. The danger of not being able to spend all of the budget (and obtain the corresponding benefits) that is associated with a yes-no decision of integer programming is fortunately reduced to a minimum by the zero-base budgeting process that breaks down activities into incremental benefit-cost levels.

We start describing our first model by writing down the objective function:

$$\text{maximize} \qquad Z = \sum_{k=1}^{p} \sum_{j=1}^{\ell} \sum_{i=1}^{n_j} w_k C_{ijk} x_{ij} \tag{1}$$

Where x_{ij} is the decision variable for decision package j, levels one to i.

$x_{ij} = 0$ if package j is not funded at level i.

$x_{ij} = 1$ if package j is funded up to level i.

C_{ij} represents the relative cumulative contribution of decision package j, levels one to i, to objective k:

$$C_{ij} = \sum_{r=1}^{s} v_{ijkr} \, ,$$

where v_{ijkr} is the vote of manager r to decision package j at level i over objective k.

w_k = weight given to objective k.

p = number of objectives under consideration.

ℓ = number of decision packages

n_j = number of incremental levels of package j.

By means of Equation (1) we attempt to maximize the benefits provided by the decision packages through the weighted contribution of the packages according to the goals of the organization.

We now proceed to add the budget constraint represented by the following inequality:

$$\sum_{j=1}^{\ell} \sum_{i=1}^{n_j} b_{ij} x_{ij} \leq B \tag{2}$$

where B is the projected expenditure level or cut-off level and b_{ij} is the cumulative cost required for package j levels one to i.

Finally, we add the following constraints:

$$\sum_{i=1}^{n_j} x_{ij} \leq 1 \quad \text{for } j = 1 \ldots \ell \tag{3}$$

$$x_{ij} = 0, 1 \quad \text{for } i = 1 \ldots n_j;\ j = 1 \ldots \ell \tag{4}$$

$$x_{ij} \geq 0 \ \forall\ x_{ij} \tag{5}$$

The set of constraints (3) assures that at most one level be chosen for every decision package; equalities (4) are the integer zero-one constraints, and finally (5) represents the non-negativity constraints.

If needed, more constraints other than the budget may be added to the model (for example, personnel limitations). The model just described requires cumulative cost-benefit considerations and the committee members should be aware of it when performing the voting process. The RPM representation of this model is shown in Figure 3-1.

C. Integer Programming with Non-Cumulative Cost-Benefits for the Decision Variables

While Pyhrr (1970, 1973) and Stonich (1976) describe the ranking process by always assigning a higher priority to the lower levels of each decision package, Davis (1975, page 12) says that the ranking process does not imply that every decision unit's base package be ranked at the top of the consolidated ranking of packages; thus, the ranking process becomes a "trade-off" between levels of activity for all decision units.

If we redefine the variables of the model of Section 3. B by considering non-cumulative cost-benefits, we will obtain a model which will allow funding for higher incremental levels of decision packages without necessarily having funded the base packages of a decision unit. In this case, the model will be consistent with Davis'

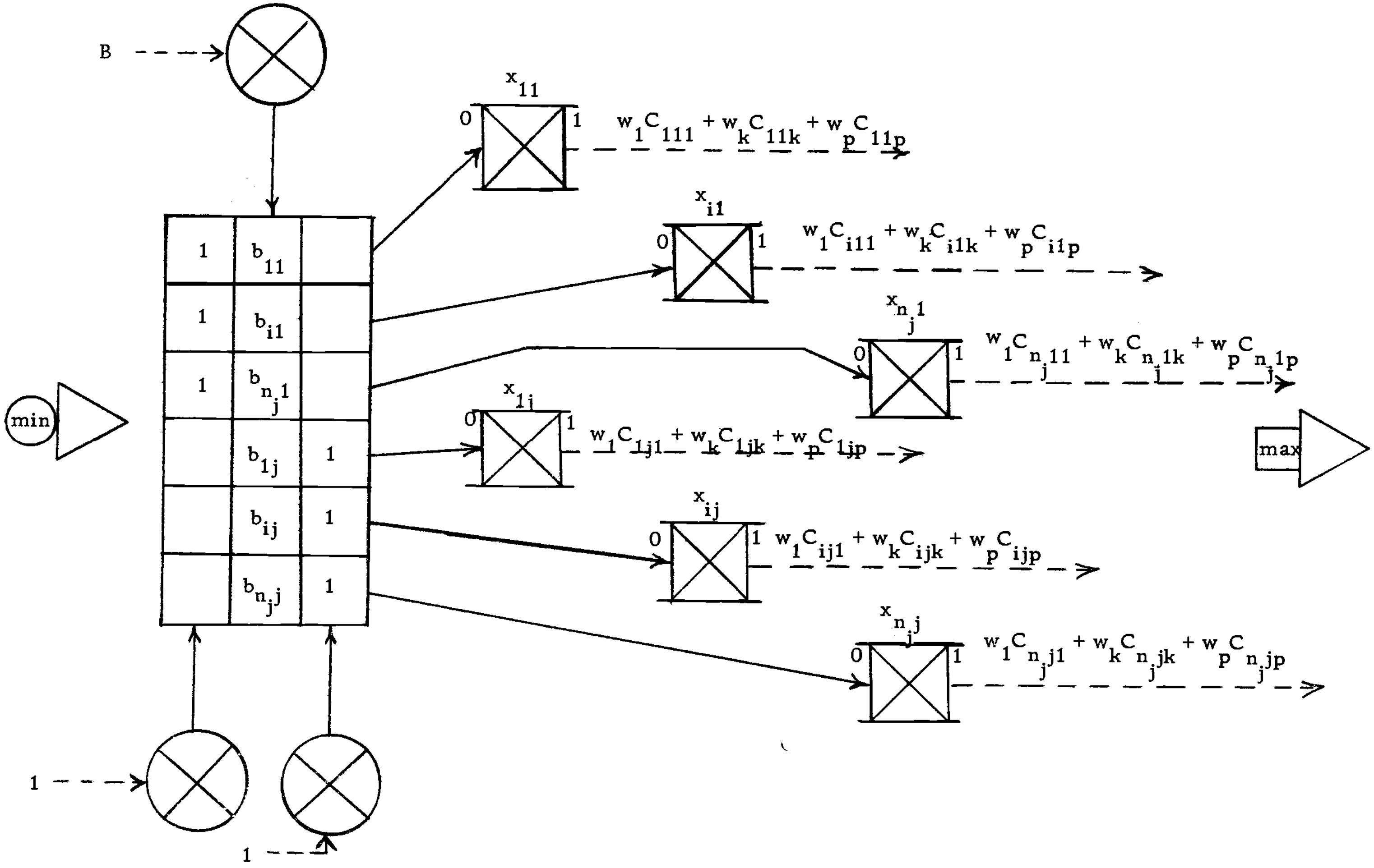


Figure 3-1. RPM representation of model Section 3.B.

opinion and we now proceed to describe such a model:

The following is a new definition of variables. The remaining variables and coefficients stay as defined in the prior section:

x_{ij} = decision variable for decision package j at level i only;

$x_{ij} = 0$ if package j not funded at level i; $x_{ij} = 1$ if package j is funded at level i.

b_{ij} = incremental cost of package j at level i only.

C_{ijk} = relative incremental contribution of decision package j, at level i, to objective k.

Now, we replace the set of constraints (3) by the new set (8), to allow for more than one decision variable per package in the solution. The model then becomes:

$$\text{maximize} \quad Z = \sum_{k=1}^{p} \sum_{j=1}^{\ell} \sum_{i=1}^{n_j} w_k C_{ij} x_{ij} \tag{6}$$

subject to:

$$\sum_{j=1}^{\ell} \sum_{i=1}^{n_j} b_{ij} x_{ij} \leq B \tag{7}$$

$$x_{ij} \leq 1 \;\forall\; x_{ij} \tag{8}$$

$$x_{ij} = 0, 1 \quad \text{for} \quad i = 1 \ldots n_j, \quad j = 1 \ldots \ell \tag{4}$$

$$x_{ij} \geq 0 \;\forall\; x_{ij} \tag{5}$$

The RPM representation of this model is shown in Figure 3-2.

D. The Goal Programming Approach

Goal Programming can also be used to optimally allocate resources in zero-base budgeting. As in Sections 3. B and 3. C, two alternative models may be developed for the allocation process. We will only describe the integer-goal programming approach with non-cumulative cost-benefits. Integer-goal programming with cumulative cost benefits may be developed consistently with the model of Section 3. B and with the goal programming concept.

A generalized model cannot be presented here because the "preemptive" priority factors depend on the particular goals and objectives of the organization (Lee, 1972). However, two somewhat general examples will be described to illustrate the goal programming modeling concept when applied to zero-base budgeting.

Example 3. 2. Suppose that a certain company has used three objectives G_1, G_2 and G_3 as guides for the voting process of zero-base budgeting. The decision units are to be funded according to such objectives, and G_1 must be met as closely as possible before G_2. Similarly, G_2 must be met before trying to achieve G_3.

We proceed to state our objective function as:

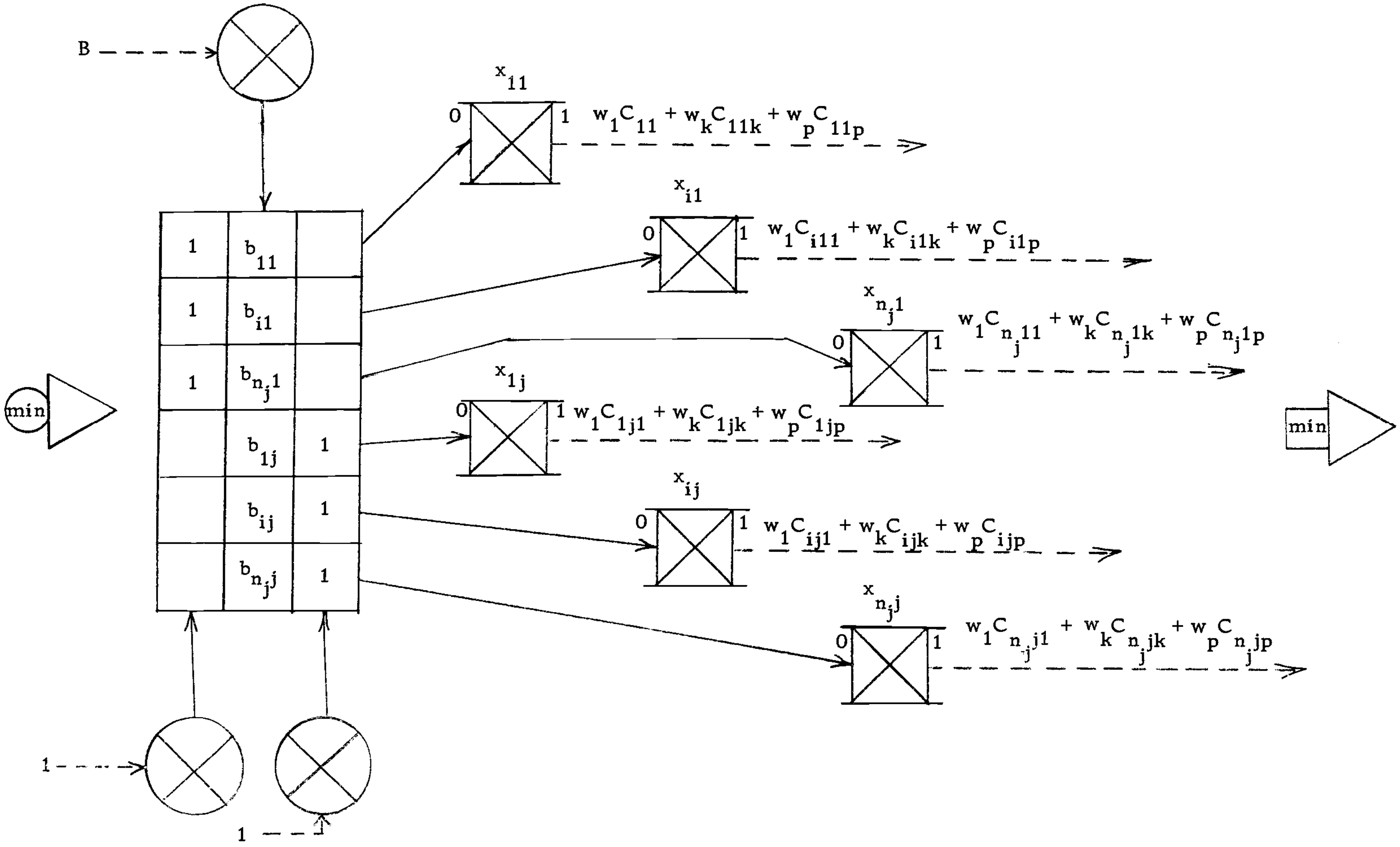


Figure 3-2. RPM representation of model Section 3. C (variables redefined).

$$\text{minimize} \qquad Z = P_1 d_1^- + P_2 d_2^- + P_3 d_3^- \tag{9}$$

where P_1, P_2 and P_3 represent the "preemptive priority factors" for goals G_1, G_2 and G_3 respectively ($P_1 \gg P_2 \gg P_3$), and d_1^-, d_2^-, d_3^- represent the negative deviational variables corresponding to the first, second and third goals respectively. To account for the contribution to each goal by the decision packages, and to define the desired level of achievement, the following set of constraints is now written:

$$\sum_{j=1}^{\ell} \sum_{i=1}^{n_j} C_{ijk} x_{ij} \geq M_k \qquad \text{for } k = 1, 2, 3 \tag{10}$$

where C_{ijk} and x_{ij} stay as defined in Section 3. C; M_1, M_2 and M_3 represent the desired level of achievement for each of the goals. The budget constraint, integer constraints, non-negativity constraints as well as the constraints that permit the decision variables to take values lower than the unity, remain as in Section 3. C. These constraints are rewritten below for this example:

$$x_{ij} \leq 1 \;\forall\; x_{ij} \tag{8}$$

$$x_{ij} = 0, 1 \quad \text{for } i = 1 \ldots n_j;\; j = 1 \ldots \ell \tag{4}$$

$$x_{ij} > 0 \;\forall\; x_{ij} \tag{5}$$

The RPM representation of this example is shown in Figure 3-3.

Example 3.3. This example will illustrate changes in the model according to changes in preemptive priority factors. Suppose now that the first goal is twice as important as the second goal. Furthermore, assume that the first two goals must be met as closely as possible before trying to achieve the third goal.

To model for this example, we only have to modify the Example 3.2 by replacing the objective function (9) by the following equation:

$$\text{minimize} \qquad Z = P_1(2d_1^- + d_2^-) + P_2 d_3^- \qquad (11)$$

Again, P_1 and P_2 represent the preemptive priority factors and d_1^-, d_2^-, d_3^- the deviational variables for underachievement of the goals. The RPM representation for this example is shown in Figure 3-4.

E. The Dynamic Programming Approach

One popular application of dynamic programming is that of the allocation of limited resources among alternatives. In fact, in describing the sequential decision process of dynamic programming, Riggs and Inoue (1975, pages 305-315) have used an example that fits very close to the process of developing decision packages in zero-base budgeting, that is, the problem is described and solved according to incremental levels of cost-benefit effects.

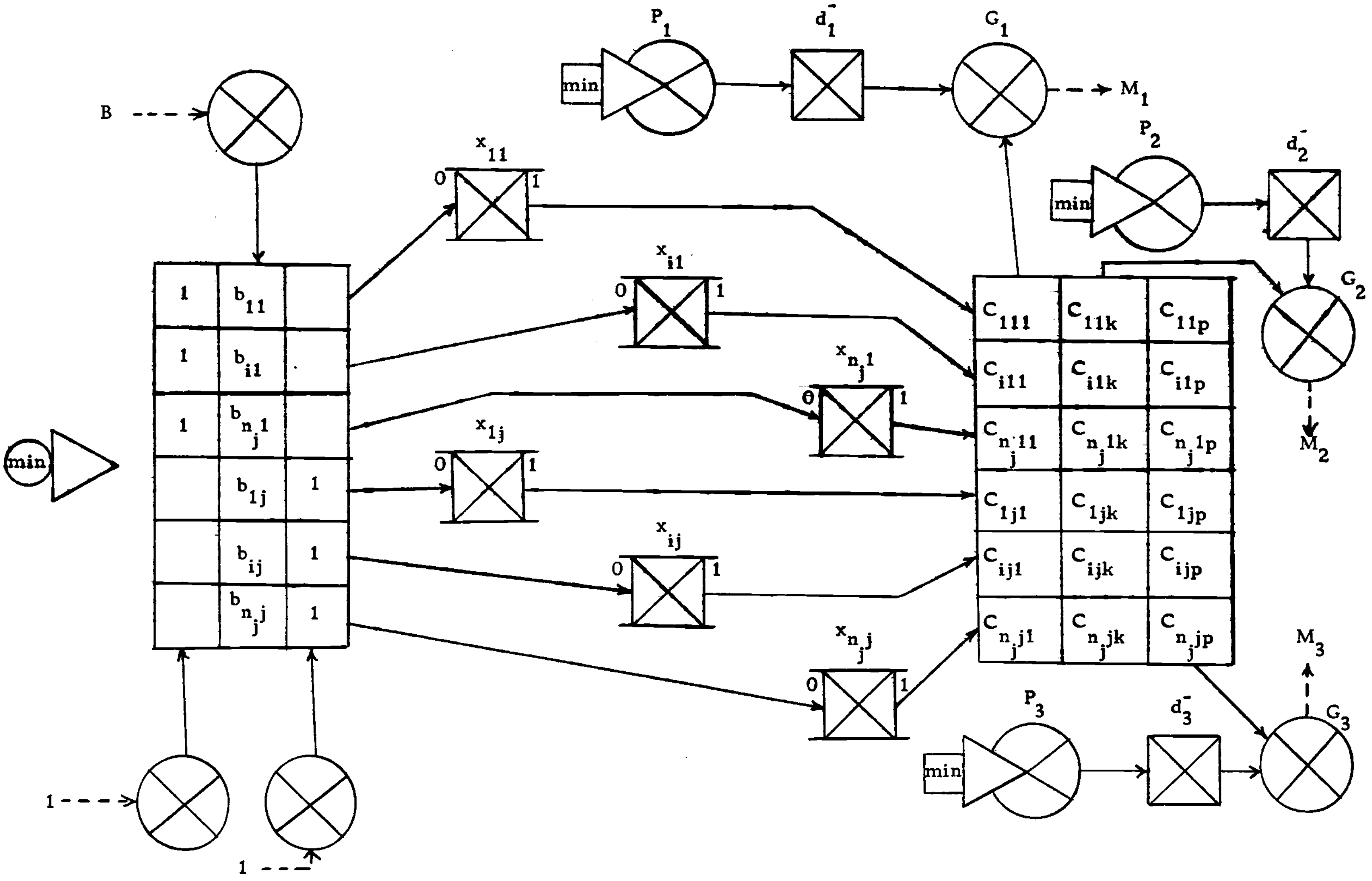


Figure 3-3. RPM representation of an integer goal programming model, Example 3. 2.

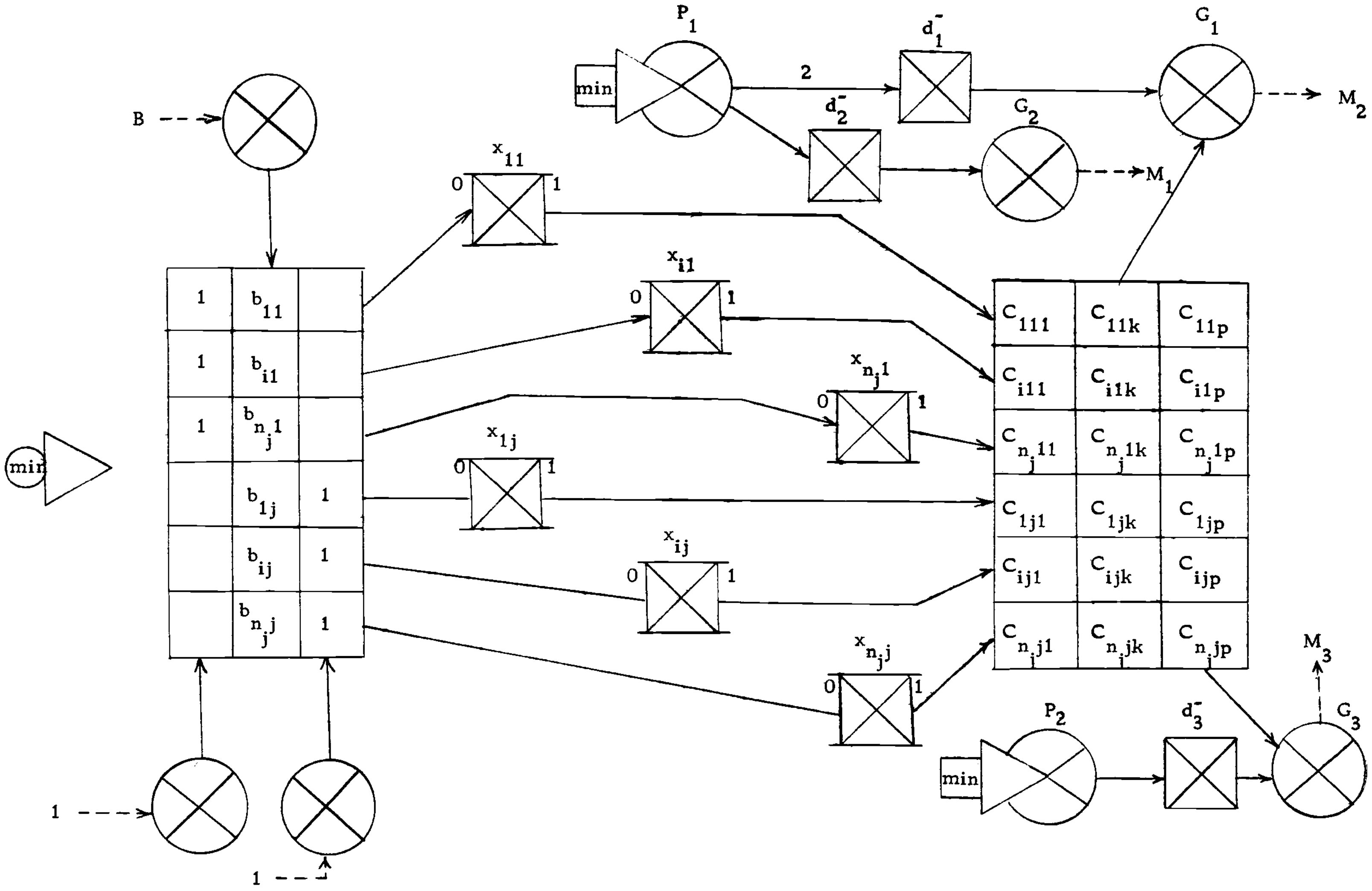


Figure 3-4. RPM representation of an integer goal programming model, Example 3. 3.

The model may be formulated as follows:

maximize

$$Z = \sum_{j=1}^{s} R_j(y_j) = \sum_{j=1}^{n_1} R_j(y_j) + \sum_{j=n_1+1}^{n_1+n_2} R_j(y_j) + \ldots + \sum_{j=s-n_s}^{s} R_j(y_j) \qquad (12)$$

subject to

$$\sum_{j=1}^{s} I_j(y_j) = \sum_{j=1}^{n_1} I_j(y_j) + \sum_{j=n_1+1}^{n_1+n_2} I_j(y_j) + \ldots + \sum_{j=s-n_s}^{s} I_j(y_j) \leq K \qquad (13)$$

$$y_j = 0, 1 \ldots \qquad (14)$$

where $R_j(y_j)$ is the cumulative weighted contribution to the objective provided by decision package j from y_0 to y_j budget levels. $R_j(y_j)$ is equivalent to $w_j C_{ij}$ defined in Section 3. B.

$I_j(y_j)$ is the cumulative budget required for decision package j levels y_0 to y_j (equivalent to b_{ij} of the model in Section 3. B).

K is the projected expenditure level (cut-off level, or B in Section 3. B).

n_j and s are the total levels for decision package j and the total number of packages respectively.

Although an RPM representation of this problem is possible, it is also complex when handling large-size problems (Riggs and Inoue, 1975, page 305). Instead, we present the recursive formula for solving this problem proposed by Wagner (1975, page 347):

$$g_j(k) = \max_y\{R_j(y)+g_{j-1}[K-I_j(y)]\} \quad \text{for } j = 1 \ldots s \tag{15}$$

$$g_0(k) = 0 \quad \text{for } j = 0 \tag{16}$$

where $k = 0, 1 \ldots K$, and the maximization is over only nonnegative integer values of y that satisfy constraint (13).

$g_j(k)$ = relative weighted contribution to the objective of the organization when the budget k is available to allocate optimally on decision packages one through j.

$y_j(k)$ = a budget level for decision package j that yields $g_j(k)$.

F. Limitations of the Models

As mentioned in Section A of this chapter, the models were developed upon the assumption that indication of benefits may be obtained by means of the voting process of zero-base budgeting. In addition, we have also included "weights", which have been used in all models except in those of Section 3. D in which we introduced indicators of desired achievement of goals.

All the factors mentioned above involve "intangibles". In fact, most of the activities analyzed by zero-base budgeting will involve many intangible factors. Therefore, the determination of the weights, priorities and indicators of the models is critical because they are the only means that our models have to include such characteristics and to produce satisfactory results.

G. Example and Comparison of the Models

The following, a highly simplified example, will serve to illustrate and compare the models presented in the earlier sections of this chapter. We should emphasize, though, that the example presented contains only ten decision units, and therefore, it does not show the volume problem that management faces when trying to allocate resources optimally. However, the models are valid for larger volumes and, as we said before, the example will hopefully help to understand and evaluate the usefulness of the models for zero-base budgeting.

Example 3.4. Suppose that ten decision packages containing up to four incremental benefit-cost levels are submitted to a five-member committee that is to evaluate and fund them according to three different objectives of the company.

A voting criterium is to be used according to the three, six-point scales shown in Figure 2-3. Each scale represents one goal, namely: meeting legal requirements, profit maximization and minimization of risks.

In addition to the presentation of the decision packages that contain information that the committee members will consider when voting, the form shown in Figure 3-5 will serve them to vote on each package.

The votes of the committee members have been totalized and summarized in Table 3-2. The committee members have decided to assign the following weights to the goals:

Legal goal: $w_1 = 3$

Profit goal: $w_2 = 2$

Risk goal: $w_3 = 1$

These weights, and the data from Table 3-2 will be used in the models of Sections 3. B, 3. C and 3. E; to use the model of Example 3. 2, the following are the priorities for the goals of the company in descending order:

1. Legal-operating goal
2. Profit goal
3. Risk goal.

The cut-off level has been set at \$3, 860, 000. 00

We now proceed to define the desired levels of achievement for the model of Example 3. 2:

$$M_1 = 690$$

$$M_2 = 690$$

$$M_3 = 690$$

INFORMATION ON THE DECISION PACKAGE					VOTING CRITERIA		
			K = $1000		(Assign vote on a six-point basis)		
PACKAGE NAME	#	LEVEL	BASE COST	INCREMENT	LEGAL REQMNTS	PROFIT	RISK
Pollution Control	1	1	50 K				
Device		2		10 K			
		3		30 K			
Automotive Services	2	-	20 K				
Advertising Campaign	3	1	1000 K				
		2		1000 K			
		3		3000 K			
		4		1500 K			
Industrial Engineering	4	1	120 K				
		2		15 K			
Industrial Relations	5	1	100 K				
		2		20 K			
		3		20 K			
Research and	6	1	200 K				
Development		2		60 K			
		3		60 K			
Facilities Planning	7	-	100 K				
Quality Control	8	1	350 K				
		2		130 K			
Production Machinery	9	1	800 K				
Investment		2		400 K			
		3		350 K			
Dining Room	10	-	25 K				

Figure 3-5. Voting form for Example 3. 4.

Table 3-2. Contribution to objectives.

Package #	Level	Legal		Profit		Risk	
		Increment	Cumulative	Increment	Cumulative	Increment	Cumulative
1	1	30	30	7	7	22	22
	2	22	52	5	12	16	38
	3	13	65	5	17	13	51
2		22	22	21	21	18	18
3	1	17	17	28	28	22	22
	2	5	22	10	38	6	28
	3	5	27	11	49	6	34
	4	5	32	28	77	5	39
4	1	7	7	29	29	23	23
	2	5	12	26	55	16	39
5	1	21	21	15	15	27	27
	2	16	37	13	28	22	49
	3	12	49	8	36	15	64
6	1	14	14	17	17	28	28
	2	12	26	13	30	23	51
	3	9	35	9	39	20	71
7		14	14	17	17	12	12
8	1	17	17	22	22	28	28
	2	12	29	19	41	24	52
9	1	17	17	30	30	26	26
	2	12	29	27	57	21	47
	3	9	36	21	78	13	60
10		16	16	7	7	14	14

Table 3-3. Funding decisions according to techniques used.

Package	Integer Programming		Goal Programming	Dynamic	Traditional
	Cumulative	Non Cumulative	Non Cumulative	Programming	Ranking
1-1	*	x	*	*	x
2	*	x	*	*	x
3	x	x	x	x	0
2-1	x	x	x	x	x
3-1	x	x	x	x	x
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
4-1	*	x	*	*	x
2	x	x	x	x	x
5-1	*	x	*	*	x
2	*	x	*	*	x
3	x	x	x	x	0
6-1	*	x	*	*	x
2	*	x	*	*	x
3	x	x	x	x	0
7-1	x	x	x	x	x
8-1	*	x	*	*	x
2	x	x	x	x	x
9-1	*	x	*	*	x
2	*	x	*	*	x
3	x	x	x	x	x
10-1	x	x	x	x	x

Code: x = Package funded at that level.
* = Level funded. Included in a higher level.
0 = Package not funded at that level.

These values were chosen as the maximum possible points that the voting process may provide; $M_1 = M_2 = M_3 = 23$ packages x 5 committee members x 6 maximum points per package = 690.

Table 3-3 shows the results provided by all models, including the traditional ranking process of zero-base budgeting; the optimization models gave the same funding decisions despite the model used, however, the ranking process did not fund packages 1-3, 5-3 and 6-3 which were among the lowest ranked packages. While the use of optimization techniques resulted in full utilization of economic resources, the ranking process resulted in $110,000.00 of leftover. Table 3.4 shows the reason of that leftover.

Table 3-4. Ranking process illustrated for Example 3.4.

Rank	Package	Cumulative Cost	
1	9-1	$ 800 K	
2	3-1	1800 K	
⋮	⋮	⋮	
16	10-1	3400 K	
17	9-3	3750 K	
18	3-4	5250 K	Packages not funded
19	5-3	5270 K	
20	6-3	5330 K	
21	1-3	5360 K	
22	3-3	8360 K	
23	3-2	9360 K	

Leftover = cut-off level - funding expenses
Leftover = 3860 K - 3750 K = $110 K

H. Comparison of the Models

All models provided the same funding decisions; the dynamic programming model was the only one that did not require the use of integer programming. The use of "weights" for all models except for goal programming is a critical function that must be carefully performed because optimal results also depend on the weights utilized; similarly, the determination of levels of achievement for goal programming presents a difficult task that might involve too many intangible factors.

In the next chapter, another budgeting process is described: flexible budgeting, which deals with activities where zero-base budgeting may no longer be applied.

IV. FLEXIBLE BUDGETING

A. Concepts and Definition

Flexible budgeting has also been referred to as variable budgeting, sliding scale budgeting, step budgeting, expense formula budgeting, expense control budget and planned cost-volume relationships (Welsch, 1976, page 303). The following definition was given by Pyhrr (1973, page 107):

> Flexible budgeting is a control technique to aid management in adjusting to a changing environment by providing an adjustable budget that is related to production volume.

Given the level of production "output" desired, the use of flexible budgeting provides the "input" budget required, or planned budget. Then, once the actual level of output is known, the flexible budgeting approach provides the control budget against which the actual expenses are compared and performance measures are obtained (Tektronix, 1975). Thus, flexible budgets express short-term cost-volume relationships within a relevant range of activity, and they are dynamic in the sense that expense (input) allowances for any particular volume (output) can be computed readily (Welsch, 1976, page 303).

Flexible budgeting is based on an adequate knowledge of cost behavior patterns (Horngren, 1972, page 229). It is for this reason that we now focus our attention on the categories of costs used in a flexible budget system. Welsch (1976) identified the following categories:

1. Fixed costs
2. Variable costs
3. Semivariable or semifixed costs.

Table 4-1 summarizes the characteristics of each of the cost categories mentioned above.

The most critical problem in a cost responsibility center is the determination of the variability of each expense item when developing variable budgets (Welsch, 1976). The same author has identified and categorized several methods for determining cost variability. These methods can be classified in three broad categories:

1. Direct estimate methods.
2. Budgeted high and low point.
3. Correlation methods.

Direct Estimate Methods. Two direct estimate methods are considered:

a) Industrial Engineering Studies. Based on analysis and direct observation of processes and operations.
b) Direct Analysis of Historical Data and Management Policies. This approach is a judgmental estimate of a particular cost directly from information obtained through historical activity of the cost, interpretation of management policies

Table 4-1. Characteristics of fixed, variable and semivariable costs. Source: Welsh (1976, pages 304-313).

Cost Category/Definition	Controllability	Relationship to Activity	Relevant Range	Management Regulation	Other
FIXED COSTS. Those that do not vary with productive activity.	Controllable over the life-span of the company. Some are subject to short-run control. Some are determined annually.	Are not influenced by activity output.	Must be related to a relevant range of activity.	Most depend on management policy decisions.	-The amount of the fixed cost must be related to a specific period of time. -Fixed in total but variable per unit
VARIABLE COSTS. Those that vary in direct proportion to activity.	Generally subject to short-run management control.	Proportionally related to activity.	Must be related to a relevant range of operation.	May be affected by management decisions.	-Adequate method of the activity must be selected. -Variable in total but fixed per unit
SEMIVARIABLE COSTS. Those items of cost that vary as output or activity varies, but not in proportion thereto.	Combined characteristics of both fixed and variable costs.				

and evaluation of the nature and cause of the expense.

Budgeted High and Low Point Method. In this approach, two expense budget allowances are developed at two different assumed levels of activity and for each item of expense. Arithmetical interpolation between the two budgets assuming straightline relationships provides with the fixed and variable components of each cost.

Correlation Methods. Correlation methods can be divided into two broad categories:

a) Graphic Methods. The use of scatter graphics permits the visual determination of fixed and variable components of costs.

b) Mathematical Methods. The method of least squares is used to compute a unique regression line that represents the behavior of a cost unit.

It is important to mention here that many factors besides volume cause costs to vary (Horngren, 1972). The relevant range in which a cost is considered and the linearity assumptions are also delicate points to consider when preparing a flexible budget. The significance of these assumptions should be determined by the sensitivity of management's decisions under such simplifications and assumptions.

B. The Scope of Flexible Budgeting

Flexible budgets are most often associated with manufacturing overhead. However, they may also include direct materials and direct labor; flexible budgets do not normally encompass administrative expenses, research and development or marketing costs (Pyhrr, 1973; Horngren, 1972). Pyhrr (1973) gave the following comments in relation to the difficulties of implementing flexible budgeting:

> Management has had much greater difficulty in budgeting and controlling manufacturing and operating overhead costs than it has had with direct labor and material costs. The difficulty with these overhead costs is created by several factors:
>
> - Overhead costs are incurred in many organizational units and include a variety of dissimilar activities with different behavior characteristics.
> - Activities may not be directly identifiable with a unit of product.
> - Complex relationships exist between overhead activities and units of product.
> - Overhead costs can lead, coincide with, or lag behind production.
> - Work load volumes may bear no relationship to production activities.

These problems have been attacked using the graphical approaches mentioned in the prior section of this chapter. Unfortunately, graphical approaches might result in excess costs built into the budget costs because of past and present inefficiencies (Pyhrr, 1973, pages 107-111). The same author proposes the use of the zero-base budgeting approach to complement variable budgeting when problems like those mentioned above are faced.

Industrial engineering studies are also used to avoid including inefficiencies into the budget cost, because its methodology implicitly accounts for efficiency considerations (Welsh, 1976; Niebel, 1967).

Flexible budgets may be adjusted to any level of activity, so that the evaluation of efficiency is not contaminated by comparing a budget for one level of activity with results for another level of activity (Horngren, 1972). Thus, flexible budgeting is an adequate control tool for management. However, it does not fulfill the desired characteristics for an adequate planning tool. This particular problem will be treated in detail in the following chapter of this thesis.

V. THE RPM APPROACH TO FLEXIBLE BUDGETING

A. The Need for a Planning Tool

Budgeting has been referred to as a "planning and control system" (Jones and Trentin, 1971). As mentioned in Chapter I, these three keywords relate to the fundamentals of the management process that dynamically considers objectives of the organization for a successful performance.

Flexible budgeting provides an adequate control mechanism that adjusts to the actual production output for performance measures and identification of problem areas. However, although flexible budgeting permits the computation of planned budgets according to planned outputs, it lacks the ability to help management find such desired outputs; it does not provide the manager with a tool that permits him to test various alternatives as a basis for his final plan of action.

The use of systems analysis and modeling techniques have been proposed by Jones and Trentin (1971) to aid management in the budgeting process. In the remaining of this chapter, we will propose and illustrate the use of RPM systems to complement the flexible budgeting process.

B. RPM Proposed for Flexible Budgeting

RPM networks are proposed as a complement and supplement to flexible budgeting because of the following features:

1. The operations included in a cost center are represented graphically through cause-and-effect diagrams. Thus, communication between management is enhanced and planning the level of operations is facilitated by a better understanding of the limitations and cost implications of the production area.
2. Optimal production plans (product mix and scheduling, in-process inventories, etc) may be obtained through RPM and linear programming techniques. Thus, management may obtain an optimal planned budget based on optimal output conditions.
3. Since an RPM network is a model that represents the real system, potential problems of operation can be analyzed by testing alternatives and answering "what if . . . ?" questions using computers (Eckholt, 1976).
4. After-the-fact analyses can be performed, because RPM models graphically show the cost of deviating from the optimal solution, thus supplementing the control mechanism of flexible budgeting.

5. Emergency make-or-buy decisions can be made by managers in order to keep the optimal conditions set by the plan, or showing the cost of deviating from such plan when necessary (Eckholt, 1976).
6. RPM networks can be used to determine product transfer costs (Eckolt, 1976).
7. Personnel decisions (second shift, overtime, range change, etc.) (Eckolt, 1976).
8. When an optimal output plan is obtained in an RPM, the network automatically shows the optimal input resources or planned budget (see Figure 5-1).

In summary, the systems concept, and in particular, the RPM approach, provides flexible budgeting with a tool that permits its incorporation to the planning process of the company, and enhances the control mechanisms of flexible budgeting by providing before-the-fact indicators to aid management improve its decision making capabilities.

C. Development of the RPM-Flexible Budgeting System

Since flexible budgeting is based on adequate representation of cost behavior patterns, the application of RPM must have such foundations in order to be useful for flexible budgeting. Recall from Chapter IV that three cost categories are used in flexible budgeting:

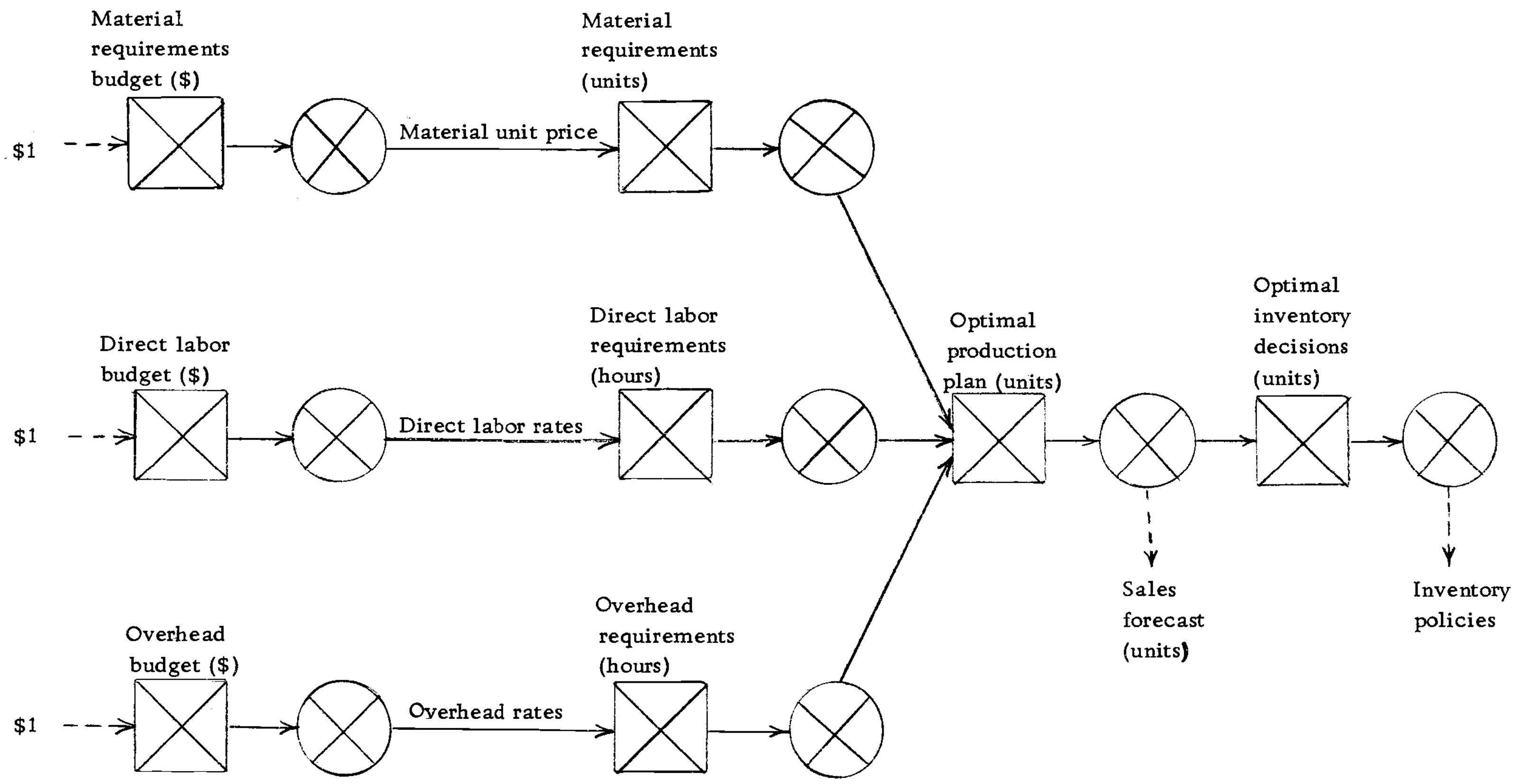


Figure 5-1. RPM general representation of a planned budget.

fixed costs, variable costs and semivariable costs. The following is a description of the RPM approach under these categories:

<u>a) Fixed Costs in RPM-Flexible Budgeting</u>. Figure 5-2 shows two ways of representing a fixed cost of $9000.00 in RPM. Since fixed costs are related to relevant ranges of activities the RPM for an activity must also be related to a relevant range of the activity. Figure 5-3 shows graphically two cases of fixed costs: Figure 5-3a illustrates an unusual fixed cost that remains constant over the entire range of activity; Figure 5-3b presents a more typical fixed cost which remains constant within various specified ranges of activity.

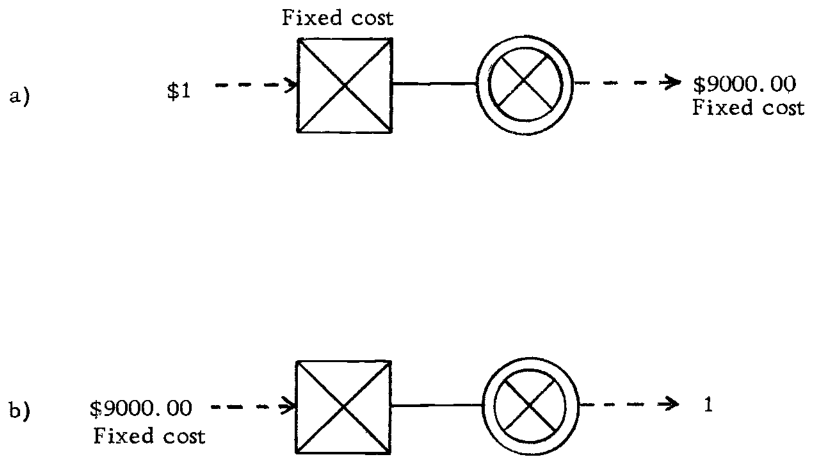


Figure 5-2. Two ways of showing fixed costs in RPM.

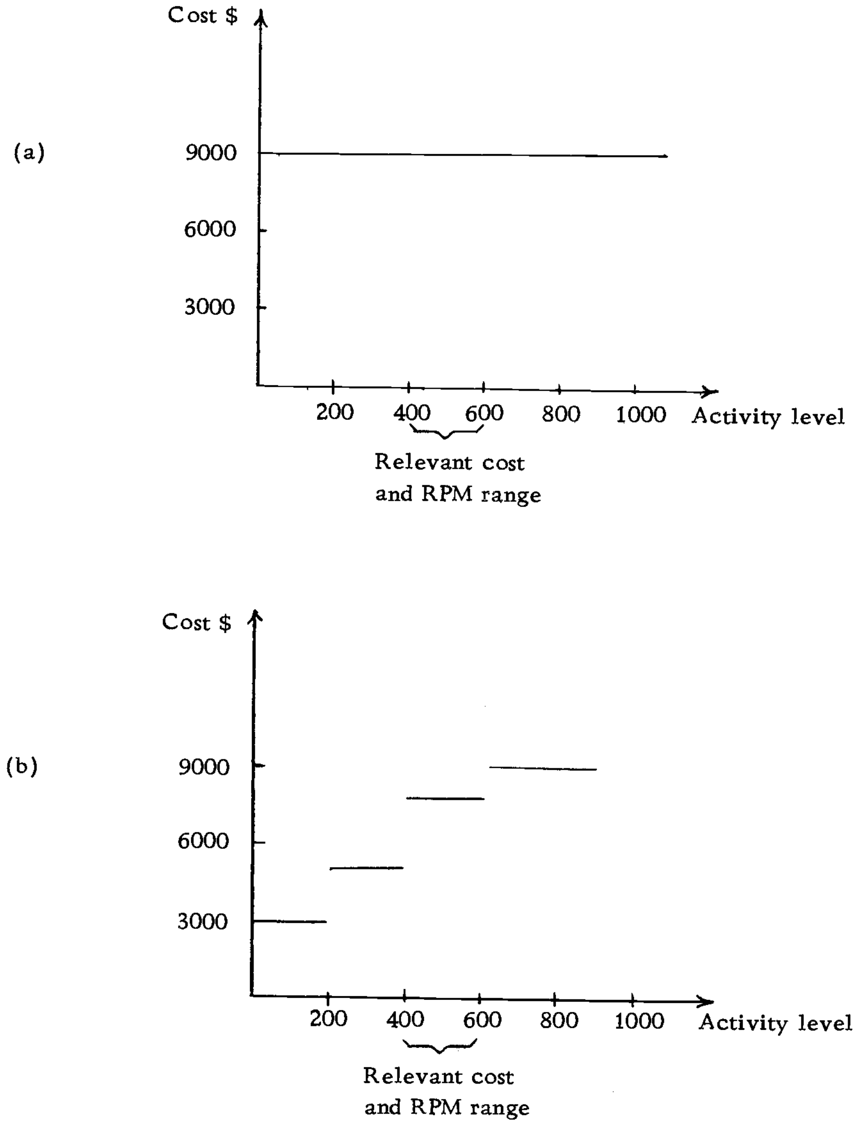


Figure 5-3. Fixed costs graphed. Source: Welsch (1976).

<u>b) Variable Costs in RPM-Flexible Budgeting</u>. Figure 5-4 illustrates the use of RPM to include variable costs. Also, both RPM and costs are only valid for certain predetermined ranges of activities. Figure 5-5 illustrates two cases of variable costs according to their respective relevant range of activity. Note that in order to represent costs such as those shown in Figure 5-5b in RPM networks, it is necessary to have one RPM for each range (A, B and C), each showing the corresponding variable costs.

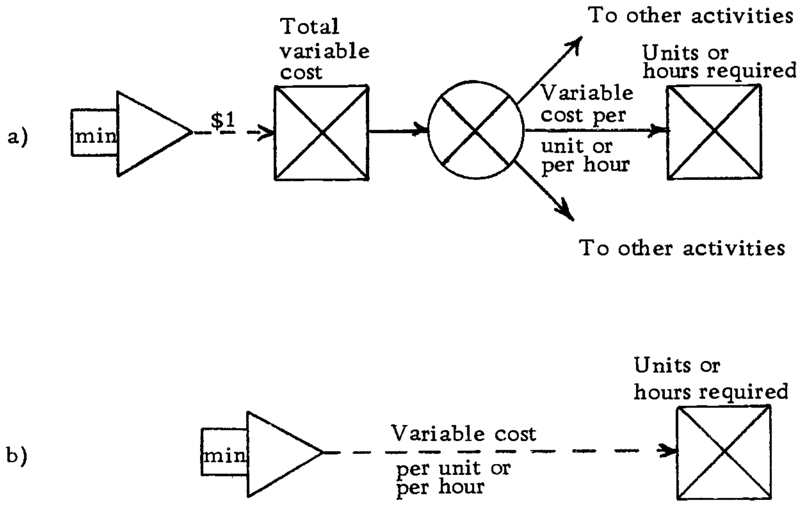


Figure 5-4. RPM representation for variable costs.

<u>c) Semivariable Costs in RPM-Flexible Budgeting.</u> Figure 5-6 shows an RPM representation that handles semivariable costs for flexible budgeting. Since a semivariable cost is a nonlinear

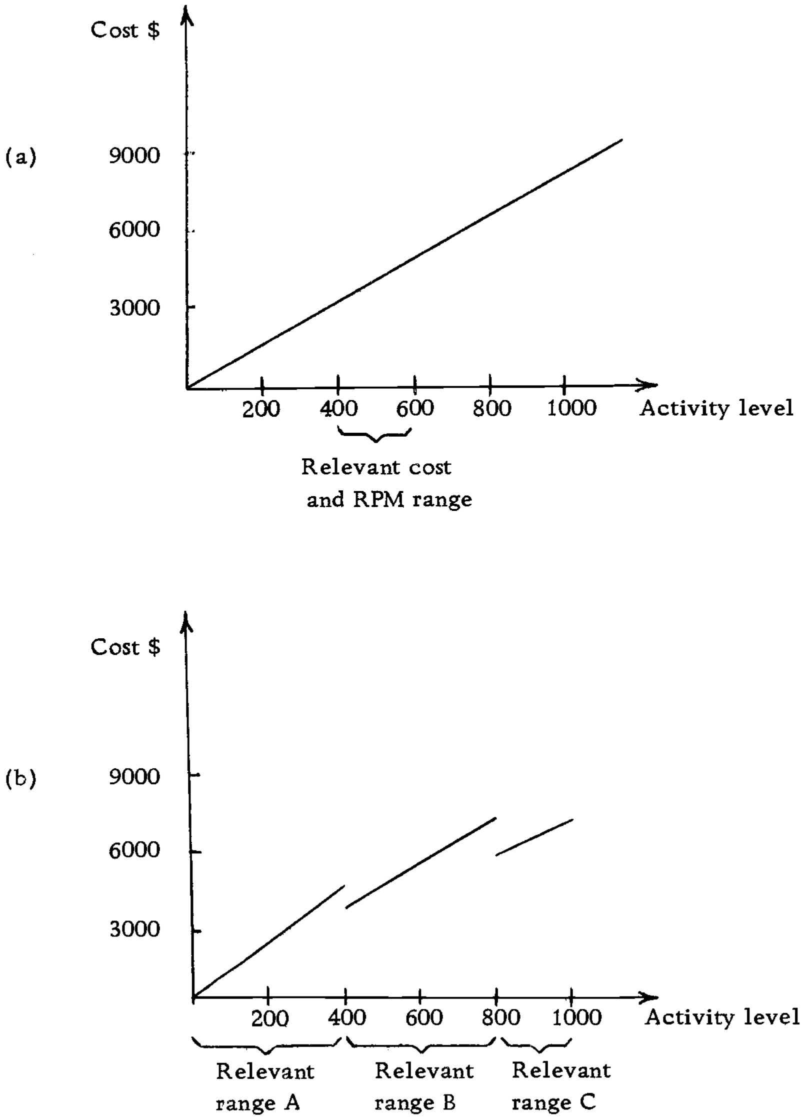


Figure 5-5. Variable costs graphed. Source: Welsch (1976).

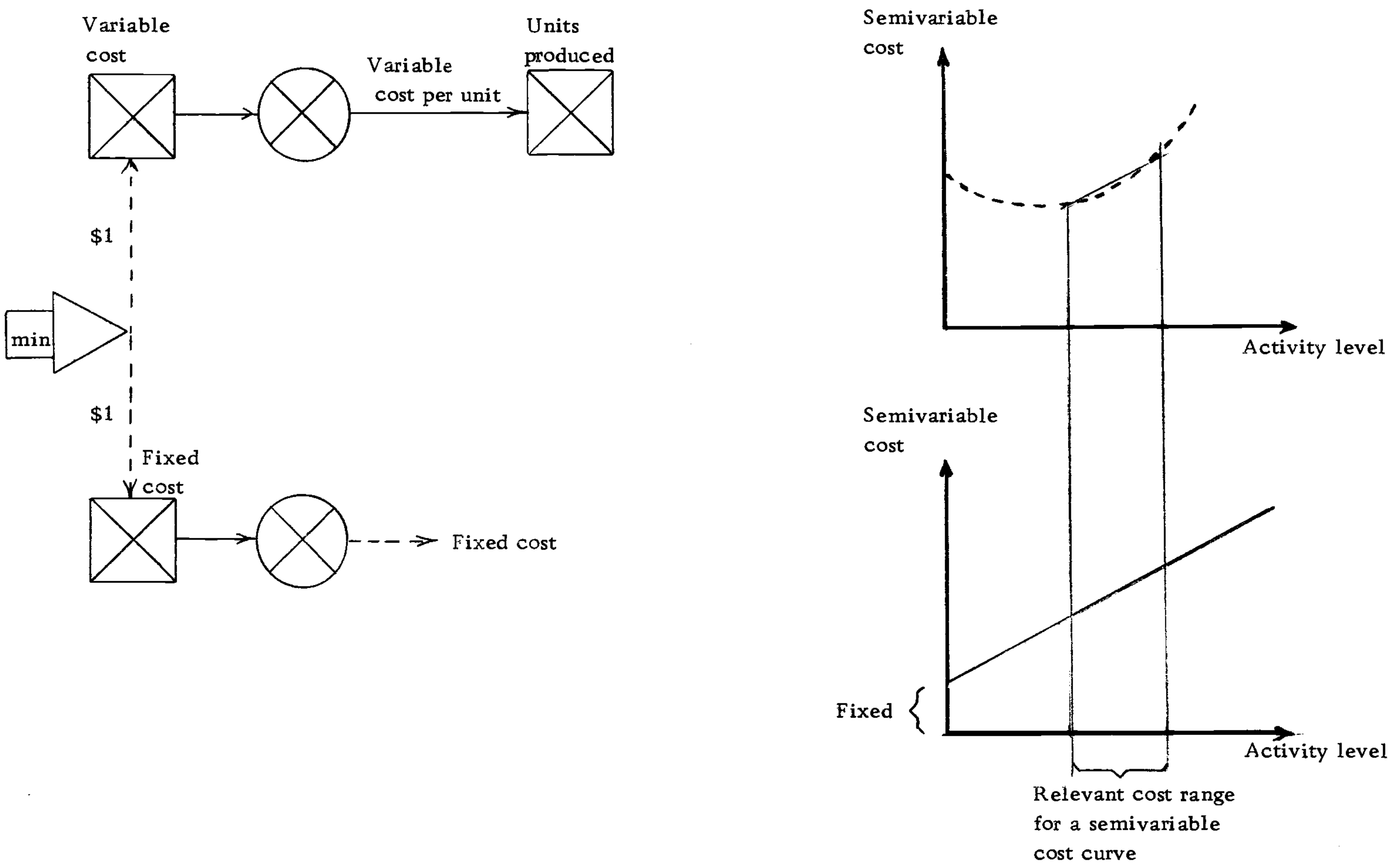


Figure 5-6. RPM representation of semivariable costs.

combination of both fixed and variable costs, the RPM approach uses piecewise linear representations resembling those used for fixed and variable costs. A graphical representation of a simple example of semivariable costs is shown in Figure 5-7.

Thus far we have assumed that cost behavior patterns may be approximated by a simple linear relationship. In reality, a cost curve might behave following a curvilinear or some other more complex nonlinear patterns such as those shown in Figure 5-8. Flexible budgeting generally assumes that curvilinear patterns are "straight within the relevant range of activity" (Horngren, 1973, page 236). Step-like cost behavior patterns are approached by flexible budgeting in two general ways depending on the width of the steps and the relevant range of activity; these two approaches are illustrated in Figure 5-9a and b, which show that when the cost steps are small compared with the range of activity, a linear-proportional-to-volume variability may be assumed; if steps are wide, fixed costs may be assumed for the relevant range of activity (Horngren, 1972, pages 237-238). All approximations cause errors; whether these errors are significant or not, it depends on the sensitivity of the decisions to the errors that approximations might cause (Horngren, 1972, page 254).

The RPM-flexible budgeting system is based upon linear relationships. The limitations caused by linear functions are determined by the accuracy built in the cost functions used in the system.

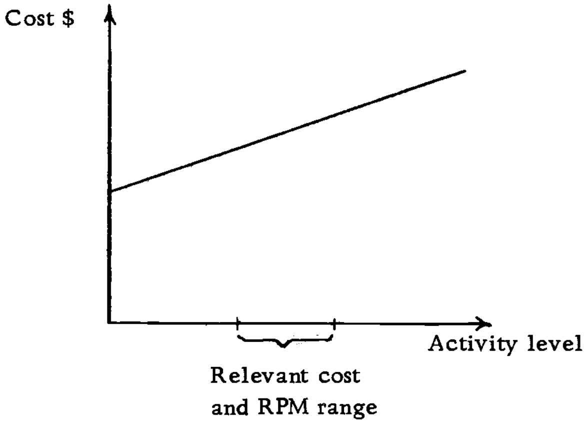


Figure 5-7. Semivariable costs graphed. Source: Welsch (1976).

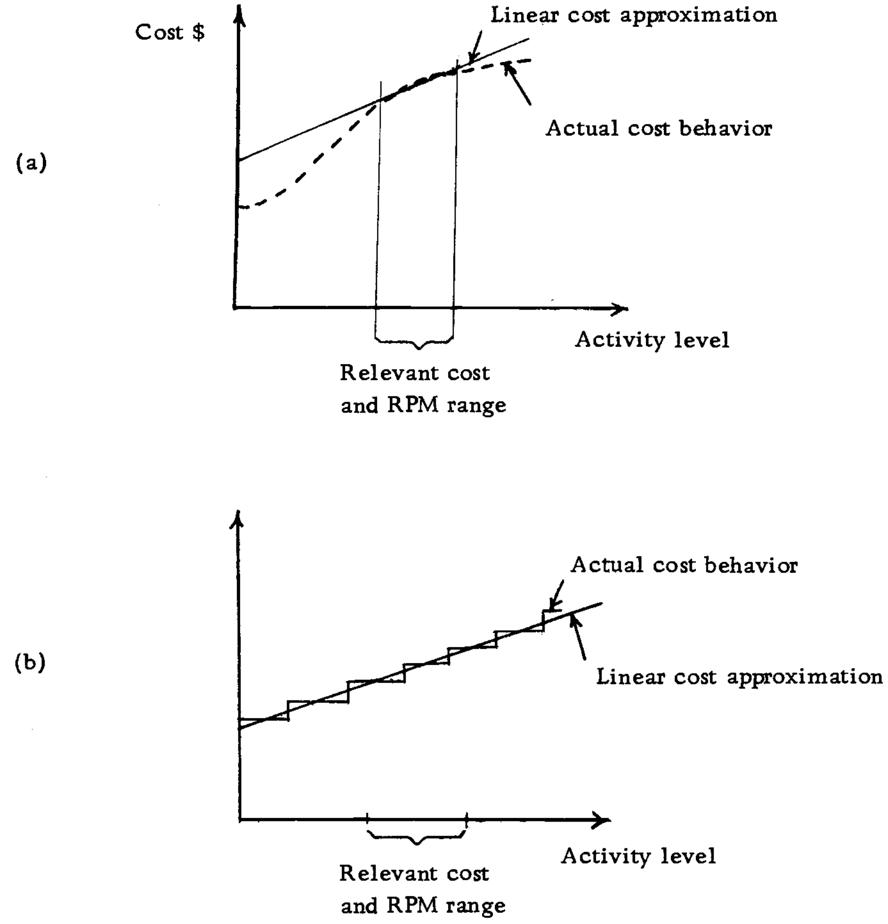


Figure 5-8. Linear cost approximation to actual cost behavior. Source: Horngren (1972, page 236).

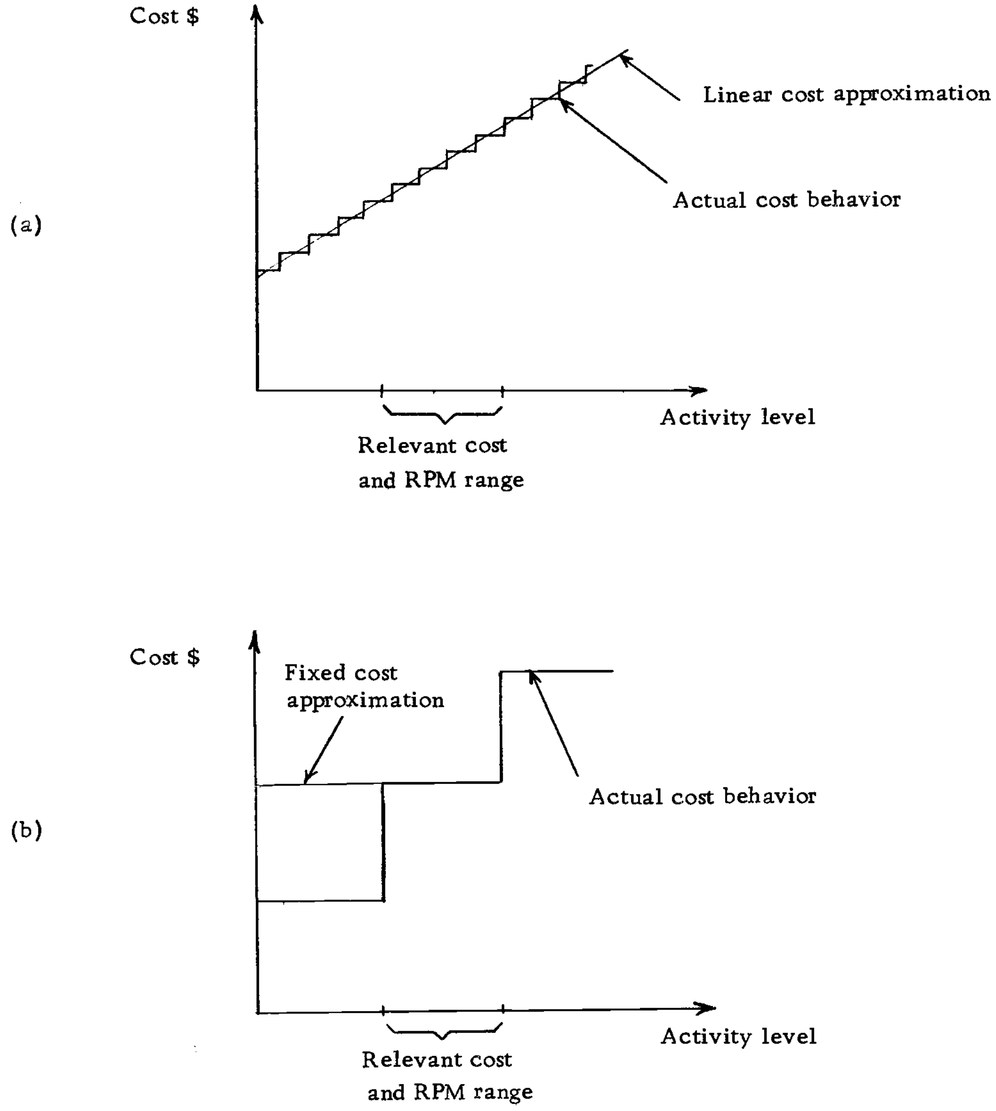


Figure 5-9. Linear cost approximation to step-like patterns. Source: Horngren (1972, pages 237-238).

D. The Implementation of RPM-Flexible Budgeting at Tektronix

1. General Considerations

Tektronix Inc. uses eight budget codes for its computerized flexible budgeting system so that information may be input to and retrieved from the computer (Tektronix, 1975). These codes have been defined according to eight cost behavior patterns, and each of the codes specifies the areas to which it can be applied within the company. Figures 5-10 through 5-17 show how RPM networks may be used to represent the planned and control budgets, including performance measures for each of the eight codes used at Tektronix.

It is important to mention here the fact that although it is possible to represent the control process of flexible budgeting through RPM, the networks do not increase the control ability of flexible budgeting. Therefore, attention should be centered on those additional skills that the RPM provides to flexible budgeting in the planning process, rather than spending time and effort in drawing networks that represent what flexible budgeting already provides.

2. Description of the Model

The RPM approach has been implemented at the Cathode Ray Tube production area in Tektronix (CRT). Two models were developed: an operational model for the "mesh target" area and a

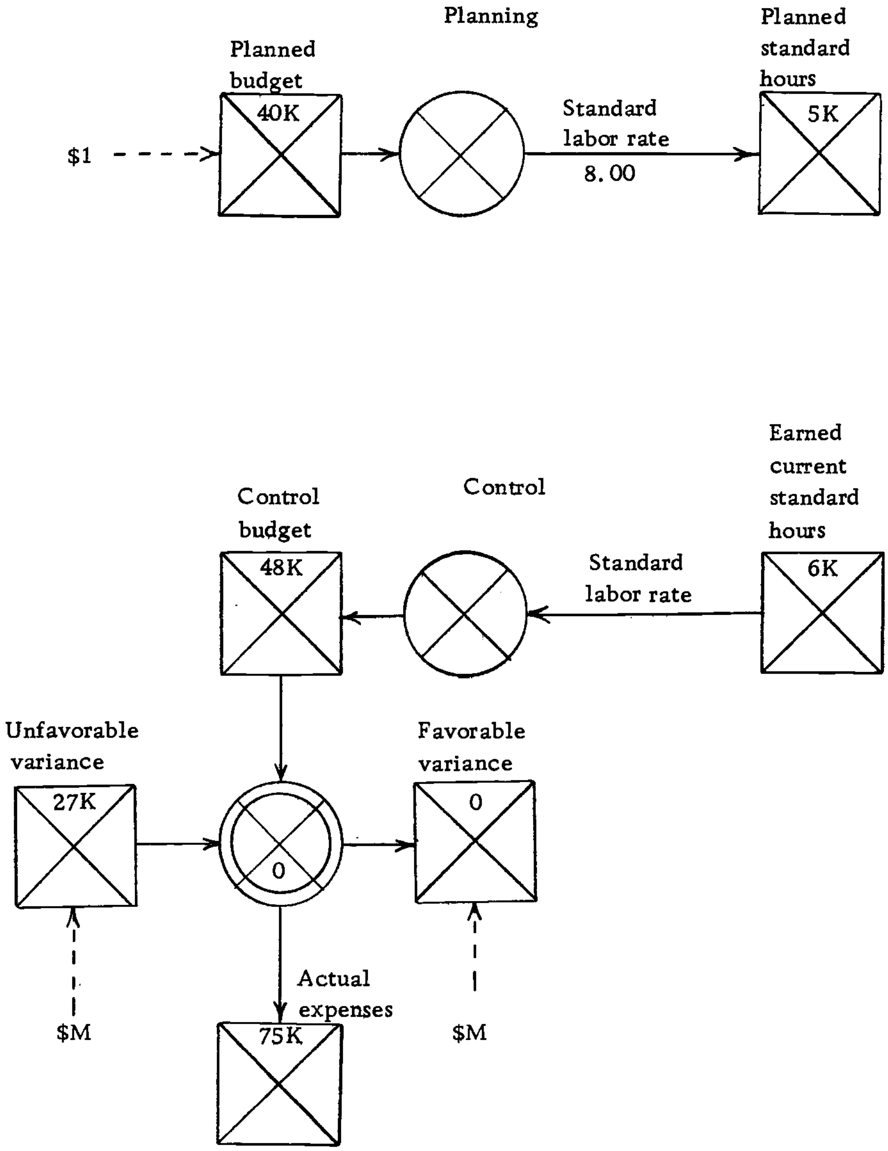


Figure 5-10. Budget code 1. May be used for product run and product support; $M represents a high penalty for variance.

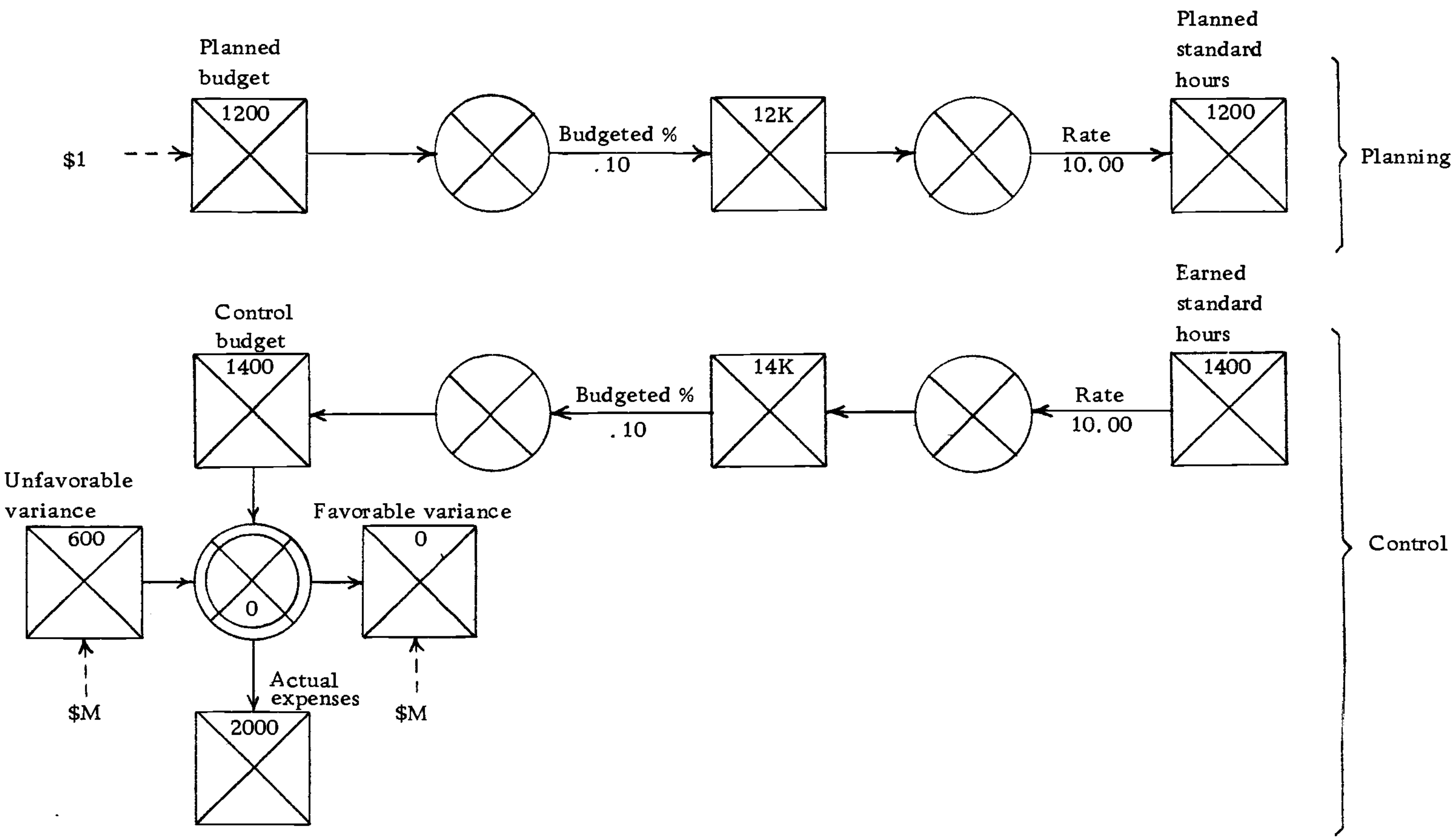


Figure 5-11. Budget code 2. May be used for product run, product support, internal projects, cost transfer, machine operator, administrative support, engineering project, training and meeting, reclaim, product services, tooling project, maintenance project, supervisory, administrative and technical project.

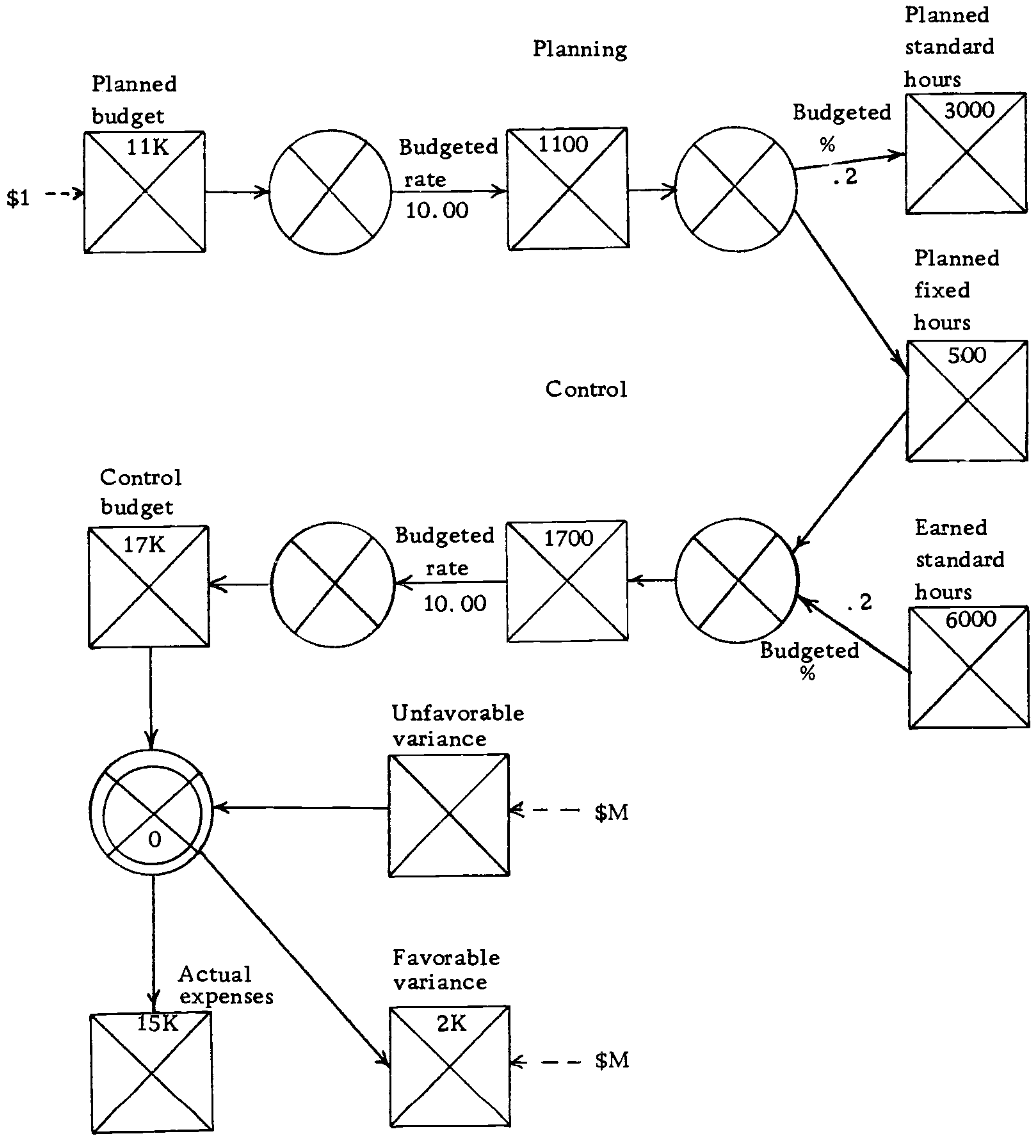


Figure 5-12. Budget code 3. May be used for internal projects, cost transfer, reclaim, product services, tooling project, maintenance project, supervisory, administrative support, administrative, engineering project, technical project, training and meeting.

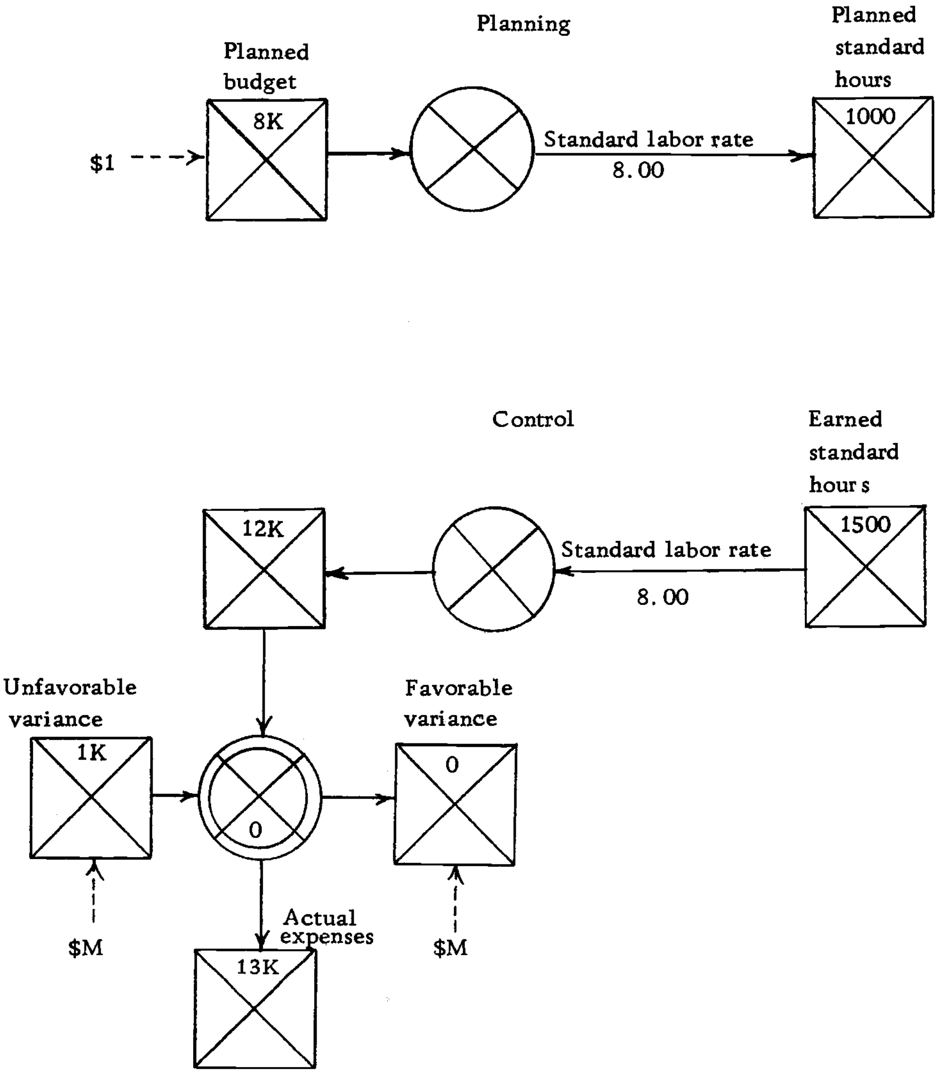


Figure 5-13. Budget code 4. May be used for product set-up.

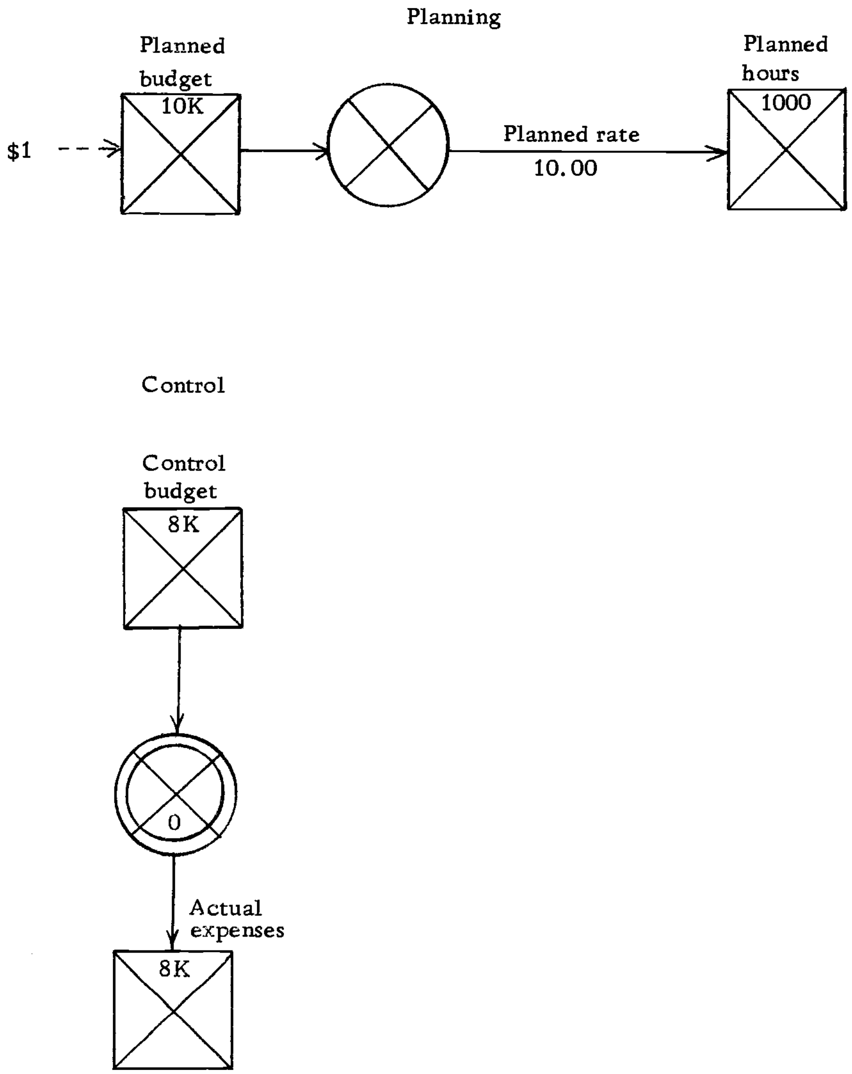


Figure 5-14. Budget code 5. Budgeted expenses = actual. May be used for vacation time, holiday time, sick-leave time and other paid non-work time (independent of production).

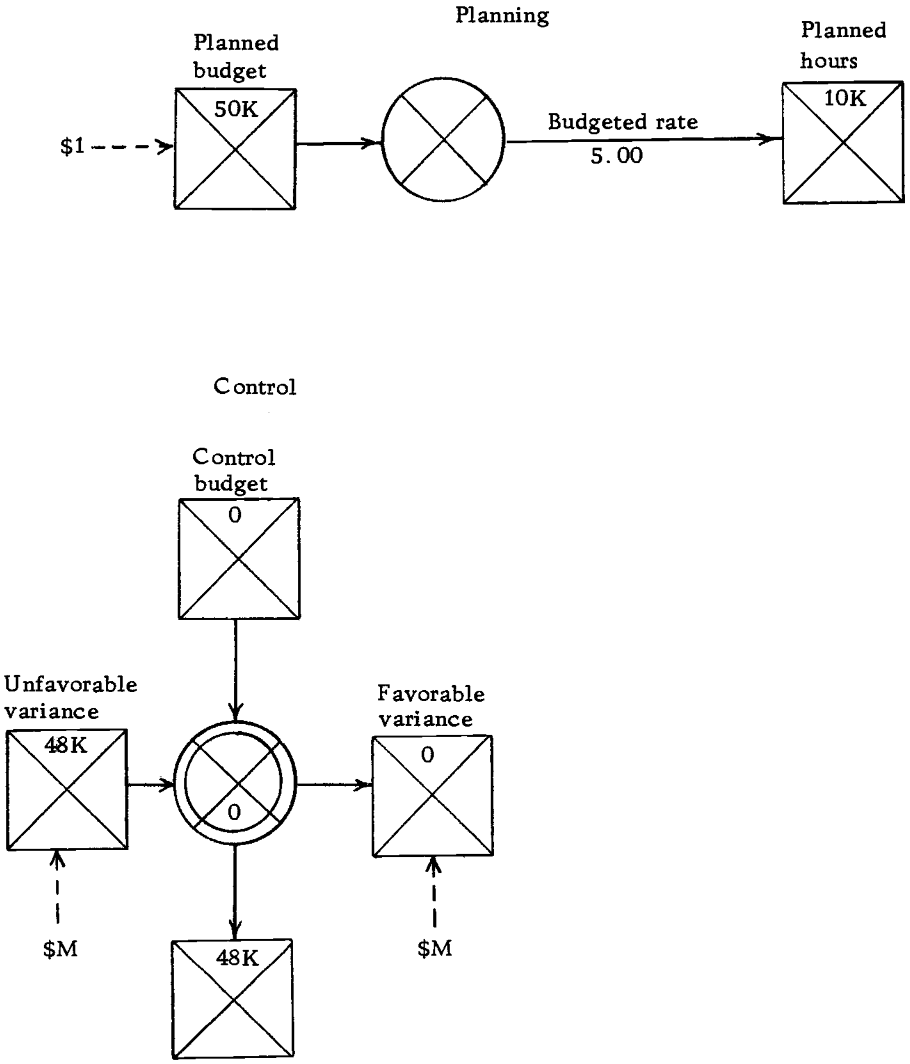


Figure 5-15. Budget code 6. May be used for rework, operation added, non-production, set-up (without standards), paid-not-reported, unmatched, (independent of production).

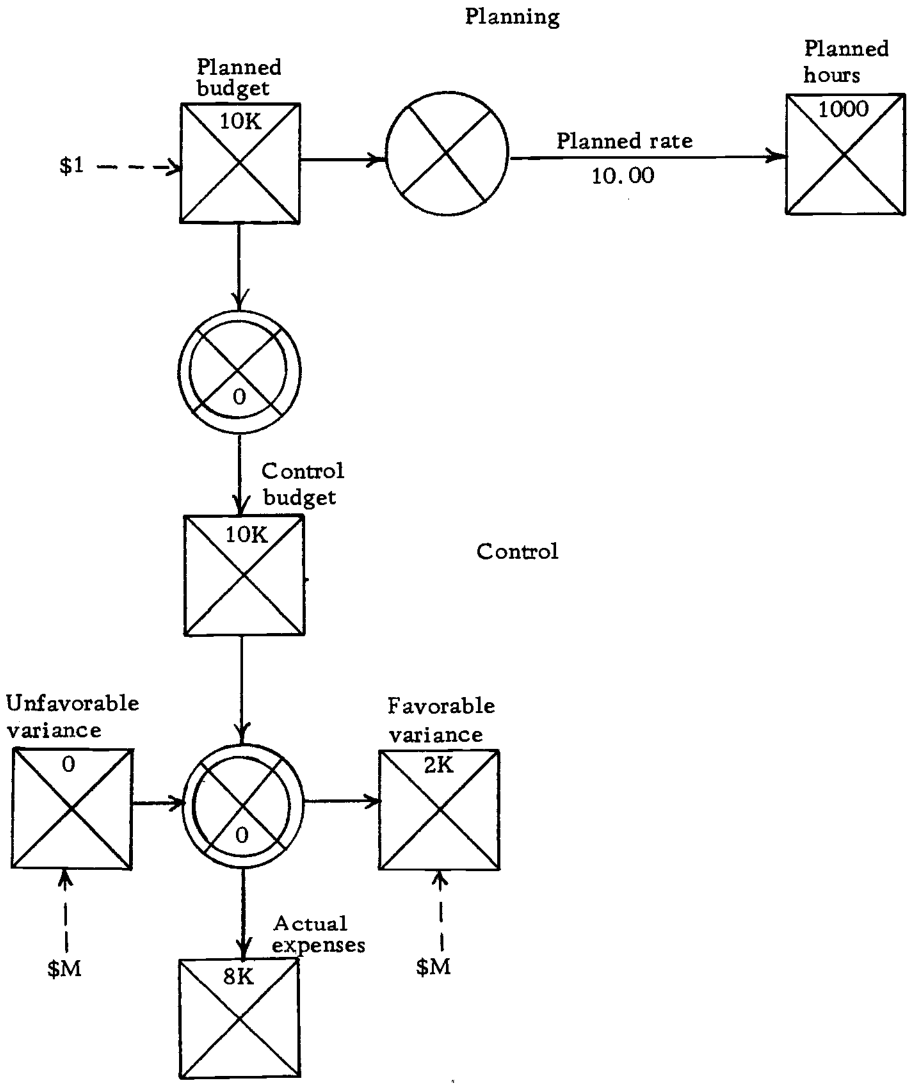
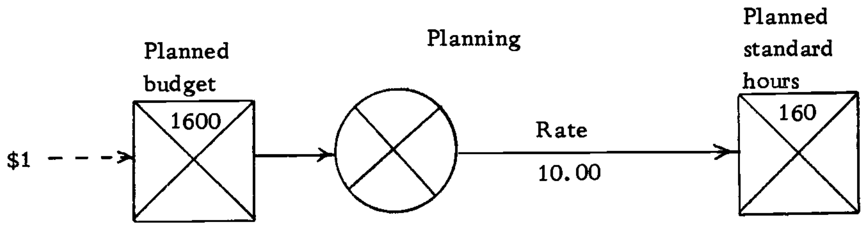
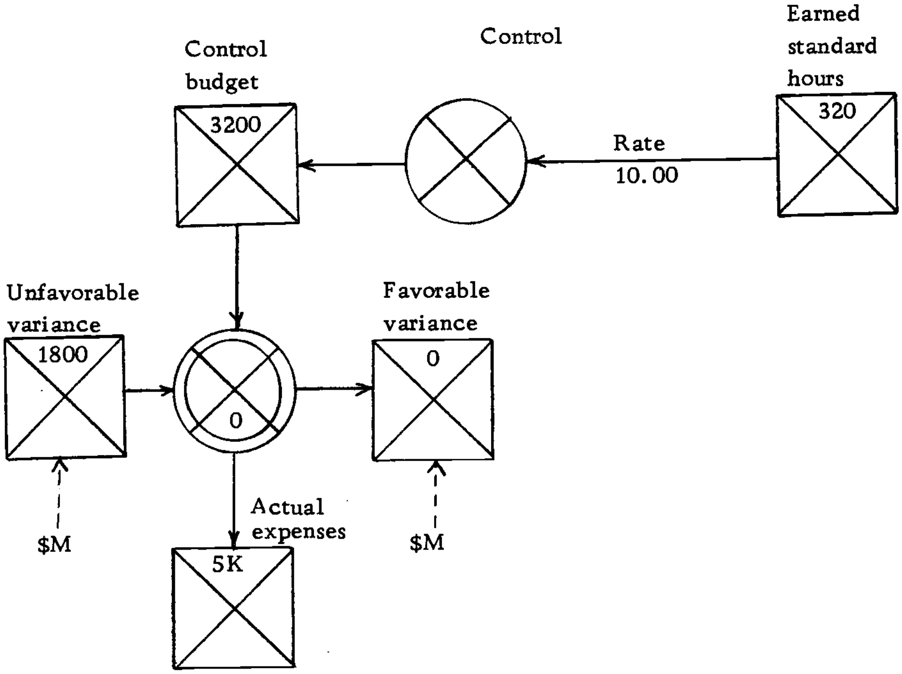


Figure 5-16. Budget code 7. May be used for internal project, cost transfer, reclaim, product services, tooling project, maintenance project, supervisory, administrative support, administrative, engineering project, technical project, training and meeting (independent of production).





% Range	< 80%	80-90%	90-100%	100-110%	> 110%
Hours	160	160	320	320	480

Average planned hours per period: 3800

Planned hours: 3000 Actual frozen standard hours: 3600

Planned %: $\frac{3000}{3800} = 79\%$ Control %: $\frac{3600}{3800} = 95\%$

Figure 5-17. Budget code 8. May be used for internal projects, cost transfer, reclaim, product services, tooling project, maintenance project, supervisory, administrative support, administrative, engineering project, technical project, training and meeting. Only one level of activity is illustrated in this figure.

managerial model for planning pruposes. In this thesis, the latter model is used to illustrate the conceptual development of RPM-flexible budgeting and to provide data for the preparation of decision packages of zero-base budgeting.

The model was built based on information provided by the CRT management. The information included data for the 20 different products according to the following fields:

Raw material requirements.

Raw material costs.

Labor requirements.

Labor rates.

Finished product transfer prices.

Processing operations (cause-and-effect relationships).

Production yields.

a) RawMaterial Requirements. Material requirements present some simplifications like the inclusion of "sets" rather than describing all the individual parts that form one set required for a certain operation; for example, the "rodding" operation of product P10 requires one "set of small parts". However, individual parts were also included in the model when its cost and/or significance so required.

b) Raw Material Costs. Consistent with material requirements, costs were provided in a "per set" or a "per unit" basis. The

RPM segment of Figure 5-18 illustrates one buying operation of the model.

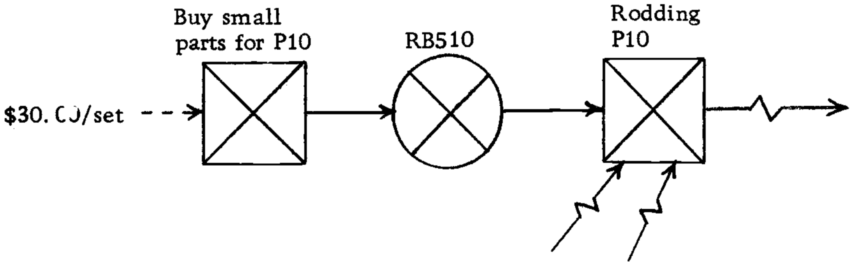


Figure 5-18. RPM segment illustrating raw material costs.

<u>c) Labor Requirements and Rates</u>. All activities requiring labor were associated with the corresponding cost center so that labor budgets were provided by the model. Labor requirements and rates information was given for each of the 11 major operations performed in the area as well as for each of the 20 products processed through those operations. The model provides flexible budgeting information for the labor budget only. Figure 5-19 illustrates the RPM-flexible budgeting approach for product P10 and P11 at the rodding operation.

<u>d) Finished Product Transfer Prices</u>. Transfer prices were used as the "selling" prices for the system. The CRT area must be profitable under this assumption to perform satisfactorily.

<u>e) Processing Operations</u>. RPM served as the communication tool between the analyst and the CRT management. Their cost and effect diagrams were soon understood by the management and the

construction of the model was facilitated.

f) Production Yields. Production yields were provided in form of percentages. Reclaim activities were also included in the model. Figure 5-20 illustrates these concepts as represented by RPM networks.

3. Validation of the Model

The model was validated by using a typical pattern of demands for one production period, where labor resources were assumed unlimited, and demands were to be met exactly. The results of this validation run are shown in Tables 5-1 and 5-2. The levels of activity obtained (Table 5-1) gave satisfactory figures when compared to actual levels of activity. Table 5-2 shows the planned labor budgets per cost center; these budgets were found within 10% variation from actual figures, which was judged by the CRT management as reasonable for planning decisions.

4. Optimality Analysis

After the model was validated properly, the CRT management provided ranges for demands, that is, upper and lower bounds for which production may vary reasonably. The linear programming solution showed optimal output patterns, optimal activity levels and optimal input expenditures or planned budgets needed to obtain such

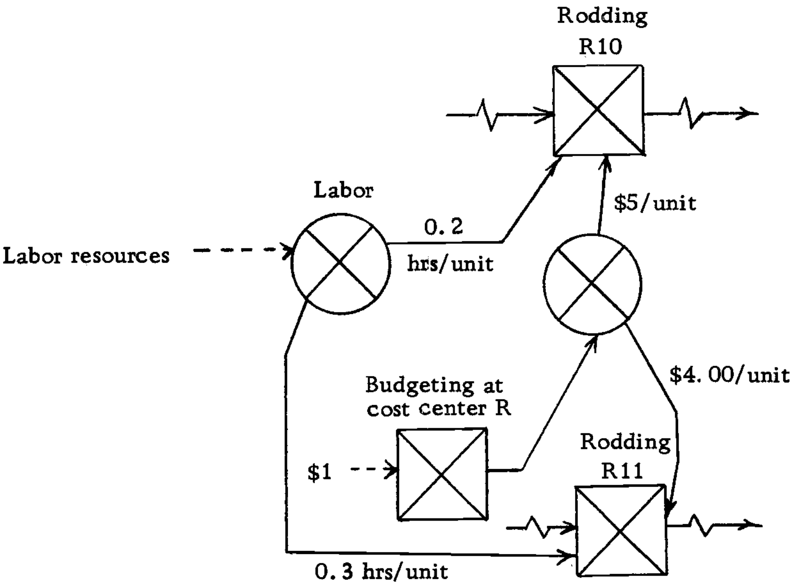


Figure 5-19. RPM-flexible budgeting segment for products P10 and P11.

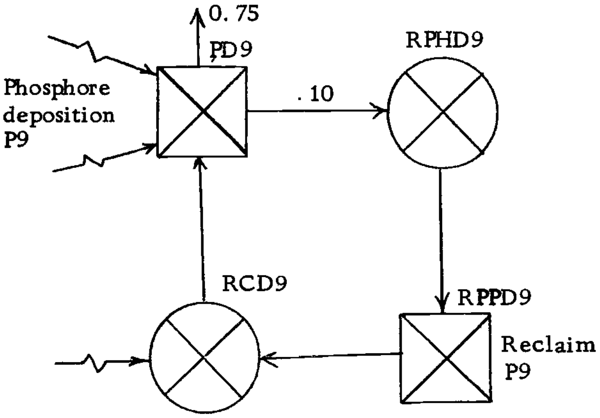


Figure 5-20. Yields and reclaiming illustrated.

Table 5-1. Planned levels of activity: validation run.

	Product #																			
Operation	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Gun rodding	160	81	285	0	0	0	0	336	155	9	0	353	163	117	243	133	62	123	125	380
Gun wiring	147	77	253	0	0	0	0	302	140	8	0	318	150	108	231	126	57	115	134	332
Face plate preparation	127	195	294	0	0	0	0	531	246	10	0	442	201	160	307	168	76	151	178	-
Cobalt dot	128	65	217	0	0	0	0	317	146	7	0	-	-	-	-	-	-	-	-	-
Phosphor deposition	130	66	217	0	0	0	0	460	131	6	0	262	162	128	248	135	62	123	144	241
Bulb preparation	95	47	164	0	0	0	0	208	96	5	0	203	97	78	150	81	35	73	87	210
													77	59	120	66	31	62	66	185
Mesh	-	-	-	-	-	-	-	-	-	-	-	-	73	51	114	61	28	55	65	-
Seal	75	39	130	0	0	0	0	163	75	4	0	162	76	154	114	63	28	57	67	-
Exhaust	64	33	112	0	0	0	0	143	66	3	0	140	65	46	100	55	25	48	58	145
Test	63	33	108	0	0	0	0	136	63	3	0	135	63	45	57	53	24	48	56	139
Ship	55	24	88	0	0	0	0	111	51	2	0	102	25	34	49	27	17	33	14	119

production outputs. The ranges of demand provided to the model and the results obtained after running it in the computer are shown in Tables 5-3 and 5-4.

5. Applications of the RPM-Flexible Budget System to Zero-Base Budgeting

The RPM-flexible budgeting model may also be used to provide relevant information for the preparation of decision packages in zero-base budgeting. Pyhrr (1973, pages 107-111) has suggested the use of zero-base budgeting for some support activities. In our case, the availability of the RPM-flexible budgeting model may provide the necessary back-up data for the preparation of decision packages because several alternatives may be tested and incremental levels of benefit-cost may also be analyzed. To illustrate, refer to decision package shown in Chapter II, Figure 2-2, in which three incremental levels of technical support for the CRT area were described in it. These different levels have direct relationship with production yields, which may be changed in the model so that optimal input and output information may be obtained, analyzed and eventually used in the preparation of the decision packages of zero-base budgeting.

In the concluding chapter of this thesis, we present the evaluation of this model as given by the CRT management. Limitations and some possible extensions of the model are also written in Chapter VI.

Table 5-2. Planned labor budget: validation run.

	Labor Budget		
Cost Center	Variable	Fixed	Total
R	1,313.27	10,800	12,113.27
W	6,265.71	13,500	19,765.71
FPP	6,480.70	9,600	16,080.70
CD	4,248.43	500	4,748.43
PD	17,684.65	28,000	45,684.65
BP	7,313.07	9,000	16,313.07
M	3,976.33	4,000	7,976.33
S	1,724.12	10,000	11,724.12
E	4,762.87	13,500	18,262.87
T	9,678.94	2,000	11,678.94
SH	2,803.77	3,000	5,803.77
		Grand Total	$170,151.86
Total labor:	4221.75 hours	Maximum profit	$6,028.74

Table 5-3. Optimal output schedule.

Product	Acceptable Output Range	Optimal Output Level
P1	55- 90	90
P2	24- 40	40
P3	88-140	140
P4	0- 30	30
P5	0- 30	30
P6	0- 30	30
P7	0- 30	30
P8	111-180	111
P9	51- 90	90
P10	0- 10	10
P11	0- 30	30
P12	102-160	160
P13	25- 50	50
P14	34- 60	60
P15	49- 90	49
P16	27- 60	27
P17	17- 40	40
P18	33- 60	60
P19	14- 90	14
P20	119-220	220

Table 5-4. Optimal planned labor budget.

Cost Center	Labor Budget		Total
	Variable	Fixed	
R	1,769.85	10,800	12,569.85
W	8,171.30	13,500	21,761.31
FPP	7,848.10	9,600	17,448.10
CD	4,970.57	500	5,470.57
PD	19,924.18	28,000	47,924.18
BP	9,466.16	9,000	18,466.16
M	5,080.10	4,000	9,080.10
S	2,536.52	10,000	12,536.52
E	6,259.15	13,500	19,759.15
T	13,433.64	2,000	15,443.64
SH	3,723.48	3,000	6,723.48
		Grand Total	$187,093.06

Total labor: 7,126.52 hours

Maximum profit: $17,725.36

VI. CONCLUSIONS

The optimization models described in Chapter III for optimal allocation of resources under zero-base budgeting were illustrated using a simplified example. However, practical applications of those models are yet to be evaluated since the models involve the determination of coefficients that might represent many intangible factors.

A. Manager's Evaluation of the Study

The RPM-flexible budgeting model described in Chapter V, Section 5. C. 2 is currently being used by the CRT management for planning decisions; the following is an evaluation of this model as given by Mr. Ronald J. Madison, manager of the Storage CRT production:

> The graphical representation of the model permitted adequate feed-back between the analyst and the decision maker in the process of development and validation. The model and the optimal decisions shown in the RPM network provide visibility of the production area as a system, and problem areas may be identified readily.
>
> It is clear how the model provides information for planning decisions under flexible budgeting. The model may be used as a simulation tool to obtain the economic impact of modifying yields and labor rates, and the preparation of decision packages of zero-base budgeting is facilitated.
>
> The assumption of infinite labor resources is acceptable, however, other production capacity constraints must be included in the model to account for additional analysis of problems.
>
> It would be desirable to have the model include lead-time constraints, so that inventory decisions may be analyzed (its relationship to the MRP system would be ideal). Stochastic situations would also be desirable to

> have in the model, especially for production yields, where probability distributions may be provided to the model, rather than deterministic figures.
>
> The model already provides information for aggregate decision-making. Its extensions and modifications would enlarge the foundations for that type of decisions (Madison, 1976).

B. Proposed Areas for Future Research

The limitations identified by Mr. Madison pinpoint the need for further research leading to the integration of operations research techniques within the corporate budgeting structure. If we refer back to Table 1-1 we may see that zero-base and flexible budgeting along with RPM networks may cover the most important activities of a company; the incorporation of stochastic considerations and the relationship of our budgeting system to the Materials Requirements Planning System (MRP) appear as immediate fields open for research that would significantly enhance the models proposed in this thesis because of the impact that such models would have in corporate decision-making.

One last word should be said about the models described in this thesis:

> Judgment is that intangible blend of intellectual ability, past experience and intuition that separates man from machine (Enis, 1974, page 168).

The formalized procedures of this thesis intend to extend and supplement managerial judgment, not to replace it.

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APPENDIX

The use of RPM networks throughout this thesis is based on the assumption that the reader has a basic knowledge of such a symbology. This appendix is presented as a brief summary of some fundamental concepts and notations used in RPM representations. For a more detailed description of the RPM methodology, the reader should refer to Riggs and Inoue (1975); the information in this appendix can also be found in Inoue and Eslick (1975).

Consider the conventional definition of a linear programming model:

$$\text{maximize} \quad Z_x = \sum_{j=1}^{n} c_j x_j \qquad (1)$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad 1 \leq i \leq m \qquad (2)$$

$$\text{where} \quad x_j \geq 0 \qquad 1 \leq j \leq m \qquad (3)$$

While constraint (3) assures the non-negativity of the primal variable, x_j, the parameters and constraints c_j, a_{ij}, and b_i are left free to vary from $-\infty$ to $+\infty$. In an RPM model, those free parameters and constants are made non-negative by distinguishing the positive (+) components from the negative (-) components. The components value equals the absolute value of the parameter or constraint when the sign matches; otherwise, it is considered to be zero. Thus, constraints (1) through (3) can be written as:

maximize $$Z_x = \sum_{j=1}^{n} c_j^+ x_j - \sum_{j=1}^{n} c_j^- x_j \qquad (4)$$

subject to $$\sum_{j=1}^{n} a_{ij} x_j + b_i^+ \geq \sum_{j=1}^{n} a_{ij}^+ x_j + b_i^- \qquad (5)$$

where $$c_j = c_j^+ - c_j^- \; ; \; c_j^+ \cdot c_j^- = 0 \qquad (6)$$

$$b_i = b_i^+ - b_i^- \; ; \; b_i^+ \cdot b_i^- = 0$$

$$a_{ij} = a_{ij}^+ - a_{ij}^- \; ; \; a_{ij}^+ \cdot a_{ij}^- = 0 \qquad (8)$$

All variables, parameters and constraints are now restricted as non-negative values:

$$x_j \geq 0 \qquad (9)$$

and $$c_j^+ , \; c_j^- , \; b_i^+ , \; b_i^- , \; a_{ij}^+ , \; a_{ij}^- \geq 0 \qquad (10)$$

for $$1 \leq i \leq m \text{ and } i \leq j \leq n \qquad (11)$$

The dual problem for the same linear programming problem, (1) through (3), can be similarly expressed as:

minimize $$Zy = \sum_{i=1}^{m} b_i^+ y_i - \sum_{i=1}^{m} b_i^- y_i \qquad (12)$$

subject to $$\sum_{i=1}^{m} a_{ij}^+ y_i + c_i^- \geq \sum_{i=1}^{m} a_{ij} y_i + c_i^+ \qquad (13)$$

$$y_i \geq 0 \qquad (14)$$

Again the same non-negativity conditions (10) and ranges (11) apply.

The RPM symbology uses circles to represent resource nodes, squares to represent process nodes and triangles to represent maximizing and minimizing nodes.

Solid arrows relate resource nodes to process nodes with the arrowhead showing the direction of the inequality. All process nodes are implicitly connected to the primal terminal by means of dotted arrows, while all resource nodes are implicitly connected to the dual terminal also via dotted arrows. No arrows are shown when flows are null, and often the connections to terminal nodes are implied and not explicit. Figure A. 1 shows the entries in all types of nodes.

To illustrate these concepts, let us refer to Figure 5-19 in which a segment of an RPM model is presented. For purposes of this illustration we will assume that the incomplete arrows do not exist and thus, we have a complete system represented by three decision variables or processes (squares) and two constraints or resources (circles). Terminal nodes (triangles) are not shown in the model although they are implicitly considered. The corresponding equations can then be written as:

$$\text{maximize} \quad Z_x = -1R + (0)R10 + (0)\,R11 \qquad (15)$$

$$\text{subject to} \quad 0.2\ R10 + 0.3\ R11 \leq \text{LABOR} \qquad (16)$$

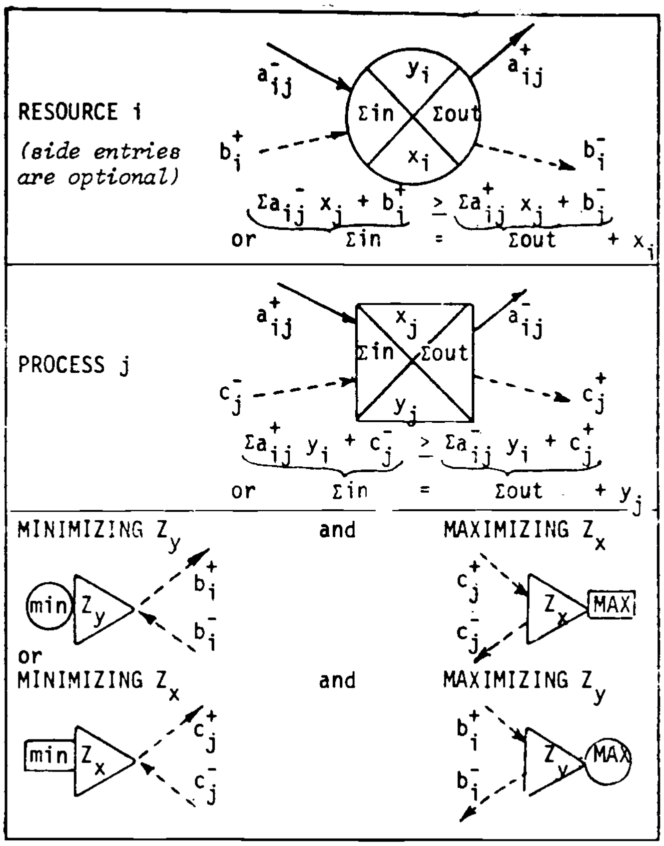

Figure A.1 *Symbology for RPM-LP network*

$$5\ R10 + 4\ R11 \leq R \qquad (17)$$

$$R,\ R10,\ R11 \geq 0 \qquad (18)$$

After solving the linear programming model, the optimal solution can be inserted back onto the network according to the notation of figure A. 1. RPM networks have the unique ability to show both primal and dual values and it provides a direct source of information so that the system can be translated to a linear programming format of standard L. P. packages without the need of writing equations (Riggs and Inoue, 1975; Eckholt, 1976).