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American Institute of Certified Public Accountants

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A MANAGEMENT SERVICES TECHNICAL STUDY

MANAGEMENT INFORMATION SYSTEMS FOR THE SMALLER BUSINESS

Staff Study Published by the
American Institute of Certified Public Accountants

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Management Information Systems For the Smaller Business

The terms "system" and "systems" have been used with increasing frequency in business writing in recent years. References are made to "information systems," "the systems approach," "total systems" and "integrated systems." To some extent the terms have been over-employed. Certainly they convey no precise and generally accepted meaning. A useful first step, therefore, will be to clarify the terms themselves and to show what meaning is attached to them in this study.

A system is a set of interconnected parts through which some activity is performed. In this sense there are many systems in any business organization, of which one is an information system. The essential activity performed by this system is the collection, analysis, summary and storage or onward transmittal of data provided by the operating systems of the business. A management information system, then, is a set of data-gathering, analyzing and reporting functions designed to ensure that management possesses the information it needs to carry out its functions of planning, organizing, co-ordinating and controlling the business. The full management information system is a very complex activity, however, and many of its constituent parts are themselves complex activities. These constituent activities, such as the inventory control activity, the operating budget and the forecasting of future sales, will therefore be referred to as sub-systems and the overall management information system will be thought of as a set of interrelated sub-systems.

The work of the professional accountant is concerned mainly with data and information flows. The mechanism through which the customary accounting reports, the income statement and balance sheet are prepared is essentially an information system and has all the features listed above. Information is collected, analyzed, summarized and reported. The information produced, however, is designed primarily for external use, by state and federal agencies, by banks and various financial intermediaries, and, above all, by the owners (and potential owners) of the company. This study will not deal with this system, but with a system which produces information for *internal* use by company management in the planning and control of company activities. The two systems are not entirely separate: Some information produced for external reporting purposes may be used for internal control, and vice versa. But the criteria by which the systems are judged are in many ways different, and the "internal" system may most conveniently be examined in isolation from the external.

The approach to management information systems used in this study will be a "total systems approach," but this term also requires clarification. The range of meanings runs from the need to look at all sub-systems before changing any one of them to, at the other extreme, the completely centralized and simultaneous monitoring of every activity being performed in the organization by a vast real-time computer. The latter concept is intriguing but not yet realistic, especially for the smaller business. The sense in which "total systems" will be used in this study is closer to the former interpretation and synonymous with "integrated systems." The various sub-systems to be discussed produce information which will be used as input to other sub-systems. Reports produced will include information from any or all the sub-systems. Obviously the form in which information is collected in the various sub-systems must be compatible in terms of units of measurement, meaning of terms, time-bases, and so forth. Care must be taken that information is not collected in one sub-system that might more effectively be collected elsewhere. The implications that change in one sub-system might have for other sub-systems must be considered. In this sense the approach used will be a "total systems" one. It might equally well be described as applied common sense. This study will be essentially a common-sense approach to the design of management information systems with special reference to the problems of the smaller business.

The information required by the management of even the smallest company to enable it to perform its functions is varied and extensive. Among the most important decisions to be made are those about the company's products, both existing and projected. Product decisions require information about sales trends, market surveys and general economic indicators. They also depend upon information about production costs to be expected at various levels of output. The production costs cannot be compiled until information about purchased parts has been obtained from the purchasing activity. Information about the financial implications will also be required: information about the likely increase in working capital, the cost of any additional capital equipment which may be needed, and the effect of these factors on the company's overall cash (and funds) flow. The estimate of working capital needs, however, cannot be made until information is supplied by the production control activity about the inventory requirements associated with the product or products being considered. Thus this single decision problem amply demonstrates both the range of different types of information required and the interdependence of the sub-systems from which that information will be obtained.

In subsequent sections of this study the information requirements of the various activities will be considered in as much detail as space constraints permit. Attention will then be given to the interplay of these various activities as exemplified in their effect upon the company's future cash-flow planning, and it will be demonstrated that information obtained from all these areas of activity may be combined to provide a solution to a complex product-mix problem by means of linear programing techniques. The case studies which form the latter part of this technical study will demonstrate situations in which defective information flows were resulting in inefficiencies and will show how these problems were solved. A second study in this series will consider a number of more complex problems in the design of information systems and will give special attention to the use of EDP equipment in information processing.

The criteria on the basis of which a management information system must be judged are straightforward but vitally important. Complexity is not one of them. The very small and very new business is likely to suffer from a shortage of data; but in the more common case of a small company which is growing and in which management functions are being delegated from the founder-entrepreneur to lower supervisory levels, it is more than likely that too many reports are being produced. The criteria here should not be the number of reports in existence but the usefulness of those reports. Management should receive just that information which it needs to reach its decisions, and not a report filled with unnecessary detail. Another important point, perhaps more difficult for many professional accountants to accept, is that absolute accuracy is not a requirement. One of the most vital criteria of an information system is speed, and the requirements of speed and accuracy will frequently be in conflict. Such a conflict should usually be resolved in favor of speed, even though accuracy is reduced.

Information used as the basis for decision making must be up-to-date and available when needed. An approximate estimate of the direct labor cost of a projected product, available at the meeting in which the decision to make the product has to be taken, is much more useful for the purposes of this decision than a better approximation obtained at the end of the first week's production. Similarly, this latter figure is much more useful than a labor cost correct to two decimal places made available a month later. The chief criteria, then, are simplicity, speed, reasonable accuracy and usefulness. To these may be added two further criteria: economy and development potential. Considerations of economy must not be allowed to override efficiency; the cheapest processing method may be too slow and, in this case, the speed and usefulness criteria would not be satisfied. Other considerations being equal, however, the cheaper method is obviously to be preferred. Also, although the system may be simple at this stage in the company's development, it must be one that can be developed as the requirements become more complex. It should not be necessary to scrap the system and start all over again. Even at this early stage, care must be taken to ensure that all the sub-systems will be compatible with each other when the information-handling workload is many times as great as it is at present. Here too, the approach may be called a "total systems" one in the sense in which the term is being interpreted in this study.

The essential features of an information system remain the same whether the system is the simplest manual one or an advanced system using sophisticated EDP facilities, and the same criteria may be applied. Indeed, the existence of computer facilities often encourages the preparation and circulation of unnecessary reports and irrelevant detail. The criterion of "usefulness" must therefore be held very much in mind when such a system is designed. Here too, the "speed" criterion is important: The computer's facility for rapid sorting and processing of data may be lost if bottlenecks occur in card-punching or if updating runs on a particularly important file have been scheduled at too long an interval. Computer-based systems may offer economies, but installations which have been implemented on the basis of projected clerical cost-savings alone have usually been disappointing. The major benefits of the computer-based system are the reduction of clerical errors, increased speed of processing and the ability to perform more sophisticated analysis than was previously possible. The experiences of some small companies which have introduced computer-based systems will be considered in the second study mentioned above.

The managers of a small company who are beginning to think about their information needs and realize the importance of a systematic approach to information handling are likely to turn for assistance to their accounting advisors. Certainly this is an area in which the CPA should be able to offer valuable assistance. Much of the information will be familiar to him: costs, budget variances, cash flows. A CPA who has some experience in management services engagements will find little that is completely new to him. In reviewing the various sub-systems, this study will assume some basic knowledge and will emphasize the information flow aspects of the particular activity. Thus, in the section on budgeting, the concentration will not be upon what a budget is or the basic philosophy of responsibility accounting, but upon the extent to which budget information uses and depends upon information output of other sub-systems, and the extent to which the budget itself forms input for other sub-systems. The closing sections will then attempt to relate all that has gone before to form an overall picture of the information needs and information flows in a small manufacturing company.

THE PLANNING FUNCTION

Information is not an end in itself. It is important as the basis of management decisions and of management's continuing functions of controlling and co-ordinating the company's operations. None of the decisions that management must make are more important than those about the future of the company: where it is going and what business it projects for the extreme limit of the planning horizon.

The planning function in a business organization may be subdivided into three phases. The planning structure may not be based upon this three-phase breakdown, but three distinct levels exist, implicitly if not explicitly. The three phases may be identified as strategic planning, long-range action planning, and short-range or operational planning. At the strategic planning stage the company's top management group makes decisions which are "strategic" to the company; that is, those decisions which will direct the broad lines of its activities and establish the goals and objectives that will determine all operational decisions. Thus, for a company whose business is automobile distribution, a decision to obtain a franchise for an imported sub-compact automobile, in addition to its existing domestic line, will be a strategic decision. A new policy is established. No funds have yet been committed, however. The second planning stage, the long-range action plan, is the stage at which resource allocation takes place. This allocation is performed within the context of the policies formulated in stage one. Thus, the distributor having formulated the policy, "handle imported automobiles in addition to domestic automobiles," will make certain important consequential action decisions: to build new and enlarged showroom facilities, to enlarge or re-plan the spare parts store and to recruit additional supervisory staff. The time span of this phase will vary with the nature of the business, but will usually take three to five years. The final phase, the short-term operations plan, will usually cover a period of one year or less. The plans made at this level will reflect those at both of the foregoing stages. The operating plans of the automobile distributor will eventually include provision for increased advertising and promotional expenditures necessitated by the decision to handle the additional line, and for additional salesmen and storekeepers to staff the new facilities. Planning at this stage is closely related to the operating budget and will be considered under the budget subsystem.

The strategic and long-range action planning activities are of enormous and obvious importance. These are the phases in which the management of the company makes and implements its "policy" decisions. Such policy decisions are the means by which a company responds to its environment. The environment includes both internal and external elements. The internal environment comprises all the factors in the organization itself: plant and equipment, managerial and operative manpower resources, financial resources, product lines, distribution network and so forth. The company's strategic decisions must be based upon a realistic appraisal of its own strengths and weaknesses. A strategy designed to capitalize on its strong points and to reduce the importance of its disadvantages has good prospects of success. Similarly, a realistic appraisal of the external environment is required. What do the economic indicators forecast—boom or recession? What are competitors doing? Are there any signs of changes in customers' tastes or in the technology of the industry in which the company operates? Such considerations are vital to sound strategic planning in any business organization.

The manager of a small business may perhaps delude himself into thinking that strategic planning is not for him, that it is something which staff specialists do in multimillion-dollar companies. Such a view is completely erroneous. The failure rate of small businesses is very high. Those which survive and grow do so because their strategy is sound, even though the formulation of that strategy was informal and implicit. Many smaller businesses which prosper do so by finding a niche for themselves in which they are able to meet effectively the competition of bigger rivals. Such a niche might be the provision of a service in a local territory neglected by larger companies, the production of a luxury, special appeal or ethnic product for which total demand is not great enough to interest larger competitors, or the identification of a demand sector which competition's products do not completely satisfy. A further factor in the success of many small companies is flexibility: the ability to respond more quickly to emergent trends and changes in demand than can their more ponderous rivals. In either instance—the identification of a niche or the identification of and quick response to new changes in the external environment—the availability of relevant, timely information is clearly all-important.

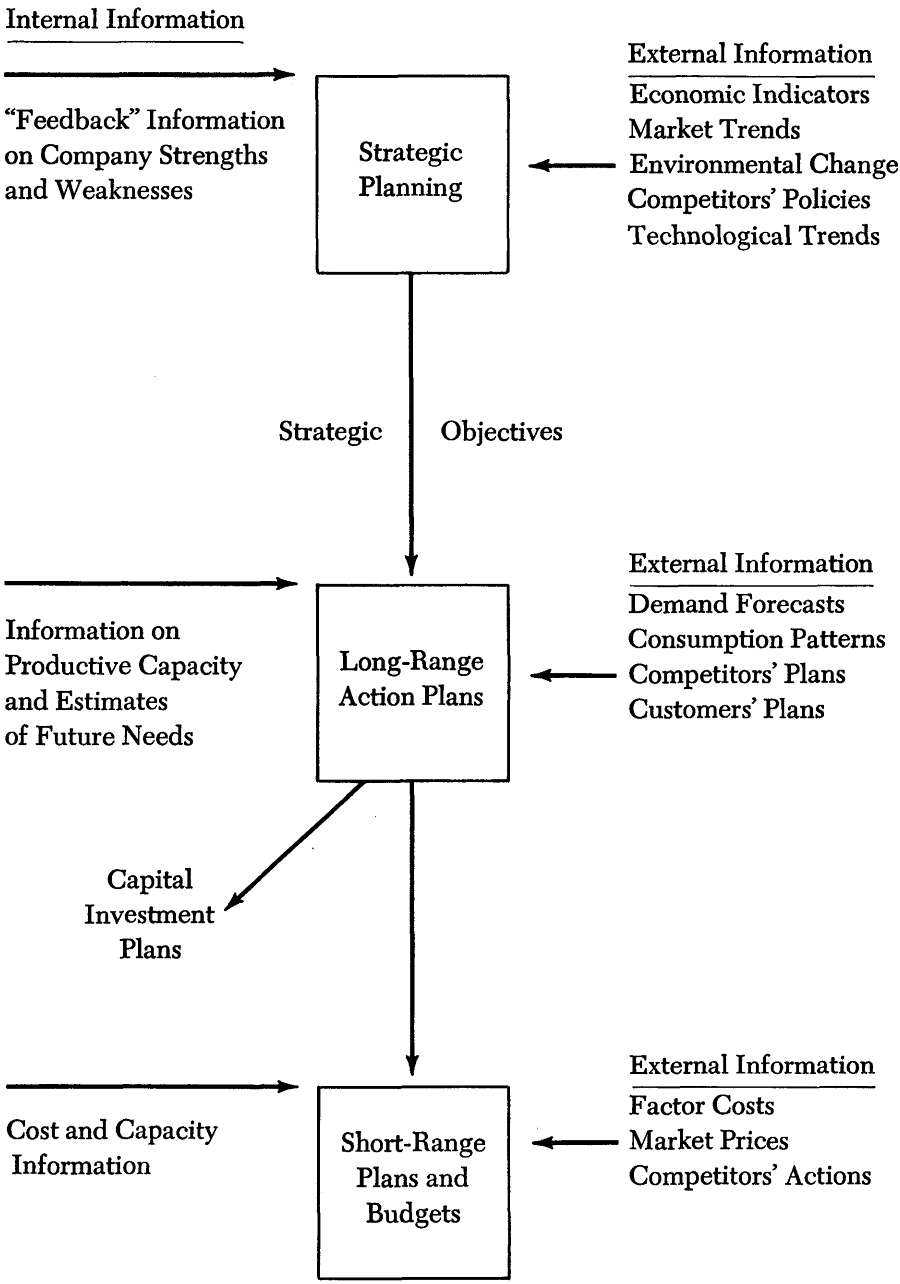
The information flows relevant to the planning sub-system may be summarized in diagrammatic form as shown in Figure 1, page 8.

THE BUDGET SUB-SYSTEM

Budgets are an important adjunct to the delegation of responsibility in the small company as in the large. The delegation of a task to a sub-unit implies that a goal has been set for that sub-unit. It is also necessary to allocate to the sub-unit certain resources which are to be used in attaining that goal. It is usual, when delegating a task, to set various standards of performance. These standards are set in terms of required quality, the time by which the task must be completed, and the acceptable costs. By setting up a budget for each sub-unit, the management of the company provides itself with a control device by which it can ensure that the activities of the sub-units are directed towards the goals indicated by overall company policy. By using budget

Figure 1

INFORMATION FLOWS IN THE PLANNING SUB-SYSTEM



variances and exception reporting techniques, management may be sure that the expenses being incurred by the sub-units and the output being produced by them are in accordance with overall company forecasts and commitments. The kind of budget referred to so far may be termed a "responsibility budget" and its primary purpose is control.

Another type of budget which may be used is the "product budget" or "program budget." A budget of this type might deal with a single product in a multi-product company or with a single type of service in a multiple-activity service organization. Such a budget facilitates decision making concerning the product, program or activity with which it is concerned, by isolating all the information relevant to that particular product or program, particularly information about profitability. This kind of budget is used infrequently in the small company. It need not be elaborate, however, and is well worth careful consideration. Its prime purpose is decision making rather than control.

A further distinction needs to be identified between fixed and variable types of budget. In the fixed budget, a single figure is set for each variable, based upon one particular targeted output volume. Thus, if a company engaged in the manufacture of metal window frames has a target output of 50,000 frames during the coming year the labor and material cost per frame used for budget purposes will be based upon the assumption that exactly 50,000 will be made. The variable type of budget, on the other hand, recognizes that output may fall short of target or that the target may be revised upwards, and that the unit cost will vary at different volume levels. A sliding scale of costs is prepared for different levels of output and is used for budget purposes. The variable budget system, though it is somewhat more expensive to design, may considerably facilitate management's interpretation of responsibility budget figures and is also relevant to many product budget systems.

In addition to using budget information for control and decision-making purposes, management may also use it for co-ordination. The activities of the various sub-units are closely interdependent. Co-ordination is required both at the planning and at the operating stages. In planning, it will be necessary to ensure that the full implications of goals set for one sub-unit are understood by and included in the budget of all other units affected. This is particularly important when volumes are increasing. An operating budget for the manufacturing activity with a production target 10 per cent above existing volumes will cause confusion unless the sales department's budget is also based upon the revised figure. Co-ordination of targets, therefore, is vital. At the operating stage an equal degree of co-ordination is required because target figures are never exactly met. Problems arise, shortages and breakdowns occur, and "specials" and "rush jobs" are accepted. Thus there is an ever-present tendency for the activities to become out of phase, with dire results: Sales people, for instance, may make delivery promises which the production activity cannot fulfill. The co-ordinating task, then, is an on-going one and represents a vital and continued information need.

The budget sub-system is composed of a number of distinct parts which can be called sub-systems themselves. The principal parts may include some or all of the following:

1. The sales budget
2. The selling and administrative expense budget
3. The labor budget
4. The direct-materials budget
5. The maintenance and consumable stores budget
6. The overhead budget
7. The manufacturing budget (combining 3 through 6 above)
8. The capital equipment budget
9. The purchasing budget
10. The research and development budget
11. The cash budget

In the very small company it is unlikely that all these separate budgets will exist. Nevertheless, all these activities will exist in some rudimentary form, and a budget system for the company must make allowance for them somewhere. They may, however, be defined under fewer headings, perhaps simply a sales budget, a factory or manufacturing budget, a general office budget and a cash budget.

One most important point about the budget sub-system, for the purposes of this study, is that the various constituent budgets are closely united in that the output of one budget becomes the input for another. They are therefore linked together in a predetermined sequence with critical timing requirements. The sales budget, which comes first, is broken down by product lines where more than one product exists. The input for the sales budget will be management's strategic objectives and long-range plans. The sales budget itself will in turn provide information input for the manufacturing budget. The manufacturing budget then becomes input for the purchasing budget and, to a lesser extent, the general office or general expense budget. Finally, the other budgets become input for the cash budget, which draws information about expected revenues from the sales budget and about expected expenditures from all sources. In effect, a cash budget cannot be prepared until all other budgets are complete. A timetable for the completion of key stages in the budgeting process is obviously necessary. And again, the need for continuing co-ordination becomes clear. Because the purchasing budget is input for the cash budget, an increase in a supplier's price for any component or material will result in changes in both the purchasing budget and the cash budget. It may then be necessary, if this increase in expenditures threatens to reduce company cash balances to an unacceptably low level, that expenditures in other areas be reduced, and that a reverse flow of information and revised instructions, standards and targets be set in motion until a new cash equilibrium is achieved.

The high degree of interchange of information emphasizes the degree to which the system must be an "integrated" one in terms of standardization of measurements also. The need for standardized time bases is obvious: The sales budget would be of limited use as the basis of manufacturing plans if the sales department estimates were based upon calendar months while manufacturing was based upon 13 standardized 28-day production periods. Equally important is standardization of any classifications upon which demand analysis is based. Consider the case of a small company which publishes and distributes a weekly magazine devoted to investment advice. The expected total sales per period is vital information to all areas. The sales department might wish to break down that forecast into subtotals by type of subscriber: private individuals, educational institutions, financial institutions. To the purchasing officer, responsible for buying paper, a more meaningful breakdown might be "regular edition—airmail edition," and for the accounting staff member in charge of cash planning, the most important division would be between newsstand sales and subscriptions.

In addition to this complex interchange of internally generated information, the budget sub-system will make extensive use of "external" information. The sales budget will be based in large part upon such outside information as: economic indicators, announcements about the programs of industrial customers, forecasts of consumers' disposable incomes, and so forth. The manufacturing budget will make use of external information about wage rate trends in the industry. The purchasing budget must take account of any expected changes in relevant raw material costs. Such information will inevitably be less detailed and more uncertain than internal information, but is usually more important because it arises from factors over which company management has no control.

COST INFORMATION

Information about costs and cost expenditures is certainly as important as any other information produced in a company. It is used for four principal purposes:

1. To make product-line decisions
2. To set product prices and determine distribution policies
3. To ensure that actual expenditures are kept as close as possible to budget
4. To help measure the performance of supervisory staff

The use of cost information in product-line, pricing and distribution decisions has already been examined in some detail in technical studies prepared earlier in this series.[1] The different possible bases upon which items of overhead cost may be allocated and the leading considerations in the question of "full" costing versus "contribution" costing are treated in detail in those studies and will not be repeated here. Three points made in those studies, however, are of very basic importance and have considerable implications for information systems; therefore, they will be restated briefly.

The first point is that the use of full-cost pricing with allocation of all fixed costs to some product or other will *not* ensure that all fixed costs are in fact covered in some magical way. The real value of full-cost allocation is "primarily in its use as a diagnostic device for management. Management must examine the production, distribution and sales aspects of a product to find out whether the product is capable of carrying its share of the capacity costs."[2]

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[1] See Management Services Technical Study No. 1, "Cost Analysis for Product Line Decisions" (AICPA, New York, 1965), and Management Services Technical Study No. 2, "Cost Analysis for Pricing and Distribution Policies" (AICPA, New York, 1965).

[2] MSTS No. 1, "Cost Analysis for Product Line Decisions," p. 14.

The second point is that there is no one correct product cost. The total unit cost of a product is a function of production volume, and it changes as that volume changes: ". . . Neither fully allocated costs nor variable costs are an accurate measure of the effect of dropping a product; an accurate estimate can only be made by a special analysis. . . . The safest generalization is that there is no substitute for a specific analysis of the costs and revenues associated with the particular action under consideration."[3]

Thirdly, the point is made that the establishment of product prices is likely to be a two-stage process. In the first stage a "desired" price is determined on the basis of internal cost information. This is the price which would cover all costs allocated to the product and still provide a target rate of profit. The second stage is the process of modifying this ideal or desired price into a realistic market price on the basis of external information about competitors' prices and sales conditions. "The measure of the success of a pricing formula is whether it works or not, i.e. whether or not the company is successful in receiving a volume of business which, in the eyes of management, is appropriate under the economic circumstances that exist at a given point in time. If the formula is not successful when measured by these standards, it should be changed."[4]

The implications of all this for the design of management information systems are considerable. Cost information is perhaps the prime basis upon which pricing and product-line decisions will be made. These decisions are among the most important made in a company. But no universal ready-made formula exists which may be used to indicate just what costs should be used and how they should be calculated. For each decision the question must be asked, "What costs and what method of allocation are *relevant* to this decision?" and the information collected will depend upon the answer to this question. This is likely to be one of the least "systematic" information flows in the information system. Moreover, the ultimate decision, especially in pricing problems, will depend upon external information as well as internal. This is one of the many areas in which the function of scanning the external environment is an important part of the management information system.

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[3] Ibid, p. 23.

[4] MSTS No. 2, "Cost Analysis for Pricing and Distribution Policies," p. 35.

Internal Cost Control

Cost information is also used to determine whether the company's profit targets are achieved (assuming that planned volume is attained) by comparing actual expenditures with the costs upon which product prices and the departmental budgets were based. The target volume established in the sales budget is therefore critically important, especially when the variable budget approach is not used. Failure to base costs on a realistic output-volume target is not an uncommon fault in small businesses. The results are likely to be disastrous. Breakeven volume is not achieved, and actual unit production costs are found to be considerably greater than those used in the breakeven calculation. A handsome expected profit turns into a realized loss and management realizes, belatedly, that if more realistic cost figures had been available, the product-line decision would have been *not* to manufacture the product.

Thus, the use of costs as a means of control is closely bound up with the budget sub-system. The manufacturing budget incorporates certain output figures taken from the sales budget (and modified in the light of any planned changes in inventory levels). It also includes target figures for the totals of various manufacturing costs on the basis of these outputs. These total-cost targets are obtained by multiplying the numbers of units to be produced by standard unit costs. The determination of these standard costs is of great importance in the costing system. Some small manufacturers do not employ standard costs. If the manufacturing activity is primarily a "job shop," performing custom jobs to special order, then standard costing may not be appropriate. However, standard cost information may be required for pricing or preparing bids. But whenever any kind of repetitive operation is performed, in either a manufacturing or a service organization, a standard-cost system offers considerable benefits and its use should be encouraged.

The Design and Construction of Standard-Cost Systems

The standard-cost system will be very complicated and sophisticated in a large company producing a range of complex products and using a variable budget system. In such a company there will be accounting and industrial engineering staff members whose time may be largely devoted to maintaining the system. The smaller company does not possess these "staff" resources or need them. Its standard-cost system may be both simple and effective. Much of the information required will already exist in various places within the company. Engineers and supervisors will be able to provide realistic estimates of the materials and labor contents of various jobs, and though these are less accurate than good time-study figures, they are better than no standard costs at all. The company's CPA may well be called upon to advise in the setting up of such a system. The basic rule is that no one ready-made system can be used in all companies and in all circumstances. The system must be tailored to the needs of the company, to its size, and to the human resources which will be available to operate it.

The design of a standard-cost system is not a once-for-all task. Frequent modifications will be required. Volumes will change, and costs must be modified accordingly. Specifications will be altered; new materials will be substituted; new equipment will be introduced. Any of these changes may make existing standards obsolete and require revision and updating. The lack of staff activities in the smaller company makes it particularly important that the responsibility for maintaining and updating standards in each area be clearly and definitely delegated to one person, even though that person's other duties may well be in a "line" rather than a "staff" activity.

The Use of Variances

The process of controlling company operations through costs is essentially one of comparing the actual costs with the standard costs to determine the difference between them. This difference is termed a variance. When actual cost is less than standard, it is called a "favorable" variance. When actual cost exceeds standard, the variance is "unfavorable." The variance is a valuable indication of whether or not production and expenditures are being held close to their budgeted target figures. Two aspects of the comparison variance calculation activity are significant for the purposes of the management information system: first, the collection and summarizing of actual cost and output figures for use in the comparison, and second, the question of what variances should be reported, in what detail, and to whom.

The collection of actual cost and output information deserves careful study because many economies are possible in this field. This is an area in which data being collected for conventional "accounting" purposes may often be used for internal "management information" purposes. The documents on which direct labor time is recorded for payroll purposes may be made to provide additional useful information by ensuring that an operation code, job number or product code is entered against all time booked. Similarly, documents used for other internal purposes may be utilized in the variance calculation also. The "shop orders" used by the production control department to route jobs through the plant may be used to collect direct-materials usage and spoilage information. Additional copies of purchase orders may provide data on actual prices paid for purchased parts and materials.

Variance Reporting and Management by Exception

Three points must be stressed here.

1. Management does not need to know about every cost and output figure in the plant every day. It does not even need to be informed every time a variance is reported. Management *does* want to be informed, however, whenever there is an indication that something is getting badly out of line – i.e., whenever a major variance occurs.

2. In such cases, management needs to know not only how large the variance is, but *why* it occurred.

3. Variances are reported so that corrective action may be taken. If a variance is worth reporting at all it is worth reporting *immediately*.

No ready-made rules can be given as to what constitutes a "significant" variance. Common-sense standards must be worked out within each company on the basis of the situation within that company. In large companies, the staff specialists may use statistical techniques to calculate "action limits" which trigger managerial action when costs, production or spoilage reaches a certain level. For the smaller company, such techniques may be useful but are not essential. In practice, the exception-reporting system will tend to find its own equilibrium. The manager who believes that his subordinates are taking up his time with unnecessary detail is likely to make his views on the subject very clear to them; so is the manager who feels that not enough information is reaching him. In this way the company will develop a reporting system suitable for its situation and the individuals concerned.

When a cost rises so much that the increase is clearly large enough to justify reporting it to senior management, the responsible supervisor will be expected to have a good explanation to offer. In other words, management will want to know what causes the variance. Assume, for instance, that direct material costs during the past week are found to have been 10 per cent greater than standard: a variance which would certainly seem to require some corrective action. The variance might arise from either of two causes: More material per unit is being used (because of increased spoilage), or the price of the material has increased. The difference is very important for control purposes. The price of the material is not a factor which the plant superintendent can control or for which he is responsible. The amount of spoilage *is* something for which he is responsible. Similarly, a major variance might be reported in that highly critical area, the sales budget. Assume that actual sales revenues are 12 per cent below those set as budget targets. The discrepancy may be due to either of two factors: Sales were lower than planned, or sales targets were achieved but at a selling price below that used in the budget. Again, the difference is important for control purposes. If sales volumes are down, management will want to know if this happened because the sales department failed to sell or because the plant failed to produce the goods requested. If prices are down, the reason may be the actions of competitors and the plant is clearly not responsible. To meet these requirements, the usual practice is to report two variances in each case, a price or cost variance and a volume, quantity or usage variance. The rules for calculating these variances are:

Volume Variance = Actual volume minus standard volume multiplied by standard price.

Price Variance = Actual price minus standard price multiplied by actual quantity.

It should be remembered that a single-period variance may include elements of both price and volume variance. Consider this information extracted from the direct-materials budget:

	Volume	*Unit Price*	*Total*
Actual	1,125	$2.10	$2,362.50
Budget	1,000	$2.00	$2,000.00
		Total Variance =	$362.50

Using the above rules for calculation:

Volume Variance = (1,125 — 1,000) × $2.00 = $250.00
Price Variance = ($2.10 — $2.00) × 1,125 = $112.50
Total Variance = Volume Variance + Price Variance
$362.50 = $250.00 + $ 112.50

The calculation and reporting of variances in this manner is not difficult. All the input information required is readily available and the calculations are simple and routine. The information produced becomes an input for managerial decision making, and the separation of price and volume effects presents this input to management in its most immediately usable form. The use of this system is therefore recommended in any company which uses a standard-cost system, however simple it may be.

THE PRODUCTION CONTROL SUB-SYSTEM

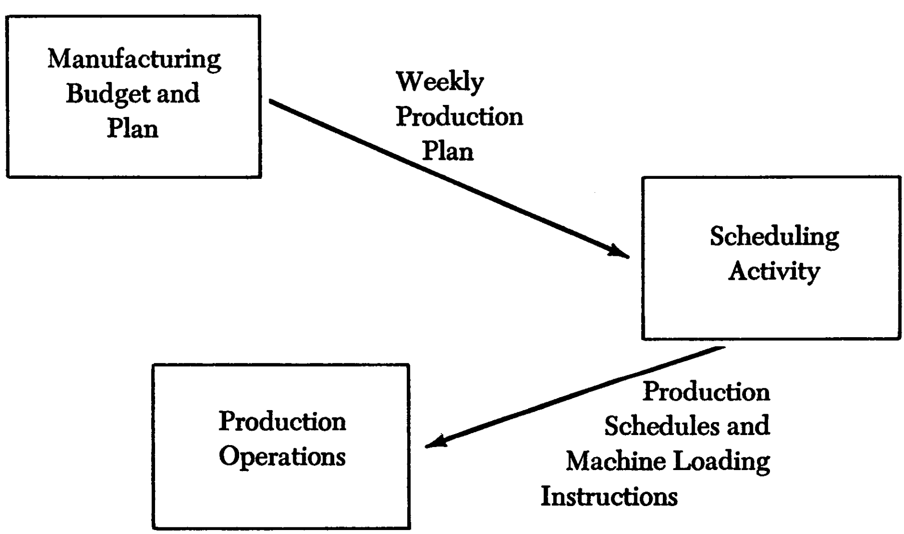
The production control area plays an important part in the management information system as both a supplier and user of information. Production control activities may be divided into two principal areas: scheduling and inventory control. The term scheduling is used here to include a group of related activities: specifications and routing, machine loading and material movement control.

The Role of the Scheduling Activity in the Information System

Scheduling is an important interpretative activity through which production plans are converted into day-to-day operating instructions. The first stage in the development of production plans is management's strategic planning. One of the announced objectives in the strategic planning of a small company in the garment industry, for instance, might be to increase production of menswear and to reduce the importance of women's items in order to lessen losses and dislocations caused by fashion changes. At the next stage, that of long-term planning, this objective is translated into a definite plan to increase production of certain menswear lines by a stated amount during the coming planning period. The third stage, the short-term plan, converts the long-term plans into specific weekly target figures in the sales budget, and from there the target information passes to the manufacturing budget. But unless the production operation is a very simple one or very great reliance is to be placed in the production superintendent, a further stage is necessary. This final stage, the production schedule, converts the weekly budget production target into a set of detailed instructions to production personnel, specifying which jobs are to be loaded onto which machines or assembly lines at any particular time. In the smaller company, this function is probably performed by the production control supervisor and his assistant, using a simple visual plan board. Such a system may be very efficient when the schedulers are experienced and thoroughly familiar with the production facilities for which the scheduling is being performed. The output of the schedulers then becomes input for the operational areas, and the role of the scheduling activity may be diagramed as in Figure 2, below.

Figure 2

THE ROLE OF THE SCHEDULING ACTIVITY IN THE MANAGEMENT INFORMATION SYSTEM



Inventory Control

The other major production control activity is the control of inventory levels. The nature of inventories, the reasons for their existence and the design of basic inventory control decision rules are discussed in Management Services Technical Studies Nos. 6 and 7.[5] That material will not be duplicated here. In summary, however, the essential purpose of inventory is to provide a "slack" or "shock-absorber" effect in the company's operations. If no inventories existed at any point, the timing requirements of various operations would be impossibly precise. It would be necessary for all purchased parts and materials to be delivered to the plant at the exact time at which they were required by production operations. When a product requires two or more sequential machining operations, it would be necessary to have machine tools which all required exactly the same amount of time or an exact multiple, to complete the machining of one item, so that machine No. 2 would become ready to accept the item just as operations on machine No. 1 were completed: clearly an impossible requirement. And it would be necessary to schedule the completion of each item at the exact moment at which it was required for shipment to a customer. These quite unrealistic conditions are avoided by building in inventory levels at various points. Materials and components are ordered and delivered in economic batch quantities and form an inventory from which production operations draw their requirements. Stockpiles of semi-finished parts are allowed to accumulate between machining operations, providing a buffer which makes the exact synchronization of these operations unnecessary. "Buffer" stocks provide protection against errors and unforeseen eventualities in procurement programs, and finished-goods stocks provide a reservoir from which customer demands are supplied. In short, inventory reserves serve to decouple the various stages in the procurement-production-distribution process.

The ability to satisfy demands and to meet delivery promises is important to any company, but probably even more important to the small company whose competitive advantage may be the ability to provide better service than their larger competitors. The provision of inventory-stock information to company management, so that emergency action may be taken if finished-goods stocks fall to a dangerous low, will there-

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[5] MSTS No. 6, "Practical Techniques and Policies for Inventory Control" (AICPA, New York, 1968), and MSTS No. 7, "Techniques for Forecasting Product Demand" (AICPA, New York, 1968).

fore be an important link in the information system. This link is of particular importance, since many small manufacturing companies tend to be production oriented. Such companies give undue emphasis to cost reduction and too little attention to realistic demand forecasting, and may overproduce in their desire to achieve economic production batches and runs.

Such overproduction is very likely to impair the company's working-capital position. In this situation, management needs to know what amounts of finished goods are on hand and scheduled so that overproduction can be avoided. A warning signal may also be obtained through a volume-variance report in the sales budget when production shows no such variance, but direct monitoring is likely to be more effective. This is particularly true in highly seasonal industries, such as fruit-canning, where production schedules depend largely upon the availability of the crop and production plans cannot be established beforehand with any degree of certainty.

A further important information link will be that between the inventory control area and the purchasing staff. The calculation of inventory levels and reorder points requires a knowledge of supplier lead times, that is, the time interval between placing an order on that supplier and receiving the goods. In practice, the stock clerk needs to know not only the supplier's declared lead time but how reliable he has been and by what margin he may have failed to meet past delivery promises. In other words, an approximate observed probability distribution for each supplier's lead time is required, and it is on the basis of this distribution that buffer-stock levels will be established. This information is usually available from the company's purchasing staff, even though they have probably never thought of their accumulated experience in terms of an observed probability distribution. The link between the stock-control activity and purchasing will usually be an informal one. Information will be requested and passed by word of mouth rather than through a written reporting system. It is nevertheless worth remembering that any organizational change which promises to improve communication between these activities is likely to result in benefits in terms of the reduction of out-of-stock conditions.

SALES FORECASTING

The importance of realistic sales forecasting has already been touched upon at a number of points. Sales objectives set in long-term planning form the basis of target figures in the sales budget and the entire budget sub-system is based very largely upon the sales budget. In the fixed-budget system more commonly used in small companies, standard costs are based upon one particular production level, and if sales fall short of target figures and production has to be reduced, the existing standard cost figures and any variance calculations based upon them will be misleading.

Flexible budgets tend to overcome the problems inherent under such restrictions, as they are based upon various production levels. This method will provide for standards at various levels of activity.

The problem of sales forecasting is most difficult for the very new business, in which there is little data available upon which any forecast may be based. The most useful data for such a company is primarily "external" data, economic indicators and forecasts of future consumer behavior or new industrial investment. A company which has been in business for some years, however, may be able to make very considerable use of past sales performance data as a basis for forecasts of future sales. These techniques have been treated at length in Management Services Technical Study No. 7, "Techniques for Forecasting Product Demand." The forecasting methods explained in that study are fully applicable to the small company, and two of the case studies included describe the introduction of simple forecasting techniques in one- and two-man enterprises.

One major complicating factor in the smaller business, however, is that the chief executive in such companies frequently continues to operate as the sales manager and chief salesman—often because of personal contacts built up in the very early stages of the company's history. Such a chief executive will obviously be well aware of the importance of sales. But he is also likely to be a very overworked executive. He may fail to recognize signs of changing trends and tastes in the market quickly enough. A system which relegates sales or at least sales-planning responsibility to an executive other than the company president is recommended even for the very small company.

One of the company's best potential sources of information about future sales, trends, changes in tastes and changes in buying habits, is its own sales force. In the larger company this potential source is often little utilized. The small company with its less formal structure is in a position to tap this source of information and to receive the added benefits of a less frustrated and better-motivated sales team.

CAPITAL EXPENDITURES *

Among the most "strategic" of the decisions that management must make are those relating to major capital expenditures. Miscalculations in this area will lead to undercapacity and to loss of orders, or to overcapacity with its attendant costs and inefficiencies. In small companies, undercapacity is probably the more likely situation. A small company entering upon a period of rapid growth is faced with demands both for capital investment and for increased working capital. Working capital requirements tend to rise more quickly than sales revenues. The company is unlikely to be able to finance both capital investment and working capital needs out of earnings. Borrowing, however, is more difficult and more expensive for a small company than for a large one. It may also be quite impractical to raise additional equity capital, because there is not yet a wide market for the company's stock or because the amount of stock which would have to be offered would lead to unacceptable dilution of earnings per share or to loss of voting control. In these conditions, the small company is very likely to be undercapitalized and may even have an outstandingly promising product which cannot be properly exploited because of shortage of investment funds. Small companies in this position are very often quickly acquired by larger, cash-rich companies looking for profitable diversification opportunities.

The reader may, while accepting the importance of capital investment decisions to the smaller company, question why the subject has been included in a study of management information systems. The answer is simply that the company's capital-budgeting decisions are one of the three most critical and strategically significant uses of the information produced by the system, the others being the pricing and product-line decisions mentioned previously. None of the decisions made in these significant areas can be any better than the information upon which they are based.

Many books and articles on capital-budgeting problems and techniques have been written in recent years. Many of the writers disagree about the methods which should be used. The disagreement is somewhat academic and concerned with points of detail, however. There is a considerable area in which a consensus has been reached,

* The reader should refer to Management Services Technical Study No. 4, "Analysis for Purchasing and Financing Productive Equipment," for a more comprehensive treatment of this subject.

and it is therefore possible to make a number of useful and practical recommendations without becoming engaged in theoretical disputations inappropriate to a study of this nature.

In many small companies the measure of investment often used in evaluating and comparing capital budget projects is the "payback" method. Every capital investment involves a relatively large cash outflow at approximately the time the new equipment or facilities become available followed by a return on the use of the new facilities, this return taking the form either of additional revenues or of reduced costs (or both). The "payback" is calculated by dividing the initial cash outflow by the average annual after-tax return, giving an answer in terms of the number of years of operations required to return the initial investment. This approach has the merit of simplicity but little else. It does not measure the true profitability of the investment, no account being taken of, for instance, depreciation-allowance tax shields. The major shortcoming of the payback method is that it fails to take into account the time value of money. The "average after-tax return" might produce the same figure from some very different patterns of expected returns. Consider the three examples following:

Project No. 1

Initial Investment:		$100,000
After-Tax Return:	Year 1	0
	Year 2	0
	Year 3	0
	Year 4	0
	Year 5	$100,000
Average Annual Return:		$ 20,000
Payback:		5 Years

Project No. 2

Initial Investment:		$100,000
After-Tax Return:	Year 1	20,000
	Year 2	20,000
	Year 3	20,000
	Year 4	20,000
	Year 5	20,000
Average Annual Return:		$ 20,000
Payback:		5 years

Project No. 3

Initial Investment:		$100,000
After-Tax Return:	Year 1	40,000
	Year 2	30,000
	Year 3	15,000
	Year 4	10,000
	Year 5	5,000
Average Annual Return:		$ 20,000
Payback:		5 years

In each case, the working life of the new equipment is assumed to be exactly five years. The payback method indicates that all three projects are equally attractive, but any practical businessman would surely choose project No. 3 under which a major part of the funds invested have been returned and are ready for reinvestment by the end of year 2. In making this choice, the businessman recognizes that money does have a time value, and that cash to be received in five years time is not as attractive as cash available now.

All of the more recent methods of evaluation recognize the time-value element. Cash to be received at some future date may be reduced to its comparable worth in cash available now by discounting it. The resulting figure is called the "present value" of the future sum. Methods using this concept are known by the general term of the "discounted cash-flow" approach. Two basic techniques exist. One, called the present-value method, discounts the expected cash flows to be produced by the investment, and the discounted amounts are then added to give a total present value of the flows. If this total exceeds the initial outflow, then the project is a profitable one at that rate of discounting and should be accepted. The problem lies in the choice of a discounting rate; some authorities argue that the company's borrowing rate should be used, others use its average cost of capital including equity capital, and yet others look at its opportunity rate in terms of recent realized return on investments in the company.

The other basic method avoids the need to make a decision on this point. Instead, the outflows and inflows are listed and, by a process of trial and error, a discount rate is found which exactly equates the discounted total of inflows with the investment outflows. This rate, and the method itself, are known as the "internal rate of return." The rate thus calculated is useful chiefly as a basis for comparison with the rates promised by other alternative projects, in which the projects are being ranked against each other to decide which of them to undertake with the limited available funds. A number of elaborations of these basic methods have appeared, some requiring the use of multiple discounting rates. Argument continues as to which method is superior and in what circumstances.

The situation probably appears highly confusing but it need not be. The methods are not difficult, and using them is considerably easier than choosing between them. A sound recommendation would be to select the present-value method for ease of calculation. For most small companies with limited funds and restricted borrowing opportunities, the opportunity rate is, perhaps, the most appropriate discounting basis. Tables of present-value factors at various discounting rates and for various time periods are readily available. The points upon which a consensus has been reached and which are here emphasized are:

1. Any of the discounted cash-flow methods are superior to the older methods such as payback which do not recognize the time-value of money.
2. In most circumstances the differences between the discounted cash-flow methods are of little practical importance and any one of them provides a reasonable basis for the selection of capital-investment projects. The important thing is to select a method and then use it *consistently*.
3. The most important question is not which of the discounted cash-flow methods should be used but *whether or not all relevant inflows and outflows have been included in the calculation as well as future conditions and options.*

This third and most important point emphasizes the extent to which sound capital investment decisions are dependent upon an efficient management information system. Some of the information used in the calculation will be obtained from external sources. If a machine of a new and revolutionary type is being considered, the suppliers will be the only source of information, not only about the price of the machine, but also its power consumption, life between overhauls, amount of spoilage produced, and so forth. But in a majority of cases, the proposed equipment or facilities will be of a kind about which considerable information is available within the organization.

The most important single figure in the appraisal of a proposed capital investment, as in so many other business decisions, is expected sales.

The project may in fact have been formulated because an increase in demand for current products is expected and existing capacity is inadequate. If the proposed investment is for equipment to be used in connection with a new product or service, the estimate of sales will be equally critical. A most important point is that many errors in sales estimates for new products are essentially errors in timing rather than in magnitude. A project is accepted and the equipment purchased, for instance, on the basis that a maximum sales volume of $250,000 will be achieved, two years hence. If the target volume of $250,000 is in fact achieved, but not until year four, the project's actual rate of return is much lower than the project-evaluation calculations indicated.

Even when the sales forecasting has been accurate, expected rates of return will not be realized unless the cost estimating was realistic. Accurate and up-to-date direct-labor and materials costs will be available from the standard-cost system, taking into account recent variances and making any necessary adjustments. Spoilage rates on comparable work will also be obtainable from manufacturing budgets. Explanatory material in volume-variance records should provide information about the incidence of breakdown and maintenance downtime for similar equipment. Inventory records will provide the usage and cost of replacement parts and consumable stores. If full use is made of the information and practical experience existing within the company, then few serious errors should be made in cost estimating for any products or processes which are not entirely unfamiliar.

A number of other factors must be taken into account, particularly the effect of the proposed investment upon the company's liability for taxes on income. Investment credit may be applicable and must be included in the calculation. When new equipment will replace existing facilities, a realistic disposal price for the old facilities must be estimated, and the tax effects of any book profit or loss on sale be taken into consideration. The correct treatment of depreciation is particularly important. The depreciation allowance is not included in the calculation as an outflow; this would result in double-counting, since the full cash cost of the facilities would have already been taken as an outflow. Only flows representing actual cash transactions are relevant. Depreciation does have real cash-flow significance in terms of tax payments, however. Depreciation is allowable as an expense in calculating income for tax purposes, and the depreciation at the maximum permissible accelerated rate will provide a "tax-shield" effect which is added to the after-tax earnings of the investment to give its total return. Two further factors require emphasis. If the proposed investment requires a significant increase in working capital, the fact that funds will be tied up in this way throughout the life of the investment needs to be included in the calculation. This is most readily done by regarding the working-capital requirement as a cash outflow in the first year of the project and as a corresponding (but discounted) cash inflow during the final year. Finally, care must be taken to make due allowance for the residual value of the projected facilities at the end of the calculation period. Clearly this is of prime importance when land is included in the investment. It may also be significant in machinery-purchase projects in which the equipment is expected to have an economic life of 20 years, but management decides to evaluate the proposal on a seven-year life because of the uncertainty of sales and cost estimates after this point. It might reasonably be assumed that such machinery will have a considerable residual market value at the end of seven years, and failure to include this value as a cash inflow in year seven might result in the rejection of an attractive project.

In the light of the above discussion, it must be obvious that sound capital-investment analysis requires the full co-operation of senior management, planning staff (where such a staff exists), engineers, accounting staff, manufacturing personnel and, of course, the sales department. In many larger companies, the formal routing of capital-investment projects reflects these complex information and review requirements. Projects originate with the plant engineering staff in co-operation with the manufacturing area concerned and, in some cases, are then passed to the plant accounting staff which calculates the economic justification. The project next goes to the divisional accounting staff which reviews it, checking the projected volumes with divisional sales. Finally, it is submitted to an executive council or capital-budget committee of senior executives which makes the final decision. In the small company a much less formal procedure is satisfactory. Indeed, one of the advantages of the small company's closer-knit executive group and shorter lines of communication is that less time is wasted on the preparation of capital-investment projects which are ultimately rejected. The need to ensure that the information on which the project is evaluated is the best available is even greater in the small company, however, because the company's survival may depend upon the accurate evaluation of every single major capital-investment proposal made.

FINANCIAL IMPLICATIONS

An earlier section of this study examined the interrelationships existing within the budgeting system, and indicated how the planning figures in all the various budgets eventually served as inputs to the cash budget. This point is sufficiently important to be emphasized further here. All the planned output volumes, revenues, expenditures and estimated costs influence the cash balances the company will hold at any point of time within the budget period, and the cash budget cannot be compiled until all other budgets are completed. The accounting staff then projects the expected levels of cash balances throughout the period on the basis of the opening balance and the net effects of all operations and transactions taking place in the company. The level indicated at each point in time is then compared with whatever sum management considers to be a minimum safe cash balance. In practice, as a "first pass" the expected balance at the end of each month is projected. If any monthly figure is disturbingly close to the acceptable minimum, then weekly figures will be calculated for each week in that month, and possibly even daily cash balances projected for a particular "crisis" week. If, at any stage, the projected balance falls below the minimum level, either plans must be laid for some short-term borrowing within the period or some expenditures must be reduced or postponed. One or more of the individual budgets is revised, and finally a satisfactory cash budget is produced.

The finished cash budget becomes a basic management-control document. The management of the company may safely assume that if all inflows and outflows during the budget period are held to approximately their target levels, there is no danger of insolvency or serious cash inadequacy. If, however, it becomes apparent that some target will not be met, perhaps because the market price of a product has fallen or the purchase price of an essential raw material risen, then it becomes a matter of great urgency to calculate the effect of this change on the company's future cash position. The cash budget-planning figures – that is, the cash-flow forecasts – provide a vehicle for this calculation. A very basic requirement of the information system is that any variances which are expected to persist be immediately communicated to the accounting personnel responsible for the cash-budget and cash-flow forecasting and that they in turn immediately communicate to company management any indication that cash balances will fall to a danger level at some future time because of these departures from the plan.

The following points are critical in the construction of accurate cash budgets and cash-flow forecasts:

1. Income as defined for accounting purposes is not a useful concept for cash-flow analysis. Accounting income is recognized only after certain write-offs have been deducted, especially depreciation. A reasonable approximation of net cash inflow may be obtained by adding back depreciation to earnings after tax. For cash-flow planning, however, all receipts and expenditures of cash should be entered individually and no "income" entry will appear. Depreciation will enter the projection only indirectly, through its effect upon income tax payments.

2. As in the evaluation of capital-investment projects, the timing of flows is as important as their magnitude in cash-flow forecasting. The treatment of sales revenues is particularly important as the major inflow and usually the most critical variable in the cash budget. A realistic estimate of sales, therefore, is not enough. The sales department – or more appropriately the credit department – must also forecast the percentage of cash sales, and the average time lag in the receipt of payments for credit sales. A similar time-lag effect will exist in many expenditure items, particularly materials purchased in companies for whom trade credit is an important source of funds. These payments will enter the cash forecast in the month in which cash payment is expected to be made, not that in which the goods are received.

3. Most financial-planning work consists of making trade-offs between competitive demands for scarce financial resources. Nowhere is this more true than in the adjustment process by which the system of budget plans is brought into equilibrium with cash-budget minimum-balance requirements. The decisions facing management in this process are invariably difficult; in a typical situation, the cash-flow projection may well reveal that the company may *either* put into effect a price reduction which the sales department has requested to meet competitors' actions, *or* undertake a projected media promotional campaign, *or* purchase labor-saving machinery which promises to reduce direct manufacturing costs *or* construct a much-needed cafeteria facility. In many cases the discounted cash-flow techniques described earlier may provide a solution, but where some projects are not independent or cannot be expressed in terms of cash returns, the decision can only be a "policy" one. There may be no obviously right answer. But manage-

ment may very easily find a wrong answer if the information upon which it is being based is not the best that can be provided.

REQUIREMENTS FOR A BASIC MANAGEMENT INFORMATION SYSTEM

The most important components in the company's information system have been examined, and an attempt has been made to explain why each is important and to show its essential interrelationships with other parts of the system. This material may best be summarized by listing the essential features and constituent parts of an efficient and effective management information system for a small business.

1. The purpose of a management information system is to supply to management the information which management requires in order to:
   a. Reach policy decisions, make plans and set objectives.
   b. Exercise control over operations to ensure that those objectives are achieved.

2. It is important that such a system be as simple as possible while still achieving satisfactory performance and produce only useful information as quickly as possible, even at some sacrifice in precision.

3. The best information system is unlikely to achieve much unless it is combined with sound strategic planning. The company's long-term plans will be the basis of the short-term targets incorporated in the budget sub-system.

   The information system is largely designed to implement these objectives. Without strategic planning the entire process becomes one of opportunism.

4. A sub-system of budgets is an essential part of the information system. Budgets constructed on "product" lines provide information which is directly useful in making product and pricing decisions. Budgets based upon areas of operating responsibility are a basic tool in controlling sub-unit performance. The budget is basically a time-scaled performance target which the sub-unit is expected to achieve. The budget sub-system for a small company may be very simple and based on functional areas rather than operating sections or departments, possibly just a sales budget, a manufacturing budget, a purchasing budget, a general budget and a cash budget.

5. A sound cost system is vital for two purposes: as a source for pricing and product-line decisions and as the basis upon which manufacturing budget targets can be determined. A set of "standard" costs should be established. This need not require a prolonged industrial engineering study. A useful first approximation may be based upon estimates made by experienced management and supervisors. When standard costs are established, they should be kept up to date.

6. The basic control procedure consists of the comparison of actual costs with standard costs and of actual production/sales volumes with target volumes. When the difference—or variance—is of critical proportions, the information system must provide for its immediate communication to management so that remedial action may be authorized. When no immediate solution is possible, the variance must also be communicated to the cash forecasting area so that its effect on the company's liquidity position may be projected.

7. Some further reports to management will be required in addition to the budget variance reports. The most important are a production report (weekly), an order-backlog report (weekly), a manpower report including absenteeism and labor turnover (monthly), and a return on investment report. Any tendency to proliferation of such reports must be resisted.

8. The information system should include a rudimentary production control activity, consisting of an inventory control and, in all but the simplest forms of activity, a scheduling facility which translates production targets into specific shop and machine-loading plans.

9. A set of rules for the preparation and evaluation of capital-investment projects should be included in the system. Any discounted cash-flow method is acceptable. The choice of a method is less important than careful selection of input data. This is one of the most important uses of management information.

10. The various parts of the management information system will be integrated in the sense that each individual part or sub-system will be designed with the requirements of the overall system in mind. No part of the system will be changed until the effect of the proposed change on all other parts of the system have been examined. In this way it will be possible to ensure, for instance, that the same time scale is used throughout, and that the same product group classifications are adopted. The need for integration of various sub-systems is empha-

sized by the dependence of the company's cash-flow forecast upon information from all sub-systems.

Finally, it must be emphasized that, however comprehensive the design of the information system and however sophisticated its constituent parts, it will not achieve its objectives unless efficient channels of communication exist in the organization. This is particularly true in the smaller company in which the information system is not EDP-based and depends upon continuing interpersonal communication across functional and departmental boundaries. Good communications may be fostered by managerial and supervisory committees, interdisciplinary project teams and similar devices. Most important of all is that the company's top executives should announce—and demonstrate by their own conduct—that company loyalty and the free communication of information across traditional boundaries are more desirable than sub-unit loyalty and secretiveness. Only in this type of environment will an efficient management information system be realized.

The relationship of the component sub-systems and the most important information flows are summarized in the diagram in Figure 3, page 34.

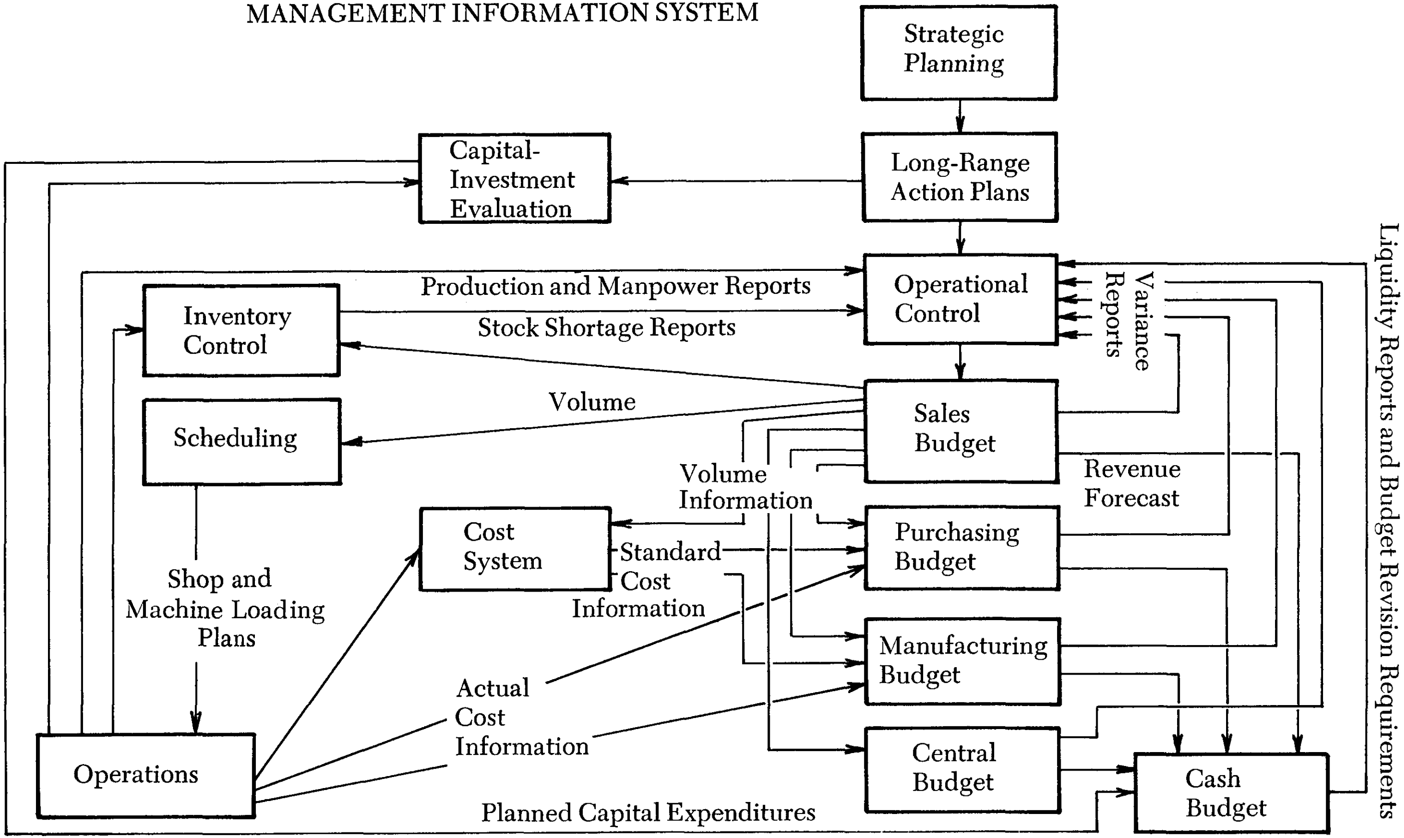
SOLVING A PRODUCT-MIX PROBLEM WITH LINEAR PROGRAMING TECHNIQUES*

The use of sales-forecast information and of cost information in product-line decisions has already received attention in this study. When such data is available it is a relatively simple task to calculate breakeven volumes for various selling prices, compare these with the distribution of expected sales at each price level, and arrive at a decision. The problem becomes considerably more complex, however, when the company has more than one product line and management wishes to determine the most profitable mix to produce in one particular period. Add the further complications that working capital is limited and that the various products require different proportions of machine time and assembly time, and solution by "heuristic" or common-sense

* There are, of course, many types of operations research formulas other than linear programing that use management information in solving management problems. This section is intended merely to illustrate a natural extension into the use of mathematical techniques.

Figure 3

INTERNAL INFORMATION FLOWS IN A SIMPLIFIED MANAGEMENT INFORMATION SYSTEM



methods becomes exceedingly difficult. Fortunately, mathematical programing techniques have been developed to provide solutions to just such problems. The use of such techniques provides a most effective example of the way in which any information bearing on the problem, regardless of paperwork flow or organizational reporting patterns, may be used toward a solution. The particular technique to be demonstrated, linear programing by the Simplex method, provides useful information in addition to the product-mix solution: a series of "shadow prices" which indicate the value of additional units of constraining factors and are thus valuable input to the planning process. This type of programing technique is very relevant to a study of management information systems, both as a use of a wide range of information and as a source of feedback information.

The present study will confine its examination of mathematical programing to a fairly simple application of the Simplex method, in which only two products are considered and the time span of the analysis is limited to a single period into the future. A second study in this series, in which more complex information-system problems and techniques are considered, will include examples of linear programing solutions with multiple products and with time spans of multiple periods into the future, and will show how such techniques may be implemented on EDP equipment.

The Simplex method of linear programing is a technique by which problems involving multiple variables and a number of constraining factors may be solved by the use of arithmetic after setting up the problem in the form of a matrix. The theoretical justification of the method is outside the scope of this study but can be found in Charnes, Cooper and Henderson's *An Introduction to Linear Programing* (see Bibliography) and in a number of other basic texts in this area.

The formulation of the problem for a Simplex solution must include an objective function and a number of constraints. The objective function is the thing which is to be maximized; in most cases this will be profit. Thus, if the company has two products, P_1 and P_2, and knows that within a broad range of volume levels the profit per unit sold is \$50 and \$70 respectively, the objective function would be written:

$$50P_1 + 70P_2 = \text{Maximize}$$

The constraints are more complex. In effect, they are the means by which the realities of the company's operations are introduced into the problem. Assume that the company produces telescopes for sale to amateur astronomers. The two lines, P_1 and P_2, are both reflective models. The mirrors are polished by company employees, then assembled into purchased body tubes and mountings. The principal operations, therefore, are mirror polishing and assembly. All operatives are skilled at one task or the other, but not at both, and cannot therefore be interchanged. The P_1 model requires four man-hours polishing and one man-hour assembly time. The P_2 requires six man-hours polishing and two man-hours assembly. Obviously no solution can be generated until the totals of polishing and assembly labor expected to be available in the coming week are known. These are respectively 190 and 72 man-hours. It is now possible to state that the solution to the product-mix problem must fall within certain bounds. The total mirror-polishing time, made up of four man-hours for each P_1 produced and six man-hours for each P_2, must not exceed the total 190 man-hours available. This may be formulated:

$$4\,P_1 + 6.\,P_2 \leqq 190$$

Similarly, the assembly man-hour constraint may be expressed:

$$1\,P_1 + 2\,P_2 \leqq 72$$

These expressions, however, are inequalities, and before they may be used to generate a solution they must be converted into equations. This is done by introducing "vector" or "dummy" variable. Let the variable S_1 represent that portion of the available polishing manpower which is not used either for P_1 or for P_2 production, i.e., the time during which the department is idle. Similarly, let S_2 represent the idle time in the assembly department. (In the solution, of course, either or both of these variables may be zero quantities.) The two inequalities may now be restated as equalities thus:

$$4\,P_1 + 6\,P_2 + S_1 = 190;\ 1\,P_1 + 2\,P_2 + S_2 = 72$$

and these plus the objective function,

$$50\,P_1, + 70\,P_2 = \text{Maximize},$$

provide all the information needed to produce a solution.

The Simplex technique of linear programing is not difficult to apply. Simple problems may be calculated by hand, while the more complex problems with many variables and constraints are readily solved by using one of the many packaged computer programs available. All major manufacturers of EDP equipment offer library programs in this area.

It must be pointed out, however, that the compilation of the various items of data required as input to the formulas may be very much more difficult than the mathematical operations. Many of the required figures will probably not be readily available unless an unusually complete management information system already exists. It will be necessary to know, for instance, how many man-hours of assembly time can really be expected to be available, and a satisfactory answer cannot be obtained simply by multiplying the assembly workers by the theoretical number of hours worked for the week. The data used in the calculation must reflect average down-time for personal reasons, absenteeism, time lost because of model changeovers and such. Similarly, available manufacturing time data fed into the formulas must reflect the time likely to be lost through machine maintenance and breakdown, tool changes, and so forth.

Where the required data is not immediately available it may be necessary to institute special surveys, work-measurement projects and statistical analyses to obtain it. If the cost of obtaining the required information seems likely to be prohibitive it may be necessary to abandon the linear programing project. Where an efficient internal information system does exist and most of the required data is available, on the other hand, linear programing provides a very powerful aid to managerial decision making.

The last case in this study, Modern Wear, Inc., illustrates the amount of detailed internal data that must be obtained before even a relatively simple operating decision can be specified in the form required for solution by linear programing methods. The reader is urged to make certain that he understands where each of the figures used in the formulation of constraints in this case have been obtained and to think about the implications of operations-research techniques of this type in the design of management information systems in even the smallest companies.

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Lincoln Leather Company

On the afternoon of Thursday, August 4, 1967, Roger Lincoln, president and founder of the Lincoln Leather Company, called the company's production superintendent into his office. Mr. Lincoln was worried about the company's performance during the first six months of 1967 and about the sales of their latest product. The *pro forma* income statement for the six-month period revealed an operating loss, the first that the company had experienced in its 12-year history. Mr. Lincoln was anxious to find out what had happened and wanted to make sure that whatever miscalculation had produced this deficit would not happen again.

Background

The Lincoln Leather Company had been founded by Mr. Lincoln in the early months of 1955, shortly after his retirement from the United States Navy. He was in his mid-40's and had just completed 20 years of commissioned service. Mr. Lincoln had no previous business experience of any kind. Feeling too young and active to retire and disinclined to become a company employee, he had decided to invest his savings and a small inheritance in some form of enterprise. He had been an enthusiastic amateur photographer for many years and thought seriously of involving himself professionally in this field, but ultimately decided that work as a photographer would be precarious and disruptive to his home life. The operation of a processing laboratory was also considered but was rejected, Mr. Lincoln deciding that he did not possess the required technical competence.

The wish to be involved in some way with the photographic field continued, and Mr. Lincoln began to look for some accessory which might be produced with a limited outlay. As a result of steadily increasing affluence in the United States, amateur photographers were beginning to accumulate more sophisticated equipment: flash units, auxiliary lenses, filters and lens shades and the like. Camera outfit cases, often called "gadget bags," capable of holding all the amateur's equipment, began to appear on the market. They were expensive, often imported and frequently of poor design. Mr. Lincoln decided that a ready market might exist for well-made outfit cases, especially if designed to accommodate specific popular cameras on a "custom" basis. Relatively little equipment would be required, primarily cutting devices and heavy-duty sewing machines. He decided to enter this field.

The Lincoln Company started operations in March 1955 and sold its first products one month later. A line of six cases was introduced, made from high-grade leathers, lined throughout with velours, each model designed to the exact dimensions of a popular, high-quality camera. Mr. Lincoln was fortunate to obtain the services of George Mills, a man in his early forties who had been working as a foreman for a nearby luggage company and was therefore experienced in leather-working operations. Product design was undertaken jointly by Mr. Lincoln and Mr. Mills. A work force of four men and ten women was recruited. Mr. Mills acted as foreman, inventory controller, production scheduler and virtually as plant manager. Mr. Lincoln performed all selling and marketing functions. Cost studies and pricing were performed by the two of them on a very informal basis, and a single clerical employee looked after all correspondence and maintained a simple bookkeeping system devised by Mr. Lincoln. Initial sales were made to nearby photographic dealers and to individual buyers through advertisements in the photographic press. Late in 1955, however, Mr. Lincoln succeeded in interesting a large photographic discount house with nation-wide sales in his products. This organization quickly became the Lincoln Company's best customer and remained so until the present time.

The company prospered and grew steadily. No serious marketing problems were encountered. The large discount store usually absorbed 45 per cent to 55 per cent of total production, and most photographic retailers who had sold the Lincoln cases placed regular repeat orders. Mr. Lincoln felt that he had little direct competition to face; many other brands of camera outfit cases were available but most were of lower quality and price and not "custom tailored." Little product-design change was required except for alterations in the internal fastenings and compartments of the cases to conform to changes in the designs of cameras and accessories for which the cases were produced. By the end of 1966, the company employed 64 operators and added an additional three persons to the clerical staff. Mr. Mills was now production superintendent, assisted by one foreman, promoted from the ranks of the company's original workers. A five-year summary of production and income-statement information is provided below as Exhibit 1, as well as a balance sheet as of December 31, 1966, as Exhibit 2 on page 42.

The New Product Line

Early in 1966 Mr. Lincoln started to consider the possibility of adding a new product to the company's line. Sales volume and revenues had shown a definite turndown in 1965; the first in the company's history. Competition in high-class camera cases was becoming increasingly intense. One large New York photographic discount house had

EXHIBIT 1

LINCOLN LEATHER COMPANY

Comparative Income Statements
(Figures Rounded to Nearest $100)
For the Years Ended December 31, 1962-1966

	1966	1965	1964	1963	1962
Sales (cases)	46,250	42,880	43,510	41,250	36,780
Sales	$1,058,200	$935,700	$957,400	$822,000	$723,600
Cost of sales	698,400	631,300	630,800	551,700	491,200
Gross profit	$ 359,800	$304,400	$326,600	$270,300	$232,400
Selling, general and administrative expenses	192,450	154,100	181,350	140,900	113,250
Income before interest charges	$ 167,350	$150,300	$145,250	$129,400	$119,150
Interest expense	150	300	450	600	750
Income before taxes	$ 167,200	$150,000	$144,800	$128,800	$118,400
Provision for taxes	73,800	65,500	63,000	55,300	50,300
Net income	$ 93,400	$ 84,500	$ 81,800	$ 73,500	$ 68,100

EXHIBIT 2

LINCOLN LEATHER COMPANY

Balance Sheet
December 31, 1966

Current Assets:		
Cash	$ 27,100	
Accounts receivable	148,300	
Inventory	192,500	
		$367,900
Fixed Assets:		
Buildings, plant and equipment	$617,400	
Less accumulated depreciation	270,100	347,300
Total Assets		$715,200
Current Liabilities:		
Accounts payable	$207,200	
Accruals	14,000	$221,200
Long-Term Debt		3,000
Owners' Equity:		
Capital stock	$250,000	
Retained earnings	241,000	491,000
Total Liabilities & Owners' Equity		$715,200

started to sell a well-made Japanese line of cases under its own brand name, at a very competitive price, and was prepared to give a very substantial discount on this price if the case was ordered at the same time as a camera or lens. Mr. Lincoln believed that other large photographic suppliers might follow this pattern. One possible strategy for the Lincoln Company might be to supply cases to these establishments to sell under their own brand names; however, profit margins in this type of business were small and would probably come under increasing pressure from imported goods. Mr. Lincoln felt that his existing products offered little scope for cost reduction: The leather cases required considerable handwork, and automation did not seem feasible at anything like the company's existing volumes. The best solution, therefore, seemed to be a new and more distinctive product, and, if possible, one with a lower labor content and greater possibilities for cost reduction.

After considerable thought, Mr. Lincoln developed the idea of introducing a hard case to supplement the leather camera bags. A line of aluminum cases with foam-rubber interiors had already been marketed by another small manufacturer, but these cases, though well-made and attractive, were relatively expensive, selling for upwards of $45. They were believed to be bought primarily by professional photographers and photo-journalists. Mr. Lincoln decided to develop a new hard case made from moulded fiber glass. Fiber glass luggage and attache cases had gained rapid and widespread market acceptance, and the material seemed ideal for a new-style outfit case. Mr. Lincoln believed that such a case would require much less labor to produce and would provide more attractive profit margins than the leather cases.

The design of the new cases was undertaken almost entirely by Mr. Lincoln and Mr. Mills, with some technical assistance from the company which was to supply the required glass fibers, resins and pigments for the new line. Molds were produced by an outside supplier, using wooden patterns constructed by Mr. Mills. No attempt was made to set long-term production schedules for the new cases. Rather, it was decided that production of a pilot batch would be undertaken in October 1966, and that the rate at which output was increased thereafter would be decided on the basis of market acceptance of the line. Mr. Lincoln and Mr. Wills were uncertain how they should go about pricing the new cases. After some discussion, they decided to attempt to capitalize on the distinctive features and novelty value of the cases by setting a price about 20 per cent higher than the comparable leather lines.

The initial batch of cases was produced in October as scheduled but proved to be defective. Further attempts were made, but persistent trouble was encountered in performing the bonding of hinges, fasteners and metal trim to the fiber glass material. These problems were finally solved by increasing the thickness of fiber glass and by using rivets to supplement the bonding process. By the beginning of December, Mr. Lincoln believed that he had a salable product, and a major part of his own time during the next few weeks was devoted to visiting the company's sales outlets to introduce the new cases to them and to obtain their reactions. Most dealers were enthusiastic but expressed regret that the cases had not been available during the pre-Christmas buying season.

During the early months of 1966, demand for the new cases grew steadily. Mr. Mills attempted to maintain a small inventory of finished cases for each popular line of camera. The cases themselves were made in two standard sizes, the interior foam rubber lining being cut to accommodate specific cameras and various accessories. Small batches of both standard cases, with the appropriate interiors, were scheduled as required. Sales volume on a month-by-month basis for the first six months of 1967 is given in Exhibit 3, below.

Sales of the conventional leather cases, meanwhile, had recovered from their decline of 1965 to reach a record level in 1966. Sales during the first half of 1967 revealed a slight decline compared with the same period 12 months earlier.

The Lincoln Company had adopted a financial year ending on December 31 and Mr. Lincoln had instructed his clerical staff to prepare an estimated income statement for the six months ending June 30. On the morning of August 4, 1967, the *pro forma* statement shown in Exhibit 4, page 45, was placed on his desk.

The August 4 Meeting

Mr. Lincoln called Mr. Mills into his office immediately after lunch. Mr. Mills had also received a copy of the *pro forma* figures. Mr. Lincoln lost no time in introducing the subject which was causing him anxiety; he opened the conversation by saying:

Lincoln: George, you've had a chance to think about these figures. I'm very concerned about them. We know that sales of the leather bags are down a bit from last year, but they are well above any previous year. The new cases were slow at first, but they have been picking up very nicely. How do you

EXHIBIT 3

LINCOLN LEATHER COMPANY
Monthly Sales Volume for the Six Months Ended June 1, 1967

	Sales in Units	Dollar Sales
January	80	$2,460
February	92	3,125
March	120	3,785
April	138	4,212
May	160	4,890
June	185	5,573

EXHIBIT 4

LINCOLN LEATHER COMPANY

Estimated Income Statement for the Six Months Ended June 30, 1967

	June 30	
	Estimated 1967	Actual 1966
Sales	$493,000	$486,100
Cost of Sales	397,000	341,600
Gross Profit	$ 96,000	$144,500
Selling, General and Admin. Expenses	98,000	90,100
Income Before Interest	$ (2,000)	$ 54,400
Interest Expense	—	75
Income Before Tax	$ (2,000)	$ 54,325
Provision for Taxes on Income	—	19,565
Net Income	$ (2,000)	$ 34,760

account for this loss? Look at that cost of sales! What is going on here?

Mills: Well, I thought that our profits were going to be down this time but I didn't expect anything like this. The trouble has to be with the new cases. We are just reaching what I call real production levels with them and the operators are getting used to them. We had a lot of wastage at first but I think we have that under control. I didn't realize how much hand finishing we would have to do on this molded stuff, but I have three or four people now who really know what they are doing. I think the year-end figures should be O.K.

Lincoln: Well I certainly hope so, but I want to know just how much of this cost is due to the new cases. I'm beginning to wonder if we have bought ourselves a real problem here. Are we going to be able to make a profit on these things? We didn't have much of an idea about what the costs were going to be when we decided to go ahead with the line. Do we know what they are even now?

Mills: We can easily work out the materials cost – in fact, I have someone working on it right now. None of the materials we use on the new line go into the old cases, so it's just a matter of extracting them from the purchase file. The labor cost is another matter, though. When the workers report their time, they don't identify which items they have been working on, and many of them have worked on both lines at different times. I have a pretty good idea myself now just how much labor is going into the new cases; it is down to about six hours a case now, and we should be able to make a profit at that rate. It could be lower, though, if we could increase the schedules; I'd like to be able to leave a team on hard cases all the time instead of making two or three batches a week. We also lose a lot of time cleaning out the equipment and then starting up again.

Lincoln: George, it looks as if things are pretty well under control now, but we need to learn a lesson from all this. We did a lot of thinking about the product, but I don't think we got ourselves half the information we should have had before we decided to make it. We need to be much more careful before we introduce any other new product lines. We need to find out why we have a setback this time, and I think it might be a pretty good idea to get some outside advice.

Questions:

1. What is the major reason behind the Lincoln Company's reported deficit? Give reasons for identifying the particular factor you have chosen.

2. How could this situation have been avoided? What changes should be made and/or new procedures introduced before any other new product is introduced?

3. How should management decide whether or not a proposed new product is economically justifiable?

Mr. Lincoln Consults His CPA

Two days after the meeting with Mr. Mills, Mr. Lincoln drove into town and called on the CPA firm which prepared the company's annual tax returns. The senior partner in the CPA firm, Mr. Walton Duncan, had suggested to Mr. Lincoln at the time of the last engagement that the Lincoln Company had reached a size at which it was a good idea to think about introducing more sophisticated control procedures, particularly in the area of costing, cost control and an operating budget. Mr. Lincoln had promised to think about his suggestion, but had been satisfied with the company's operations at that time and had taken no further action. The present difficulties had reminded him of Mr. Duncan's comments, however, and the CPA now seemed to be the obvious source to turn to for advice and assistance.

On his arrival, Mr. Lincoln was shown into Mr. Duncan's office. He explained the reason for his visit and his growing realization that some kind of improved control procedures were required at Lincoln Leather. He concluded this explanation by saying:

Lincoln: So there it is, Walt. I'm not particularly concerned about the new line or the six-month figures; I think things are under control now, and the loss isn't disastrous. What worries me is that we went ahead and made a major decision on a combination of hunches, rough estimates and sheer enthusiasm. There must be a better way of doing things, and I'd like you to tell me what it is.

Duncan: Well, Roger, I think I could make a fairly accurate appraisal right now of what the problems are and what we need to set up for you, but we won't jump to any conclusions. I'm going to let Mike Harnet spend a few days with you and take a thorough look at your setup, and then we'll get together again. What I think you need is an information system. That may sound like an elaborate system, but it certainly doesn't have to be anything of the sort. It merely means that we have to develop procedures to make certain that in the future, when you have to make a decision, you will have the necessary information available. In addition, you should have the data you need to follow up on your decisions and make sure that everything is going as planned.

Two days later, Mr. Harnet, one of the firm's younger CPAs, started his survey of the Lincoln Company's procedures. He was welcomed by Mr. Lincoln who called in Mr. Mills, and the two executives outlined the systems and methods used by the company and the recent problems. Mr. Mills then introduced Mr. Harnet to the clerical staff and other key employees. A desk was provided for Mr. Harnet, and during the next week he talked to the clerical staff and watched them at work, made himself familiar with the clerical procedures and files used by the company, and spent a considerable amount of time with the production supervisors. Mr. Lincoln and Mr. Mills made themselves available to him, and he had many discussions with each of them. He talked to them at length about the way the decision to introduce the new line had been made and the information upon which the decision had been based.

One week later, Mr. Harnet believed that he had formed an accurate picture of the problems at the Lincoln Company. He discussed them with the senior partner, Mr. Duncan, and decided that an informal presentation should be made to Mr. Lincoln and Mr. Mills. A meeting was planned for the following afternoon in Mr. Lincoln's office.

The Meeting of August 16

The meeting that took place the next day was attended by Mr. Lincoln, Mr. Mills, Mr. Duncan and Mr. Harnet. Mr. Lincoln introduced the main topic of the session by saying:

Lincoln: Well, let's get down to business. I just want to say, Walt, that George and I don't claim to know much about accounting or management systems or whatever you call it these days. So, whatever you and Mike have found we are doing wrong, and I'm sure you have found plenty, just let us have it straight.

Duncan: It isn't so much a question of doing things wrong. Let me put it this way. When you start a business on a very small scale, it can be a pretty informal affair: You have a one-man management who makes all the decisions, carries all the important information in his head and can keep in touch with everything going on in the organization. Now, let's suppose the business prospers and gets larger. It could realistically outgrow its original building, which may have been just a garage. It also outgrows its original informal methods of management. When that happens, you need to introduce a set of systems and procedures for handling information and for using that information to make decisions and keep in touch with things. The system can still be pretty simple at this stage, but it is well worth giving some thought to setting up something which is basically sound and will be able to expand with the company. We think that the Lincoln Company has reached this stage. It just isn't possible for you and

George to run a company with sales of over a million dollars as you ran it when you were taking in a few hundred thousand. Problems of growth can be eliminated by introducing a few simple procedures.

Lincoln: Fine. But I feel that one reason we have made good profits until this year is that we have kept our clerical staff to a minimum. You will recall that in the past you recommended that we hire a more qualified accounting staff and prepare ourselves for opinion audits. Well, so far we haven't felt the need. It will be pretty hard to talk me into anything that involves a lot more office workers.

Duncan: Roger, the way you are growing, you may one day look for outside financing. Isn't it better to prepare for that event now rather than get hit all at once? In any event, for this engagement I doubt whether you would need more than a few extra clerical people at the most, but Mike will explain more about that. First, I'd like him to give you a summary of his findings and an outline of what we are suggesting.

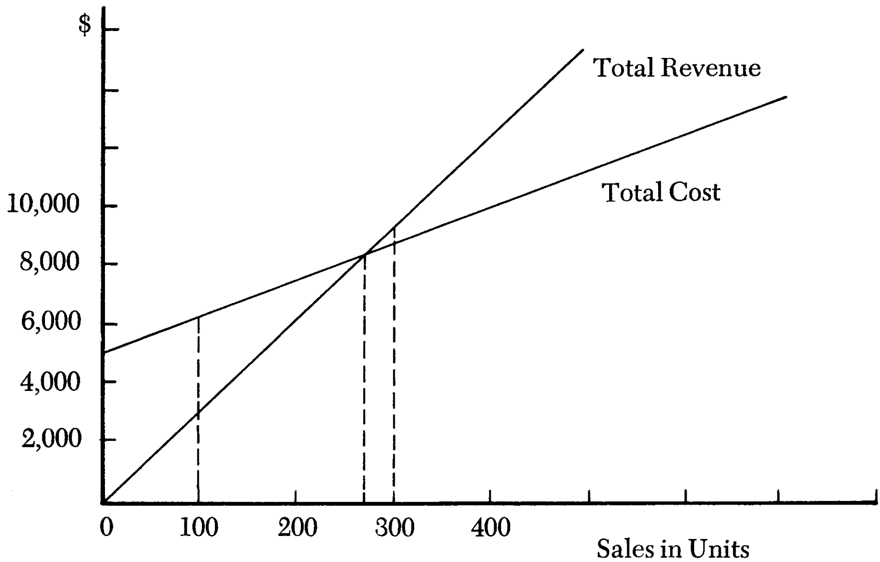
Harnet: Let's talk about the introduction of the new line, because I think it illustrates all the areas in which we need to think about the information system. And I should like to identify four areas of primary importance: sales forecasting, break-even analysis, costing and cost control.

The management information system is not a simple one-way flow system. Information produced in one area is used in a number of other areas, and there is a lot of feedback and many interrelationships. But the most important piece of information in the whole system is the sales forecast, because it forms the basis of almost everything else: profit plan, manufacturing plan, cash budget, variable costs, purchasing plan and inventory levels and batch sizes. So, it is hard to exaggerate the importance of a sound, realistic sales forecast. Now, no one is going to be able to make a forecast that is completely accurate. You can't say with certainty that you will sell exactly 45,274 cases this year, for instance. But you may have a good idea that you will sell "about" 45,000, or "somewhere between 43,000 and 47,000" perhaps. A good estimate is essential, and an estimate of a range within which you expect sales to fall is even better. Better yet, you should go one step further and try to make some kind of probability assessment of the chance that sales will or will not be within the specified range.

As far as I have been able to understand it, you decided to produce your new product line without a specific sales forecast of any kind. You designed a product and asked yourself "will it sell?" and the answer was yes. But you didn't ask yourselves how many it would sell, how wrong your estimate could be, or how long it would take to reach the volume you predicted. I'm sure you had a volume in mind, but I suspect you didn't allow for the time needed to reach a reasonable volume, the high cost per unit associated with a low volume, the inexperience of the operators with the line, and the small batch sizes.

That brings me to the next matter, costs. You need to know what the direct costs involved in producing the line are likely to be before you can decide its price or do a meaningful breakeven analysis to see if the line is worth producing. The sales forecast is used here as well. Your approach to the pricing of this line was based on the product itself, and you decided what premium people would be willing to pay for such a case compared with the conventional soft bags. Well, you know the trade and I'm sure the line is priced just about right – but you didn't really know whether you could make a reasonable profit on it at that price. In fact, you embarked on a technology which was quite new to you, with only a very rough idea about what the costs were likely to be. You will probably say that there was no way of getting that information except by going ahead and trying it for yourselves. This may be true, but in such a case it would be good to compile a "sensitivity analysis," making various assumptions about sales volume and calculating at each set of assumptions how profitable the line would be and what variable cost figure is the maximum which would let you break even. Let me show you what I mean. Just to keep things simple, assume that you have only one model in the new line, that the highest price you can hope to sell it at is $30 and that the fixed costs associated with producing it are $5,000 per month. You are not sure what the variable costs are going to be, but you think they will be around $12. You can now easily do a breakeven analysis that looks like this: (Mr. Harnet's sketch is reproduced as Figure 1, page 51.)

Figure 1



You can see immediately that the breakeven volume under this particular cost assumption is around 275 units a month; it actually works out to 278. So at anything over 278 units a month, you can expect to make a profit. But if your variable cost estimate of $12 a unit is wrong, this breakeven figure isn't going to mean very much. It might well be true that you have better information and can make a better judgment about sales volume than you can about variable costs. In this case, you might want to assume that sales are unlikely to be above 250 units a month, for example, and ask what is the highest variable cost that will still let you break even. You can do this by setting up a simple formula, letting X = variable cost:

$$\begin{aligned} \text{At breakeven, } 30 \times 250 &= 5{,}000 + 250\,X \\ 7{,}500 &= 5{,}000 + 250\,X \\ 250\,X &= 2{,}500 \\ X &= 10 \end{aligned}$$

That is, at your "most likely" sales estimate, you will not break even unless the variable cost per unit can be kept down to $10 or less. With this information, you are in a much stronger position to decide whether or not to go ahead with the new line. If you *do* decide to put the line into production, you now have *two* vital pieces of information which can form the basis of your control of operations: You know that to insure profitable operations you must achieve a certain sales/production target *and* control costs below a certain limit.

This brings us to the other area in which adequate information is vital, the control of operations. You introduced the case line without knowing what the costs would be. Though I recognize they were hard to determine at that time, I have tried to indicate that you could have developed some idea of *permissible* cost levels. But you have now had the line in production more than six months, and you still do not know what the labor cost of the line is. What we need are: first, target figures for sales and variable costs that will allow a reasonable profit margin; and second, a data recording system that will tell you whether or not targets are being achieved or at least let you know if they are not being achieved. Once we have these, we have the basis of a good information system. The other figure needed is a cash budget to synthesize all the information and to make sure that our operations do not lead to insolvency.

Lincoln: I like your ideas but we need help in establishing the system. You have mentioned all the areas that need improvement.

Mills: We do need to know more about costs. However, I'm not convinced about your "production plan." I see the need for a sales target, but I need flexibility in using it for production orders. But you have some ideas there that we can certainly use.

Lincoln: Walt, you fellows certainly put a finger on our problems. However, we don't have the time or staff to implement your suggestions. Where do we go from here?

Duncan: I recommend that first of all, you hire a controller. You should have someone who will be trained in the system and who could make the necessary adjustments to the system as business events warrant the change. Once you do that, we will schedule Mike Harnet to work with him.

Lincoln: I can agree with you that we should have someone here to monitor the system, but a controller will add a pretty steep cost for an information system.

Duncan: That's not really true, Roger, because you will need additional clerks anyway. If you follow my recommendation, you will have someone who can pick up the rest of the work that needs to be done in the internal control and accounting system area and also begin preparing for annual audits. I would expect that a controller for your needs would cost about $18,000. In the first year, he may spend about half his time on the information system. The first year cost therefore should be: $9,000 for the controller, and $3,500 for our time. However, the benefits should compensate for much of that cost.

As in all these kinds of engagements, Roger, we will send you an engagement letter and proposal. If you agree with what we set forth, we will develop the system.

Conclusion

Mr. Lincoln did hire a controller and invited the CPA firm to help him design and install the systems they considered necessary. Mr. Harnet spent a considerable amount of time in the Lincoln Company during subsequent weeks. His first action was to design and introduce modified material usage tickets and time sheets through which materials and labor costs could be identified and related to the particular line and model on which they had been used. Mr. Lincoln and Mr. Mills decided, after considerable thought, that a realistic sales target for the latter half of 1967 would be 3,500 old-style and 260 new-style cases per month. Tentative labor and materials cost targets were established on the basis of these figures. At the time of writing (November 1967) sales of the new cases are running ahead of target, and a sales budget of 350 new-style and 3,200 old-style cases per month had been established for the first six months of 1968. Mr. Mills continues to schedule production batches and model runs "by ear," but the existence of an overall monthly budget target has encouraged him to use larger batch quantities with consequent savings in production costs. Operations in the second half of 1967 were profitable, and a small profit was reported for the full year's operations. The new system proved its value in October 1967 when a sudden and definite increase in the labor cost of the new-style cases was reported. Inquiry revealed that a new adhesive used in the bonding of the internal rubber case lining to the outer shell was defective and needed considerable rework. Under the old system, this problem might have persisted for some weeks before its seriousness was realized. A simple cash budget has been established and is revised each month by the controller on the basis of actual sales recorded in the month.

The system which has been introduced in the Lincoln Company is essentially a simple one, and has required only one addition to the clerical staff plus the controller. A cost clerk has been appointed with responsibility for identifying and compiling costs for each line at the end of every week, comparing them with the target figures established in the cost budget, and reporting any significant variances. The daily production figures are collected by the shop foreman and passed to the controller and to Mr. Mills who compares them with the monthly target, making any necessary revisions in his schedules for the rest of the month. The controller maintains the cash budget, and attention is now being given to the possibility of a more systematic control of information about supplier performance and its significance for inventory levels. The controller has also improved the accounting system to the point where management now wishes to have an annual audit as well.

No new product line has been added since the system was introduced. But Mr. Lincoln is considering the extension of the hard-case line in the near future. He has discussed the proposal with Mr. Harnet and is well aware of the importance of a realistic estimate of the potential market for the cases. He feels that the cost information now available to him makes the decision a much less hazardous matter than was the previous new model introduction.

Neptune Pump Company

On April 5, 1967, Mr. Miles Richland, chief financial executive of the Neptune Pump Company, was concerned about the company's cash management procedures. On April 4 he had been informed by the company cashier that the balance in the demand deposit accounts maintained with two local commercial banks had fallen to a combined total of $27,000. This was considerably below the company's estimate of a "safe minimum" level and would only be adequate to meet the forecasted cash requirements of the next two months. The Neptune Pump Company did not maintain savings deposit accounts and had no other liquid assets. Any threat of cash deficiency was obviously a serious matter and demanded immediate action.

On April 17 Mr. Richland believed that the crisis was past. His first actions on hearing of the threatened cash shortage had been to approach the company's banks, and after prolonged negotiations he had been able to arrange a $100,000 line of credit with one of the banks. But the experience had not been an enjoyable one. Mr. Richland did not like having to negotiate from a position of weakness, and the banks made it clear that their faith in the company's financial management had been shaken. The rate of interest on borrowing under the line of credit was set at one per cent above the bank's prime rate; previously the Neptune Company had never been asked to pay more than one-half of one per cent above the prime rate. The bank had made it clear that they expected the borrowing to be liquidated or replaced by more permanent financing within six months. Mr. Richland hoped that this could be accomplished, but was disturbed that the need for such emergency borrowing had arisen at all.

Background

The Neptune Pump Company was a small manufacturing company located in an industrial center in the State of Ohio, and had been founded in the early 1920's. The original products had been small piston-type pumps, often hand operated, that were sold primarily to agricultural users. Over many years the product line had been extended, and in 1967 it included piston and centrifugal pumps of many types, submersible electric pumps for use in wells, air and gas compressors used in paint spraying equipment and commercial refrigeration units, and small, portable fire pumps. All production and assembly was concentrated in one plant, which had been enlarged and modernized in the early 1960's.

In 1966 the company's sales had reached their highest total of $4,200,000 and 1967 first quarter figures indicated that 1967 sales would set a new record, reaching the company's 1967 sales target of $4,500,000. The company's income statements are reproduced in Exhibit 1, on page 57, and the company's balance sheet as of December 30, 1966, is Exhibit 2 on page 58.

Mr. Richland's anxiety about the threatened cash shortage in April 1967 was greatly intensified by the fact that he had spent considerable time introducing systems which should have made such an occurrence impossible. Since his appointment to his present post in 1964, he had designed and installed a comprehensive budgetary control system. This system included a 12-month sales budget setting monthly sales targets which in turn provided the basis for the production plan, labor budget, purchasing budget, and production-scheduling and inventory-control activities. A long-range sales estimate for a five-year period was also made, and this served as the basis for the capital-investment program. Finally, information from the various budgets and operating activities was brought together in the company cash-flow forecast which indicated the overall changes expected in company cash levels. This cash-flow forecast was made on a monthly basis, but it was Mr. Richland's practice to make weekly forecasts for any month in which cash levels were expected to fall below "safe levels," the safe level being determined as $50,000. The cash-flow forecast for 1967 (Exhibit 3) indicated that cash balances had been expected to remain above this "safe level" throughout 1967. (See Exhibit 3, page 59).

The control system used in the company included three sets of variance reports, based on the sales, purchasing and labor budgets. Actual performance in each of these areas was compared with budget target figures each month and any significant variances were reported to the controller's department and to the appropriate line or staff executive. The budget and variance system was further refined by provision of both price and volume targets in the manufacturing budgets, and both price and volume variances for labor and materials were calculated and reported.

The first indication that something was wrong had come to Mr. Richland at the end of March, when he received a report that the

EXHIBIT 1

NEPTUNE PUMP COMPANY

Five-Year Income Summary
For the Years Ended December 31, 1962-1966
(000 omitted)

	1966	1965	1964	1963	1962
Units Sold:	15,100	14,350	13,670	12,240	13,120
Net Sales	$4,215	$3,685	$3,415	$3,074	$3,244
Service & Spares	522	503	714	542	481
Total Revenue	$4,737	$4,188	$4,129	$3,616	$3,725
Cost of Goods Sold:					
Direct Materials	$1,180	$ 936	$ 845	$ 672	$ 683
Direct Labor	1,355	1,214	1,236	1,051	1,160
Plant Overhead	1,014	911	927	790	870
Total	$3,549	$3,061	$3,008	$2,513	$2,713
Gross Margin	$1,188	$1,127	$1,121	$1,103	$1,012
Selling & Administration	$ 725	$ 670	$ 682	$ 690	$ 584
Total	$ 463	$ 457	$ 439	$ 413	$ 428
Interest	10	10	12	12	15
Net Income Before Tax	$ 453	$ 447	$ 427	$ 401	$ 413
Federal Income Tax	211	207	198	186	192
Net Income	$ 242	$ 240	$ 229	$ 215	$ 221
Dividends Paid	$ 80	$ 80	$ 75	$ 75	$ 70
Transferred to Retained Earnings	$ 162	$ 160	$ 154	$ 140	$ 151

EXHIBIT 2

NEPTUNE PUMP COMPANY

BALANCE SHEET
December 31, 1966

ASSETS		
Cash	$ 210,600	
Accounts Receivable	445,000	
Inventories	232,300	
Total		$ 887,900
Land & Buildings	$ 720,000	
Plant & Equipment	1,572,500	
	$2,292,500	
Less Accumulated Depreciation	462,700	
Net Fixed Assets		1,829,800
Total Assets		$2,717,700
LIABILITIES AND CAPITALIZATION		
Accounts Payable	$ 284,500	
Accruals	78,400	
Total		$ 362,900
Long-Term Liabilities		250,000
Total Liabilities		$ 612,900
Capital Stock	$ 775,000	
Retained Earnings	1,329,800	
Total Stockholders' Equity		2,104,800
Total Liabilities and Capitalization		$2,717,700

company's cash balance had fallen to $87,000. This was comfortably in excess of the $50,000 "minimum safe balance" level, but was considerably below the figure of $146,000 that was projected for this cash-flow forecast. During the first two weeks of April, Mr. Richland's staff examined all departmental budget variance reports submitted during the previous month and checked with the originating departments to insure that all variances had indeed been reported. Their

EXHIBIT 3

NEPTUNE PUMP COMPANY

Cash-Flow Forecast for 1967
(000 omitted)

	J	F	M	A	M	J	J	A	S	O	N	D
Sales	320	345	350	370	390	420	440	400	380	365	360	350
Cash at beginning of the month	$211	$236	$286	$146	$156	$136	$156	$176	$236	$281	$330	$370
Cash sales	$ 40	$ 40	$ 45	$ 45	$ 50	$ 60	$ 65	$ 55	$ 50	$ 50	$ 45	$ 45
Receipts from credit sales	270	275	300	305	325	340	355	375	360	335	315	315
Total inflow	$310	$315	$345	$350	$375	$400	$420	$430	$410	$385	$360	$360
Wages and salaries	$115	$115	$115	$125	$125	$140	$140	$130	$125	$120	$120	$120
Purchases	90	85	90	95	95	105	110	100	95	90	90	85
Other cash expenses	60	65	70	70	75	80	100	90	85	70	70	70
Capital investments	—	—	170	30	100	—	30	50	—	36	40	—
Interest payments	—	—	—	—	—	5	—	—	—	—	—	5
Tax payments	—	—	40	—	—	50	—	—	60	—	—	60
Dividends	20	—	—	20	—	—	20	—	—	20	—	—
Total outflow	$285	$265	$485	$340	$395	$380	$400	$370	$365	$336	$320	$340
Cash at end of the month	$236	$286	$146	$156	$136	$156	$176	$236	$281	$330	$370	$390

inquiries did not produce any information leading to an adequate explanation of the low cash balances. Sales during March and the two previous months were slightly ahead of the sales targets, and production plans for May were being revised upwards in consequence. The labor budget indicated that labor costs were very close to planned levels, with no significant variance in either efficiency (number of labor hours) or wage rate (average hourly rate paid). The materials purchasing budget showed no price variance. There was, however, a volume variance indicating that purchases of some parts and materials were in excess of planned figures. The variance was not large. The excess purchases were primarily of components and sub-assemblies, which made up 30 per cent by dollar value of total company purchases, and showed an average increase of approximately 15 per cent.

Mr. Richland had been considering what to do next when the news of the impending cash shortage at the end of March reached him. The cash-flow forecast indicated that cash outflows were expected to exceed inflows by $20,000 during May, and the matter was thus one of great urgency. A temporary solution was found by negotiating the short-term line of credit mentioned earlier. In the third week of April, however, Mr. Richland set about the task of determining just what was happening and of finding a solution to the company's cash-management problem.

Questions

1. What explanation can you offer for the Neptune Company's cash shortage? Why has cash fallen below the level predicted in the cash-flow forecast (Exhibit 3)?
2. Where should Mr. Richland direct his inquiries? If you were asked to assist him, where would you start?

Mr. Richland Talks to Mr. Stanton

During his three years as chief financial executive of the Neptune Company, Mr. Richland had developed an excellent relationship with Mr. Joel Stanton, a principal in the CPA firm of Stanton, Chub and Glauber. Mr. Richland knew that this firm had built up a reputation for management services activities and that Mr. Stanton was particularly interested in this area. He decided to invite the CPA to call on him and to see if he could offer any help in the cash-management problem.

The initial meeting between Mr. Stanton and Mr. Richland was held on April 24. Mr. Richland related the relevant information to Mr. Stanton and described the company's control and reporting system. Mr. Stanton asked a number of questions and spent some time looking over a summary of variance reports made during the past three months. He then suggested an approach to the problem that has been summarized in the following quotation:

Stanton: You seem to have a basically sound, well-designed budgetary control system, but you might consider whether it is sufficiently comprehensive. The areas covered by the system certainly do not explain the current cash position. That purchasing volume variance needs looking into, but it doesn't account for a difference of $119,000 between the forecast and actual cash positions. I think we are going to find that the answer is in something external to the budgetary system. The operations of any company are closely dependent on each other and, if they are to function in harmony, there must be mutual interchange of information that goes far beyond the budgetary control system. I think we have a breakdown in communications somewhere in this wider information system, and we should find out where that breakdown is.

Miles, this is what I think we should do. As you know, those external causes are in functional areas not under your immediate control, and in order to root out this problem we will have to cross functional lines.

Based on what I see here, I had better talk with Bill Holster (president of the Neptune Pump Company) and get his support.

Richland: That certainly makes sense to me. Bill will want to have some indication of what you will be charging us anyway. Knowing that he is management minded, I'm sure you will be back soon.

Mr. Stanton briefly spoke with Bill that day. As agreed, Mr. Stanton submitted a proposal a few days later. The proposal is reproduced in Exhibit 4, page 62.

Mr. Holster agreed with the proposal. Shortly after, the project team began to identify the cause of the current problem and see what modifications might be required in the company's procedures. During the following weeks a thorough investigation was carried out. Particular attention was paid to the purchasing activity. The key to the increased purchasing-volume variance, however, was revealed when Mr. Stanton talked to Mr. Graham Bannister, production control manager, whose responsibilities included inventory planning and control.

When asked why the production control activity had been placing an increased volume of orders for parts and sub-assemblies with the

Exhibit 4

Stanton, Chub and Glauber
Certified Public Accountants

277 North Main Street
Dayton, Ohio

Dear Mr. Holster:

We submit the following proposal relating to a management services engagement dealing with your information system.

The objectives of this engagement are to determine your reporting requirements and the installation of a system that will meet those requirements. It is understood that the last phase will be undertaken only after your approval of the recommended system. The benefits of this engagement can be identified with better information reporting and should result in the improvement of your operations.

We propose to meet with all functional heads of the Neptune Pump Company to determine their informational needs, and develop the necessary forms to gather that information and to develop a suggested informational system. At that stage we expect to meet with you and your management team to discuss our recommendations.

We expect to utilize Mr. Richland and selected members of his staff. You will therefore receive an additional benefit in that your staff will be trained in the system and can adjust that system as the need arises.

I anticipate that our firm will devote approximately 60 man-days to this engagement, at an approximate cost of $10,000. We expect to bill for this engagement in two parts. The first billing will be made at the conference called for above with the last bill to be submitted at the conclusion of the engagement.

If you concur with this proposal, please sign the carbon copy and return it to this office in the envelope supplied.

Very truly yours,
Joel M. Stanton
Stanton, Chub and Glauber

purchasing department, Mr. Bannister replied: "Partly in anticipation of higher production schedules: I know that sales are running ahead of targets and, in these circumstances, I would expect the production plan to be accelerated sometime in the year. I don't want to be short of parts if that happens. There is another reason, though. Once or twice recently we have had emergencies when an outside supplier failed to produce parts when we needed them. We avoided work stoppages only by panic action: taking parts away from the service department, sending a car to the suppliers' plants, and so on. That isn't the way I like to run my department.

"I am a bit suspicious about the purchasing department's screening of suppliers and their estimates and assurances on lead times. So, if the purchasing boys tell me that the lead time on a part is three weeks, I now tend to call it four weeks and recalculate my buffer stock on that assumption."

Mr. Stanton pointed out the consequences of Mr. Bannister's behavior. Most parts were controlled on the "Fixed Order Quantity" system, and the procedure included an element of "safety stock" in that the quantity in the buffer was designed to cover the maximum foreseeable demand during the lead time. Thus, if lead time for a particular part was three weeks, and normal usage was 150 units a week, with the highest foreseeable rate of usage being 33 per cent above normal, then the buffer stock in this case would be determined as follows:

$$\text{Buffer stock} = 3 \times (4/3 \times 150) = 600 \text{ units}$$

Average inventory in this case would be the buffer level plus half the order quantity. If the order quantity was, say, 2,000 units, then

$$\begin{aligned}\text{average inventory} &= \text{buffer} + Q/2 \\ &= 600 + 2000/2 \\ &= 1{,}600 \text{ units.}\end{aligned}$$

The effect of Mr. Bannister's adjustment of lead times may easily be calculated. Increasing lead time to four weeks, the buffer becomes $4 \times (4/3 \times 150) = 800$ units and average inventory becomes $800 + 2000/2 = 1{,}800$ units.

This factor provided the explanation for the adverse purchasing-volume variance, and Mr. Stanton estimated that over the past two months the growth in average inventories had necessitated an increase in working capital of approximately $22,000, thus reducing available cash by that amount. The cause of the balance of the cash drain, approximately $100,000, had still to be identified, however.

After further analysis, Mr. Stanton decided that a sum of this magnitude could be explained only by a change in the pattern of receipts from sales. A conversation with the industrial sales manager, Mr. Karl Schultz, confirmed that his deduction was correct.

Mr. Schultz told Mr. Stanton: "We were forced to make a change in credit policy a couple of months ago. In the past we have always used terms of '2 per cent discount for ten-day payment, 30 days net' in the industrial area; in the agricultural market we have to be more generous. Well, we have been getting increasing competition in our main market area from the pump division of the Universal Foundry & Machine Corp. We have a better product than they do and we can tailor our specifications to the customer's needs more easily, but they have been fighting us in the area of credit terms. Also, they have made use of the financial strength of their parent organization to set up a very attractive conditional purchase contract scheme for some of the more expensive items. We can't match that. What we have done is to start giving longer credit terms, if it seems the only way to make sure we get the sale. We haven't publicized this at all, but we have extended these terms to quite a few of our larger industrial customers. The terms have typically been 'net 60 days,' but we have gone to 90 days in a couple of cases."

Mr. Stanton realized that a change in credit policy of this magnitude was quite sufficient to explain the company's cash shortage. Industrial sales represented 60 per cent of total company revenue, approximately $180,000 per month at the present time. A change in policy from 30 to 60 days credit, made effective in February, would mean that a significant portion of the $180,000 industrial sales receipts expected in March would not, in fact, be received until late in April. In effect, the company's working-capital needs had been increased by the amount on which the longer terms had been granted. Mr. Stanton asked Mr. Richland to have an estimated balance sheet prepared as of May 1, and the result confirmed his diagnosis. Accounts receivable had increased to $538,200, almost $95,000 more than at the previous December 31 balance. At the current rate of sales of approximately $350,000 per month, this represented a collection period of:

$$[538 \div (350 \times 12)] \times 365 = .128 \times 365 = 47 \text{ days average collection}$$

The estimated balance sheet, reproduced on page 65 as Exhibit 5, also indicated that inventory had increased by $20,300.

EXHIBIT 5

NEPTUNE PUMP COMPANY

Estimated Balance Sheet

May 1, 1967

ASSETS		
Cash	$ 24,000	
Accounts Receivable	538,200	
Inventories	252,600	
Total		$ 814,800
Land & Buildings	$ 720,000	
Plant & Equipment	1,782,500	
Total	$2,502,500	
Accumulated Depreciation	$ 462,700	
Net Book Value		2,039,800
Total Assets		$2,854,600
LIABILITIES AND CAPITAL		
Accounts Payable	$ 305,100	
Accruals	75,000	
Bank Loan	78,400	
Total		$ 458,500
Long-Term Debt		250,000
Capital Stock	$ 775,000	
Retained Earnings	1,371,100	
Total Shareholders' Equity		2,146,100
Total Liabilities & Capitalization		$2,854,600

Summary and Conclusion

The cash deficiency crisis in the Neptune Company arose because of failures in communication. These events convinced Mr. Richland that an overall management information system, considerably more comprehensive than the existing planning and budgetary system, had to be developed if such crises were to be avoided in the future.

In developing the company's information system, the budget system was extended to include a cash budget which establishes monthly targets and reports variances from those targets, rather than a simple cash-flow forecast. The manufacturing budgets had been improved by the introduction of variable labor and material cost figures for different levels of output, and steps were taken to improve the integration of production scheduling, inventory-decision rules and capital expenditure programs with the sales and production plans.

The management of the Neptune Pump Company realized that their most important task was an educational one. In a dynamic, changing organization, no system of procedures, nor even a completely centralized data handling activity, can insure that all available relevant information is available to all decision makers at all times. An efficient information system is achieved only when the management team realizes the importance of communications and is aware of the extent to which events and decisions in their own areas may influence the performance of other company activities. Mr. Richland is now convinced that many managers whose careers have bcen confined to a single specialization are not aware of these wider implications of many of their actions. A series of company seminars was organized to help these executives think in broader terms and to see problems from a "company" rather than departmental level. Mr. Holster believes that this educational program resulted in greater improvement to the "informal" content of the company's information system and will, as an added bonus, produce men who are better qualified to assume top management positions when the opportunity arises.

Modern Wear, Inc.

In May 1967, Modern Wear, Inc., of Elizabeth, New Jersey, a small manufacturing company producing children's clothing for sale to large retail stores, had almost finished production of its summer lines. The founder, president, and chief executive of the company, Mr. Robert Ogden, was trying to decide upon his production plans for the fall season models which would go into production in the early part of June. The number of factors which had to be taken into account seemed formidable, and Mr. Ogden was not sure how he could resolve the situation to produce an optimum product mix.

Background

Modern Wear, Inc., had been founded by Mr. Ogden in May of 1948 shortly after he left a management position with Formidable Wear, Inc. The company was small, with sales of less than $300,000 in 1966, but had made a profit in every year except 1953. Operating from a three-story brick building in the industrial part of the town, the company produced a limited range of low-priced, hard-wearing cotton slacks for young children.

The fall line produced in each of the past three years had included three basic models: the top-of-the-line model, the Dapper, which was described as dress slacks; a line of rugged play trousers in denim materials called the Digger; and an easily washable drip-dry line known as the Diver. All were produced in boys' sizes for ages five to 12.

The Company's products had a regional distribution, selling primarily to department and major clothing stores in New Jersey and in New York City. Sales were made in lots of 100 garments or in half lots of 50. Some garments were also sold to jobbers who bought lots and then resold them in smaller quantities to small retail outlets. All garments were sold under the Modern Wear label. In 1964 a major mail order house had offered to purchase regular quantities of garments to be sold under the house's own brand name, but Mr. Ogden believed that under such a system he might become dangerously dependent upon a single customer, and he therefore declined the offer.

Most of the company's production equipment had been replaced in recent years, and had an average age of about seven years and approximate life expectancy of 12 years. The equipment was mostly of two types — fabric cutting machines which could duplicate a pre-set pattern and required a skilled operator, and stitching machines which required only semi-skilled labor. The latter were, in effect, simply heavy-duty sewing machines. Most of the company's operators were paid on a piecework basis. The workers were primarily drawn from the low income area of Elizabeth, and included many recent immigrants. This potential labor supply was almost entirely unskilled, and labor turnover was high. Persistent labor problems had led Mr. Ogden to consider moving his business elsewhere, perhaps to the Appalachian region of Tennessee. So far, he had made no decision to do so. This uncertainty, however, had discouraged him from making any recent increases in productive capacity even though demand for the company's products was at an all-time high.

The company's production plans were entirely on a seasonal basis, with a lead time of three to four months; thus, winter production was devoted to spring lines, spring production consisted of summer clothing, and so forth. Orders usually began to arrive about six months in advance of the start of the season, and reached a peak eight to ten weeks before the season opened. In May 1967, the summer-line production plans had been completed, and finished-goods inventories of these items were running low. Delivery of fall-line goods would have to begin during the first week in August. The seasonal production cycle was normally of ten weeks' duration, and production of these lines would have to start by June 1. Mr. Ogden was worried about the coming season's production for a number of reasons. The fall season was usually the company's most profitable, largely because of "back to school" purchases, often accounting for 40 per cent of total annual sales. Demand for the company's products in the coming fall season seemed fairly certain to be much greater than supply. The problems facing Mr. Ogden were primarily internal ones. The scarcity of skilled labor was a continuing problem. The availability of machine time would certainly be a limiting factor, especially because no additional equipment had been purchased during the past two years. Finally, and even more serious, the company's operations were being constrained by a shortage of cash. Despite profitable operations, the company's cash balance had been drawn down because of a recent debt maturity and because many of Modern Wear's customers had been slow in settling their accounts. Mr. Ogden was not certain that the available cash would be adequate to purchase all the materials required for the fall production runs. He had decided to look into the possibility of obtaining short-term funds from the company's bank, and was wondering how best to present his request to the bank officials. Mr. Ogden decided that he would seek the advice and assistance, both about the financial position and about his overall planning problem, from his "auditors" as he had done in the past.

First Meeting with Mr. Murphy

Fellin & Murphy was a respected, small CPA firm with offices in downtown Newark. Mr. Ogden visited Mr. Murphy in his offices on May 17. After some exchange of news about their respective families, Mr. Ogden explained the need to reach a decision about the fall-line production program and the factors constraining his decision, and finished up by remarking:

Ogden: I guess my business is really going pretty well. Last year was a good year and we have had a reasonable summer despite some headaches. As orders are coming in now I know that I can sell just about anything I produce this fall. The problem is, how do I produce it and where do I find the cash?

Murphy: Bob, you may be in danger of confusing two separate problems. The main one seems to be deciding the most profitable mix to produce. I suspect that your approach to this problem is on the basis of what you feel the demand may be. The second problem is to raise some additional cash. That should not be too difficult, and we'll turn to it later.

Ogden: That's probably right. What about this product-mix problem? Is there some logical way of getting at an optimum mix? I certainly don't know one. You know that different models' lines require different amounts of cutting and sewing time. Further, different materials have different prices. Therefore, one mix ties up more working capital than another – there are just so many possible combinations that I don't see any way of working them all out.

Murphy: There is a technique that is designed to solve just this kind of problem. It is called linear programing. It's a straightforward mathematical technique that consolidates information about the relevant activities in the company that play a part in the decision, not only information about profit per unit and costs, but also the potentially limiting factors. These include shortage of machine time, labor, and working capital. If you can provide reasonably accurate information about these matters, we can express them in terms of equations and solve the equations to find our optimum product mix. The various models in your product range are, in effect, competing for scarce resources: money, machine time and labor. The problem is one of allocating these resources in a way that produces the maximum profit. Problems of this kind are certainly complex, and it's hardly surprising that you were not able to work out an optimum solution. The linear programing technique can't produce an answer in one step straight from the formulation of the problem. What it *can* do is produce a possible answer and see if it is the optimum. If it is not, it's possible to change the least optimal part of it until a solution is achieved by a series of systematic steps. So in a sense it is a trial-and-error approach, but certainly not a hit-or-miss one. I think we might find it useful here if you can provide all the relevant information.

It was decided that Mr. Murphy should visit Modern Wear's offices the next day so that work could be started on gathering the required information and arranging it in the form necessary for a linear programing solution.

Formulating Modern Wear's Problem

On May 18, Mr. Murphy, Mr. Ogden, Janis Dawson, the company's bookkeeper, and Sam Pringle, the production supervisor, met in Mr. Ogden's office.

The Profit Function

Mr. Murphy explained that the first requirement was a criterion function, a factor to be maximized or minimized according to the problem. In this case the purpose of the analysis was to maximize profit. To do this, it was necessary to know how much contribution to total profit was provided by the sale of one item of each line. Mr. Murphy stressed the importance of a direct-cost approach here. Fixed costs, which would have to be paid regardless of the product mix or level of output, were not relevant to the problem. The required figure was each line's contribution to total profit – or contribution to overhead, since maximization of contribution to the coverage of fixed costs will automatically maximize profit. The group set about assembling the necessary information on this basis and eventually produced the data given in Exhibit 1, below.

All such items as rent, heating and lighting and managerial salaries were excluded. Depreciation as normally calculated on a time basis was also excluded, but a machine time charge was included because additional running time increases deterioration of the machinery and the overhaul requirement, and this cost should be apportioned to the various lines in proportion to their machine-time requirements.

EXHIBIT 1

VARIABLE COSTS AND CONTRIBUTIONS OF FALL-LINE PRODUCTS, 1966

	Per Lot of 100 Items		
	DAPPER	DIGGER	DIVER
Selling price	$650	$690	$860
Costs:			
Variable labor	$150	$220	$245
Raw materials	160	80	240
Variable machine time	155	175	135
Finishing, inspection, packing	15	15	10
Miscellaneous	5	5	5
Total	$485	$495	$635
Gross contribution per lot	$165	$195	$225

It now became possible to formulate the "profit function" for these lines. If each 100-lot of "Dappers" produces a contribution of $165, each lot of "Diggers" a contribution of $195 and each lot of "Divers," $225, then the total contribution will obviously be: $165 (No. of lots of Dappers) + $195 (No. of lots of Diggers) + $225 (No. of lots of Divers). In stating the formula the number of lots of Dappers produced was assumed to be A; the number of lots of Diggers produced U; and the number of lots of Divers produced I. The formula was then expressed as:

$$\text{Maximum profit, } Z = 165A + 195U + 225I$$

The next step was to find a similar mathematical formulation for the various factors which might limit the company's ability to produce any particular product mix – the scarce resources; money, machine availability and labor. The group decided to tackle the machine-time problem first. (Note: In linear programing, it is usual to refer to these "limited resource" factors as *constraints,* and this term will be used in the remainder of this case.)

The Cutting Machine Constraint

Two large cutting machines were available. Mr. Murphy explained that the first step was to determine how much cutting machine time would be available. Mr. Ogden said that it was necessary to complete all cutting sometime before the end of the complete production run. After some discussion, Mr. Ogden and Mr. Pringle decided that 36 working days of cutting machine time would be available, and that after making allowance for all down-time (see Exhibit 2, page 73), the total machine time available would be 27,000 minutes.

The next step was to determine the cutting machine time requirements of the various lines. Mr. Pringle was able to supply this information, having made an informal study of the machine time required for various models and materials so that the information was available to him for scheduling purposes. The Digger required more time than the Dapper; the material used for this line was considerably thicker than the other two and the "stack" of material which could be cut out at one time consisted of fewer thicknesses. The Diver required even more time; the material used for this line was thin but the design required extra panels to be cut. Mr. Pringle estimated that the Dapper required one hour of machine time per lot, the Digger two hours and the Diver three hours. Converting all these to minutes, and using the

EXHIBIT 2

CALCULATION OF CUTTING MACHINE TIME AVAILABLE

Working day = 9 hours = 540 minutes

Less: Maintenance and repairs	20
Daily setup time	35
Parts change	20
Labor breaks: lunch, etc.	50
Blade changing and recalibration	40
	165

Running time per machine per day = 375

375 × 2 (machines) × 36 (work days available) = 27,000

same symbolic representation as before, it was possible to formulate the constraint:

$$60\ A + 120\ U + 180\ I \leq 27{,}000$$

The Stitching Machine Constraint

The problem of stitching machine availability was treated in a similar manner. Eight heavy duty stitching machines were available and were used to piece together the main panels and sew the major seams; minor operations such as stitching pockets and cuffs were done subsequently on smaller machines. The Digger, with its sturdier construction, required two extra seams per pair. Mr. Pringle had recently performed an informal time study on stitching operations and was able to supply the information that the Dapper and Diver lines required six minutes stitching per pair, and the Digger eight minutes.

Total available machine time was calculated on the basis used for the cutting machines, but in the case of the stitching machines, 44 working days were estimated to be available. The calculation is shown in Exhibit 3, page 74.

Rounding the machine time available and converting the minutes required per pair to minutes per lot, it was possible to formulate the constraint:

$$600\ A + 800\ U + 600\ I \leq 124{,}000.$$

EXHIBIT 3

CALCULATION OF STITCHING MACHINE TIME AVAILABLE

Working day = 9 hours ≐ 540 minutes

Less: Maintenance and repairs	18
Setup time	32
Labor breaks	66
Handling and alignment of materials	72
	188

Running time per machine per day = 352 minutes

352 × 8 (machines) × 44 (working days) = 123,904 minutes

The Labor Constraint

After the stitching of the main seams on the stitching machines, the garments were passed to a group of female workers, operating smaller sewing machines, who stitched the pockets, cuffs, and belt loops. This work was not "machine controlled" – rather, the time taken per garment depended upon the skill and experience of the worker. The company found it increasingly difficult to recruit suitable operators and Mr. Ogden considered that this stage certainly could be a limiting factor in the production schedule. It was necessary, therefore, to formulate this activity also into a constraint.

The work in this area did not start until a reasonable stock of cut and seam-stitched articles had been built up; Mr. Pringle estimated that 39 working days would be available. Twenty operators were available, so the available labor time was 39 × 20 = 780 man-days.

The labor-time requirements of the various lines were readily available, both from past piece-payment records and from the time studies upon which the piece rates had been based. The standard rate of production for the Dapper was one-third of a lot per worker per day, more usefully expressed as three man-days per lot. The Digger required six man-days per lot, and the Diver, which required particular care and attention, eight man-days per lot. The labor constraint, then, could be formulated:

$$3\,A + 6\,U + 8\,I \leq 780$$

The Financial Constraint

The group then turned to the more complex problem of formulating the threatened cash shortage as a constraint equation. The first step was to gather all of the relevant information together. The company's cash balance at this time (May 18) was approximately $19,000. The amount available for the purchase of materials, however, would depend upon the other expected cash flows during the production period. A cash-flow forecast for the period was therefore necessary. Most of the information required for such a forecast was available, except one essential item, the "minimum permissible cash," below which the balance should not fall. Mr. Ogden admitted that he had never formulated such an amount. After discussion with the bookkeeper, Miss Dawson, it was decided that $12,000 would provide more than adequate provision for any unforeseen event, and this figure was used for planning purposes. The cash-flow forecast that was then compiled is reproduced in Exhibit 4, below.

The cash-flow forecast indicated that the cash surplus above "minimum requirements" would fall to a low point of $2,000 in July. Of the cash currently available and the net cash inflows during the period, therefore, only $2,000 could safely be used for raw-materials purchases.

Two other sources of financing raw materials were available, however: trade credit and existing inventory. Mr. Ogden believed that he could without difficulty obtain credit up to $20,000 from his main raw-material supplier, a large textile manufacturers' agent and broker,

EXHIBIT 4

CASH-FLOW FORECAST FOR FALL-LINE PRODUCTION PERIOD

	June	July	August
Cash at beginning of period	$19,000	$26,000	$14,000
Receipts (sale of summer line)	$36,000	$34,000	$32,000
Payments (excluding purchases of materials)	29,000	46,000	27,000
Net inflow (outflow)	$ 7,000	$(12,000)	$ 5,000
Cash at the end of period	$26,000	$14,000	$19,000
Minimum cash level	12,000	12,000	12,000
Cash surplus (deficit)	14,000	2,000	7,000

and that it would not be necessary to repay any part of this sum until the receipts from the sale of fall lines became realized in September and October. (The large cash outflow of $46,000 scheduled in July in the cash-flow forecast included repayment of a $15,000 credit from this same source for summer-line materials).

Mr. Ogden also pointed out that some of the materials used for summer lines could also be used for the Dapper fall line. The use of such material on hand would in effect represent a saving in cash equal to the present market value of that material; this market value should therefore be added into "available cash." A brief examination of the stock records showed that this material amounted to $3,600. The cash available could now be formulated: $2,000 + $20,000 + $3,600 = $25,600. At this point Mr. Ogden raised a question:

Ogden: I don't know how realistic this figure is. As I told you, I have decided to go to the bank and approach them about a short-term loan. I'm sure they will lend me at least $10,000. Don't you think we should include that in the available cash?

Murphy: No, I don't. I think the loan is a separate issue. You should first determine your optimum product mix without the bank loan and the profit that the mix would produce. Then you can go a step further and calculate the extra profit you would make if you had the bank loan, and whether the loan would be worthwhile.

Having determined the figure to be used for "available cash," the next step was to find the cash requirements (material cost) of the various lines. This information was available from the company's elementary standard-cost system. The Dapper required $160 of materials per lot, the cheaper heavy denim and cotton-cord materials used for the Digger, $80 per lot; and the drip-dry minimum iron materials for the Diver, $240 per lot. All these amounts included allowance for normal wastage. It was then possible to formulate the financial constraint in these terms:

$$160\ A + 80\ U + 240\ I \leq 25{,}600$$

The Demand Constraint

Mr. Murphy was pleased with the progress made so far and believed that the problem had now been expressed in a form that could be solved by the linear programing technique. One final matter still bothered him, however. Mr. Ogden believed that the company could sell more than it would be able to produce in the coming season and had therefore left demand completely out of his calculations. Mr. Murphy doubted the wisdom of this decision. He believed that the firm obviously could not sell an infinite amount of the fall line, and that the situation would be more realistically formulated if a demand constraint were to be included. He asked Mr. Ogden the highest demand that he could imagine experiencing for the fall lines.

Mr. Ogden thought for a while, then said: "Well, last year we had orders for more than we could turn out. The orders amounted to about 300 lots – maybe a bit more. That was certainly more than we have ever had before. I think it could be bigger still this year, though."

Murphy: How much higher? Could it be 400 lots?

Ogden: No – I don't think so. But I think it could be fairly close to it.

Murphy: About 350 lots?

Ogden: No, more like 380 lots.

On that basis Mr. Murphy decided to take 380 lots as the maximum foreseeable demand. Obviously, therefore, the total production of all lines could not be allowed to exceed that figure, and therefore, the following constraint was formulated:

$$A + U + I \leq 380$$

Solving the Problem

Mr. Murphy now had all the information he needed to formulate the problem for solution by the Simplex method of linear programing. He set out the equations that had been derived:

$$\text{Maximize } Z = 165\,A + 195\,U + 225\,I \qquad (1)$$

Given the Constraints:

$$\begin{aligned} 60\,A + 120\,U + 180\,I &\leq 27{,}000 && (2)\\ 600\,A + 800\,U + 600\,I &\leq 124{,}000 && (3)\\ 3\,A + 6\,U + 8\,I &\leq 780 && (4)\\ 160\,A + 80\,U + 240\,I &\leq 25{,}600 && (5)\\ A + U + I &\leq 380 && (6) \end{aligned}$$

He then proceeded to restate these equations in the form of a Simplex tableau by adding slack variables to each of them. This is simply a way of converting these expressions, which are called equations but in fact are inequalities, into true equations. An additional term is added to each inequality. This term represents the time or cost which is *not* expended. The effect is to change the "equal to or less than" sign, $\leqslant$, into the normal "equals" sign. This is best illustrated by an example. The cutting machine constraint, inequality (2), states that "cutting machine time spent on producing the Dapper plus time on the Digger plus time on the Diver must in total be equal to or less than 27,000 minutes."

Now, by adding a *slack* (or dummy) variable, P, which is time *not* spent on any of the products (that is, potential running time during which a cutting machine is idle), the inequality can now be turned into an equality or true equation, thus:

$$60\,A + 120\,U + 180\,I + P = 27{,}000$$

and the interpretation is now straightforward and obvious: "The total cutting machine time spent on the Dapper plus time on the Digger plus time on the Diver *plus that time in which the machine or machines could have been used but are in fact idle* will amount to *exactly* 27,000 minutes."

Similar slack variables were added to inequalities (3) through (6), and Murphy proceeded to solve the problem by deriving successive Simplex matrices until an optimum solution was obtained. The successive matrices are given as an appendix (see page 82). (The reader who is unfamiliar with the Simplex method and wishes to have a step-by-step explanation of the procedure is advised to consult one of the basic texts listed in the bibliography. The book by Metzger is recommended as the best introduction to the mechanics of the technique.)

Mr. Murphy completed his solution and turned to Mr. Ogden.

Murphy: Well, Bob, here is the answer, but I think it may make a lot more sense to you if I work right through the solution with you and try to show you what is happening at each step.

Ogden: Please do that. It looks terrifying at the moment, and I don't really see how you have produced an answer at all, or why you say that it is the optimal one.

Murphy: Well, first of all I look at the profit function. The profit per lot on the Diver is considerably higher than either of the others, so it is a reasonable starting point to say that you will make as much of the Diver as possible. Then you must look to see which factor is the limiting one, which constraint you encounter first. As you can see it is the labor constraint. The labor shortage limits your production of the Diver to 97.5 lots, and you would have 9,450 minutes of unused cutting machine time, 65,500 minutes of unused stitching machine time and $2,200 of unused cash from the amount allocated for materials purchases.

Now look at the effect that introducing a second item into the line would have. The Dapper offers more additional profit than the Digger ($80.62 per lot against $26.25 per lot), therefore that line is introduced into the mix. The result is a program of 31.43 lots of the Dapper, with the Diver falling to 85.71 lots. The total profit is now $24,300: that is, $2,300 more than if you made the Diver alone. The matrix now indicates, however, that we can increase profits even more by introducing some Diggers into the mix.

The revised program resulting from the introduction of the Digger is interesting. The Digger takes up all the remaining slack time on the stitching machines. The Diver schedule is cut to only 7.5 lots, but the resources freed by this reduction make it possible to increase the Dapper schedule up to 118.13 lots. This mix gives a total profit of $33,010, an increase of $8,000 over the two-product mix.

The matrix indicates at this point that there is no additional profit to be made by further changes or substitutions; all marginal contributions are now negative or zero. The optimum product mix, therefore, is:

Dapper:	118.13	lots
Digger:	60.63	lots
Diver:	7.5	lots

So there you are. That is your optimum product mix, if all the figures you have given me are reasonably correct.

Ogden: But Mike, this looks crazy. The Diver is my most profitable line and you are telling me to cut production of it down, almost to nothing!

Murphy: No, Bob, the Diver isn't your most profitable line, not when you look at it in the context of the overall production plan. One of your main problems is your shortage of labor for the finishing operations, and the Diver line requires so much labor that this area becomes a bottleneck. You can produce very little of the other lines and you end up with the cutting and stitching machines standing idle. Reducing the Diver schedule gives you a much more balanced production pattern, and your total profits rise accordingly.

Ogden: I see. That begins to make sense. Now, what about the loan question? You said that you would be able to tell me whether or not it was worth borrowing money to finance more materials purchases.

Murphy: Right. This is one of the most useful aspects of this type of analysis. The final tableau shows that at the point at which our optimal solution was obtained, the available cash was one of the effective constraints. That means that if we had *more* cash available, we could continue the process of substitution to give us an even better mix, up to the point at which cash was *not* an effective constraint and we came up against some other limiting factor. We can even get a pretty good idea of how much you should try to borrow by increasing the "available cash" constraint by different amounts and calculating the resulting change in total profits. In fact, we will try one such assumption right now and see how it works out. Let's assume that available cash is increased by $10,000 and work out the effect of that.

Mr. Murphy then began to rework his solution with the revised assumption. (That is, inequality (5) had now been changed to read

$$160\,A + 80\,U + 240\,I \leqq 35{,}600.)$$

After about 25 minutes he said: "There we are. On that assumption you get a very different product mix. The answer is now:

Dapper:	173 lots
Digger:	nil
Diver:	33 lots

"This is a pretty radical change, but again it makes sense. With all that additional cash, the cash constraint is no longer effective. The limiting factor now is going to be the stitching machines. The Digger, with its extra seams, is the line that requires most stitching time and it is dropped from the mix. The total profit now would be $36,000; and that is $3,000 more than the previous solution promised. Of course, you would have to pay interest on the loan, but assuming a rate of 6 per cent per annum, the total interest for three months would be just $150 which leaves you a very nice profit margin."

Ogden: You know, I think you have really got something here. What should my next move be?

Murphy: I would like to spend a few days going over the assumptions we have used to make sure that the formulation of the constraints is the best available. Then I think it might be a good idea to use a "sensitivity analysis" approach, to change various assumptions and see what effect the change makes on the results. For instance, I could ask, "What if you employed another five skilled workers?" or, "What if you ran the stitching machines on a two-shift basis?" and find out what the results would be. After that, I think you will really be in a position to do some planning.

Appendix

MODERN WEAR, INC.

Stages in the Simplex Solution of the Product-Mix Problem

1. Formulating the inequalities:

$$\begin{aligned}160A + 80U + 240I &\leq 25{,}600\\ 600A + 800U + 600I &\leq 124{,}000\\ 3A + 6U + 8I &\leq 780\\ 60A + 120U + 180I &\leq 27{,}000\\ A + U + I &\leq 380\end{aligned}$$

2. Introducing the slack variables:

* Note: At this point, some of the inequalities have been divided by a common denominator to simplify subsequent calculations. The first line has been divided by 80, the second by 200 and the fourth by 60.

$$\begin{aligned}2A + U + 3I + P &= 320\\ 3A + 4U + 3I + Q &= 620\\ 3A + 6U + 8I + R &= 780\\ A + 2U + 3I + S &= 450\\ A + U + I + T &= 380\end{aligned}$$

3. Showing coefficients of slack variables:

$$\begin{aligned}2A + 1U + 3I + 1P + 0Q + 0R + 0S + 0T &= 320\\ 3A + 4U + 3I + 0P + 1Q + 0R + 0S + 0T &= 620\\ 3A + 6U + 8I + 0P + 0Q + 1R + 0S + 0T &= 780\\ 1A + 2U + 3I + 0P + 0Q + 0R + 1S + 0T &= 450\\ 1A + 1U + 1I + 0P + 0Q + 0R + 0S + 1T &= 380\end{aligned}$$

The profit function is now:

$$165A + 195U + 225I + 0P + 0Q + 0R + 0S + 0T = Z$$

— obviously all idle time is unprofitable.

4. Setting up the first tableau:

Restate the array in matrix form with the constraint maximum to the left:

	P	Q	R	S	T	A	U	I
320 =	1	0	0	0	0	2	1	3
620 =	0	1	0	0	0	3	4	3
780 =	0	0	1	0	0	3	6	8
450 =	0	0	0	1	0	1	2	3
380 =	0	0	0	0	1	1	1	1

The first tableau is now constructed. See page 85.

The *index row* at the foot of this tableau plays a vital part in the next step. It has been developed by the following formula:

Number in index row = Σ [all numbers in that column multiplied by the corresponding number in the objective column] minus the number in the objective row at the head of the column.

For the A column, the index number is determined thus:

$$
\begin{aligned}
2 \times 0 &= 0\\
3 \times 0 &= 0\\
3 \times 0 &= 0\\
1 \times 0 &= 0\\
1 \times 0 &= 0\\
\Sigma &= 0\\
&- 165\\
&= -165
\end{aligned}
$$

These index-row numbers indicate the relative extent to which the solution could be improved by introducing into the solution the variable at the head of that particular column. In this instance the variable to be introduced is obviously I.

The next step is to calculate which variable currently in the solution will be *replaced* by I. The I column will be called the *key column* for this tableau. This is done by dividing each number in the constant column by the corresponding positive non-zero number in the key column:

$$
\begin{aligned}
320 \div 3 &= 106.7\\
620 \div 3 &= 206.7\\
780 \div 8 &= 97.5\\
450 \div 3 &= 150.0\\
380 \div 1 &= 380.0
\end{aligned}
$$

The *smallest* of these quotients, in this case 97.5, is then selected. This now becomes the *key row*. The variable shown in the variable column for this row, R, will therefore be dropped from the solution in favor of I. The number at the crossing point of the key row and key column is called the key number: In this example, it is 8 as indicated in the first tableau.

It is now possible to construct the next tableau, known as the first iteration. The first step is to take the key row from the first tableau and divide it throughout by the key number:

$$
\begin{aligned}
780 \div 8 &= 97.5 \\
0 \div 8 &= 0 \\
0 \div 8 &= 0 \\
1 \div 8 &= 0.125 \\
0 \div 8 &= 0 \\
0 \div 8 &= 0 \\
3 \div 8 &= 0.375 \\
6 \div 8 &= 0.75 \\
8 \div 8 &= 1
\end{aligned}
$$

This new row is inserted into the new tableau in place of the old key row. The appropriate variable and objective are also inserted at the left of this row: I and 225 respectively.

The tableau is completed by taking each remaining number from the first tableau and applying formula to it:

Old number minus: (corresponding number in key row multiplied by corresponding number in key column) divided by key number

Thus, to obtain the new constant column entry for the P row, we have:

$$320 - \frac{(780 \times 3)}{8}$$

$$= 320 - \frac{2340}{8}$$

$$= 320 - 292.5$$
$$= 27.5$$

The remainder of the tableau is constructed in the same manner.

	Objective Column	Variable Column	Constant Column	0	0	0	0	0	165	195	225	Objective Row
				P	Q	R	S	T	A	U	I	Variable Row
$\frac{320}{3}$	0	P	320	1	0	0	0	0	2	1	3	Constraint Equations
$\frac{620}{3}$	0	Q	620	0	1	0	0	0	3	4	3	
$\frac{780}{8}$	0	R	780	0	0	1	0	0	3	6	8	
$\frac{450}{3}$	0	S	450	0	0	0	1	0	1	2	3	
$\frac{380}{1}$	0	T	380	0	0	0	0	1	1	1	1	
			0	0	0	0	0	0	−165	−195	−225	Index Row

5. First iteration:

Ratio				P	Q	R	S	T	A	U	I	
				0	0	0	0	0	165	195	225	Objective Row
				P	Q	R	S	T	A	U	I	Variable Row
27.5 / .875	0	P	27.5	1	0	—.375	0	0	**.875**	—1.25	0	
327.5 / 1.875	0	Q	327.5	0	1	—.375	0	0	1.875	1.75	0	
97.5 / .375	225	I	97.5	0	0	.125	0	0	.375	.75	1	Constraints
157.5 / —.125	0	S	157.5	0	0	—.375	1	0	—.125	—.25	0	
282.5 / .625	0	T	282.5	0	0	—.125	0	1	.625	.25	0	
			21,937.5	0	0	28.125	0	0	—80.625	—26.25	0	Index Row

A new key column, key row and key number are now calculated as before, and the second iteration is calculated:

6. Second iteration:

			0	0	0	0	0	165	195	225	Objective Row
			P	Q	R	S	T	A	U	I	Variable Row
165	A	31.43	1.143	0	—.43	0	0	1	−1.43	0	Constraints
0	Q	268.57	—2.14	1	.43	0	0	0	4.43	0	
225	I	85.71	—.429	0	.287	0	0	0	1.29	1	
0	S	161.43	.143	0	—.43	1	0	0	—.43	0	
0	T	262.85	—.715	0	.143	0	1	0	1.143	0	
		24,300.7	92.07	0	—6.375	0	0	0	—140.7	0	Index Row

Again, the key column, row and number are calculated and the next tableau can be constructed:

7. Final iteration:

			0	0	0	0	0	165	195	225	Objective Row
			P	Q	R	S	T	A	U	I	Variable Row
165	A	118.3	.457	.329	—.291	0	0	1	0	0	Constraints
195	U	60.3	—.48	.23	.097	0	0	0	1	0	Constraints
225	I	7.50	.190	—.297	.162	0	0	0	0	1	Constraints
	S	187.5	—.063	.099	—.388	1	0	0	0	0	Constraints
	T	193.5	—.166	—.263	.032	0	1	0	0	0	Constraints
		33,010	24.7	32.3	7.4	0	0	0	0	0	Index Row

↑ Solution (33,010)

No negative numbers (24.7 to 0): indicative that optimum has been reached

It can now be seen that there are no negative figures left in the index row, and therefore no new index column can be calculated. This indicates that the solution cannot be further improved by introducing any other variables into the current solution. The optimum product mix can now be read from the constant column, and the index row entry at the foot of this column indicates the expected profit for this solution.