Faculty Working Papers

LP IN THE MANAGERIAL ACCOUNTING INFORMATION SYSTEM: A CONSIDERATION OF SOME IMPLEMENTATION PROBLEMS

William Hopwood, Assistant Professor of Accounting
John Wragge, Assistant Professor of Accounting,
University of Florida

#495

College of Commerce and Business Administration
University of Illinois at Urbana-Champaign

FACULTY WORKING PAPERS

College of Commerce and Business Administration

University of Illinois at Urbana-Champaign

July 7, 1978

LP IN THE MANAGERIAL ACCOUNTING INFORMATION SYSTEM: A CONSIDERATION OF SOME IMPLEMENTATION PROBLEMS

William Hopwood, Assistant Professor of Accounting
John Wragge, Assistant Professor of Accounting,
University of Florida

#495

Summary:

The advent of computerized planning and control systems now provides the opportunity for managerial accountants to reconsider the structure of their accounting systems and the data they provide to the organization. This paper suggests that linear programming (LP) is an appropriate technique for inclusion in the managerial accounting information system and addresses the following implementation problems: (1) the accountant's role in the LP process, (2) obtaining data, (3) understanding the assumptions of the LP model, (4) behavioral problems, and (5) special problems of using LP as a planning and control device. Examples are drawn from accounting and other disciplines to illustrate the progress that has been made towards solving the problems. Whenever possible, the impact of new computer technology is considered. Operational accounting is presented as one modification to present systems that is deserving of special consideration. Finally, several areas for future research are presented.

Acknowledgment

We wish to thank Dr. Larry Benninger of the University of Florida for his helpful comments on an early draft of this paper.

LP IN THE MANAGERIAL ACCOUNTING INFORMATION SYSTEM: A CONSIDERATION OF SOME IMPLEMENTATION PROBLEMS

The accounting literature has considered linear programming (LP) for sometime. Yet, it appears that LP has had little lasting effect on the managerial accounting information system (MAIS) in most companies.

The advent of computerized planning and constrol systems now makes it possible to include LP as a regular part of the MAIS. Since many organizations are just starting to develop extensive data bases to support their management information systems, recommendations can be made to include the data needed to drive the model. Once LP is institutionalized, fast answers can be produced and comparable problems solved at a very low marginal cost. Using Mason's (1969) classification scheme, the MAIS is moved from being a "databank system" (which only collects and files data) past the "predictive information system" (which answers "What if?" questions posed by the decision maker) to a "decision-making information system." A system of this type includes the organization's value system (objective function for LP) and criteria for choice (maximize profit or minimize cost) in its analysis but the decision maker retains veto-power over the implementation of the solution.

While LP has great potential as a managerial accounting tool, there are a number of problems which have prevented it from making its maximum contribution. These must be recognized and dealt with before LP can become an integral part of the MAIS. However, because much of the LP research has been done in other disciplines (notably in industrial engineering), the accounting literature has not adequately considered these problems and their solutions in an integrated manner. Therefore,

the purpose of this paper is three-fold. First, it will discuss the following five problem areas relating to the inclusion of LP in the MAIS: (1) the accountant's role in the LP process, (2) obtaining data, (3) understanding the assumptions of the LP model, (4) behavioral problems, and (5) specific problems of using LP as a planning and control device. Second, it will consider the progress (often from other disciplines) that has been made towards the solution of these problems and the implications this progress has for future MAIS's. Operational accounting will be presented as one possible modification deserving special consideration. Finally, several subject areas for future research will be identified.

THE ACCOUNTANT'S ROLE IN THE LP PROCESS

LP is an operations research technique. Therefore, before LP can have a significant impact on the MAIS, both the managerial accountant and the operations researcher must clearly understand the role of the accountant in the LP process.

One possibility is that the accountant should be involved at a high administrative level since he is in a unique position to recognize potential application areas for LP. In some cases, controllers have even managed the entire LP project (Morton, 1958).

Another possibility is that the accountant should serve only as a data gatherer. This is illustrated by Goldschmidt (1970) who, in conducting LP projects in 25 firms, used the following iterative process:

Phase	Person(s) Responsible
1. Define the problem	MG, AN
2. Make assumptions	MG
3. Formulate the problem	AN
4. Assemble the data	AT, AN
5. Construct the tableau	AN
6. Run on the computer	AN
7. Analyze the results	AN, MG
8. Change the assumptions	AN, MG
9. Assemble additional data	AN, AT
10. Change the tableau	AN
11. Return to step 6 (if necessary)	

(MG = management, AN = analyst (operations researcher), AT = accountant)

A third possibility is that the application of LP should be a joint project with the managerial accountant and the operations researcher cooperating with each other at various stages of the implementation process. This is the basic conclusion reached by Hartley (1968) although he did not adress LP specifically. This position becomes more and more acceptable when one considers the quantitatively-oriented curriculums many managerial accountants have been studying under and the emphasis on the MBA degree (which includes some accounting) for operations researchers.

The advent of user-oriented LP software packages makes it easier for the accountant to assume more of the initial implementation responsibities and to carry-out more of the ongoing maintenance of the model. In fact, many relatively simple applications may require no assistance at all from the operations researcher. Therefore, regardless of who developes the

initial application and maintains the model, it seems reasonable that the managerial accountant should be responsible for institutionalizing it as a recurring part of the MAIS.

OBTAINING DATA

The technical problems associated with LP have largely been solved. Computer software is readily available to perform an LP computation. However, a very critical problem is that of obtaining good data for the model to work with. This problem is composed of two subproblems: (1) data availability, and (2) what data to use.

Data Availability

Planning data and control data are generally needed for an efficient LP model application. The former consists of cost coefficients (CC), revenue coefficients (RC), technical coefficients (TC), and right-hand side capacity coefficients (RHCC). Control data consists of planning data plus feedback on environmental states and performance.

Jensen (1963) feels the accounting department should be able to furnish the CC's, the marketing department the RC's, and the engineers the TC's and RHCC's. He also notes that the accounting department can estimate the TC's from historical data if they are not available. The feedback on environmental states and performance is currently generated by many MAIS's. Additional control data that is desired on the various coefficients can be obtained from the departments that furnished the planning estimates.

A serious problem in practice is that a gap may exist between the reliability of the information required and the reliability of the

information supplied by the existing information system. For example, Degarmo (1966) found two comparable foundries whose valuations of an important input in metal making differed by $132 per gross ton ($110 and $242, respectively). He also notes that the foundry's staff may not even know the exact composition of its product.

What Data to Use

The second problem in obtaining data is specifying what specific data should be used to determine the CC's, TC's, and RHCC's for the model.

Cost Coefficients. Jensen (1963), Lea (1971, 72), and Ross (1960) have addressed the CC determination problem. Jensen states that opportunity cost is the desirable measure. Lea, however, feels that opportunity cost is only a short run view of the firm which could, in some cases, lead to a suboptimal solution. He believes that a long run view can be achieved by using replacement cost. Ross argues that there is a "hidden cost" called "user depreciation" that needs to be included in the decision analysis but seldom is. His basic argument is that since use decreases the present value of the receipts, what appears to be profitable may, in fact, be unprofitable. For example, the Sanborn field study (Ross, p. 427) discovered that farms producing corn and wheat were earning apparent high returns at the expense of soil productivity.

From a data collection standpoint, a useful distinction can be drawn between a first order variable cost, i.e., one that varies only with the level of production (such as the cost of raw materials), and a second order variable cost, i.e., one that varies with the level of production and the first order variable costs (such as FICA taxes). First order variable costs generally must be included in the CC's while

second order variable costs can often be omitted without significantly affecting the optimal solution of the model.

Technical Coefficients. TC's are nondollar data. As such, they have traditionally not been collected by the accounting information system.

The actual determination of the TC's can be a very complex problem. Jensen (1963), as previously mentioned, suggests that they should be obtained from the engineers. He also suggests that judicious use of standard cost records can produce useful surrogates. In addition, as on-line data recording stations become more common on the production floor, it seems reasonable to assume that reasonably accurate TC's will be determinable from the data base that results.

Right-Hand Side Capacity Coefficients. The RHCC's are the maximum amounts of service factors available. One difficulty in RHCC determination is that many service factors have never been used to full capacity. Another problem is that full capacity may be variable since many types of service factors can be used in excess of their stated full capacity. For example, a machine can be run harder and faster than recommended. When this occurs, user depreciation will increase thus creating a nonlinear constraint. A solution to this problem can be reached by computing an optimal capacity limit for the service factor and then using this limit in the LP analysis. However, a complication is that this limit may depend on the shadow price of the factor (often referred to as the "secondary opportunity cost") as well as the time value of money, warehouse space, price indexes, inventory carrying costs, etc. This problem can be approached by using an iterative process.

Foremen, engineers, and the manufacturers of the service factors are possible sources of capacity data. In addition, as data bases become more sophisticated, it will be possible to approximate these limits by analyzing past performance. This will be especially useful in cases where service factors are being used above their stated capacities.

UNDERSTANDING THE ASSUMPTIONS

There are two classes of basic assumptions underlying LP, "mathematical" and "economic." A problem is that accountants often either misunderstand them or are not aware of both sets simultaneously. Part of the reason is that the accounting literature has not generally discussed both sets in one place.

Hiller and Lieberman (1973, pp. 3-12) give a good presentation of four mathematical assumptions:

(1) Divisibility - LP assumes that the solution variables can contain fractional parts. In the real world, however, they often can only take on integer values (e.g., it is not possible to have one-half of an airplane). When it appears that an integer constrained solution will produce significantly different results than simply rounding-off the LP solution, an integer programming technique may be used.

(2) Linearity (proportionality) - LP requires that the objective function and all of the constraints must be linear. Some items may fail this assumption such as (a) coefficients that vary with output levels (there can be no economies or diseconomies of scale within the relevant range), (b) setup costs, cleanup labor, and

avoidable overhead, and (c) those inputs for which a learning curve (or boredom curve) exists (Lea, 1971).

(3) Additivity (the addition of activities with respect to the measure of effectiveness of each resource) - For example, if two goods are to be sold individually for one dollar apiece, then their selling prices must remain one dollar apiece regardless of their sales mix.

(4) Deterministic - All of the model coefficients must be deterministic. If this assumption does not hold, it is often possible to use chance constrained or stochastic programming techniques. The latter is possible where the coefficient takes on only a finite number of possible values.

Even if one or more of these assumptions is violated in practice, LP may still be a good enough approximation to provide valuable information to the decision maker.

Some of the typical economic assumptions are:

(1) The length of the planning horizon will determine which costs are variable and which are fixed - Edge (1966) discusses the use of LP in the North British Columbia forest industry where it requires 130 years to replace trees. There, maximizing with respect to a short period would probably produce suboptimal long run results.

(2) Profit maximization or cost minimization - These are typical objectives in an LP project. However, in practice, it has sometimes been found that an objective such as to maximize gross revenues or production is more useful.

(3) Perfect competition - It is often assumed that the firm's demand curve is horizontal and that demand is infinite. A possible solution to the problem of a downward sloping demand curve (a nonlinear problem) is the use of quadratic programming. The problem of infinite demand can be circumvented by constraining demand.

There are other economic assumptions that could be discussed. However, those presented give an idea of some of the problems involved.

BEHAVIORAL PROBLEMS

In order to implement and institutionalize an LP model, the managerial accountant must deal with people. When this happens, special behavioral problems may arise such as:

(1) Intolerance to change - Goldschmidt (1970) found that it is easier to introduce a new technique that to change an old one. Thus, it may be desirable to introduce LP and operational accounting (to be discussed later) as new systems, rather than as changes in the old system.

(2) A tendency for foremen and managers to not have faith in scientific analysis - Continuing education courses and quantitatively-oriented college curriculums are helping to reduce this problem.

(3) A fear that LP will render the employee useless - In his study of the Columbia Cellulose Co., Edge (1966) continually stressed that LP was an aid to management and not a replacement.

(4) Important data may exist only in the mind of the employee and may, therefore, be difficult to get (Morton, 1958).

(5) A language based communication problem - All foremen, for example, do not understand LP terminology such as "technical coefficients" or "objective function."

(6) An "LP fixation complex" may arise on the part of the implementor or user - This happens when the accountant, operations researcher, or manager becomes so enamored with the tool itself that he loses his perspective and ascribes more importance or preciseness to it than he should.

These examples illustrate the need for care and planning in regard to the implementation of LP.

LP AS A PLANNING AND CONTROL DEVICE

Planning

LP is useful for providing for the optimal budgeting of scarce resources. It can be used to determine sales, production, and cash budgets for the long run (See Cohen, 1966; Charnes et al., 1959; Garvin, 1957; Madge, 1966; Martin, 1955; O'Mally, 1966; Stasch, 1965; and Welch, 1970). Further, by forcing management to consider various interrelationships they would not have considered otherwise, formulating the problem in an LP context may lead to a greater understanding of the situation (Koenigsberg, 1961) which may produce a profitable change even before LP is used (Goldschmidt, 1970).

LP sensitivity analysis can be used to analyze risk in the budgetary process. Although sensitivity analysis is not complicated in theory, there is an inherent danger in its use since the range of the coefficients is only valid if there are no simultaneous changes in the coefficients. In practice, this is very likely to be violated. The

difficult part of the problem is that it may not be possible to determine the error introduced by the violation. This error can be quite large, even when such violation is small. For a refined analysis, stochastic and/or parametric programming should be used.

A criticism leveled against LP is that the unidimensional objective function traditionally used is not adequate for planning purposes. This has led some individuals to suggest that the tool should be expanded.

Lee (1971) recommends the use of an adaptation of LP called "goal programming." In it, the objective function is the sum of the differences between planned performance and management's goals (with each deviation weighted by its relative importance). Constraints are constructed and the model is solved as an LP minimization problem. In addition to industrial applications, goal programming has been suggested as a planning model for a public accounting firm (Killough and Souder, 1973).

Goal programming suffers from some of the same problems traditional LP does. Both Lee and Kornbluth (1974) recognize that management may not be able to specify their goals and/or correctly assign weights to them. Further, the behavioral problem of gaining acceptance by management plagues goal programming as it does any operations research technique.

Kornbluth (1974) proposes a Multiple Objective Linear Programming model to avoid the necessity of predetermined weights. In it, each objective is represeted by a separate objective function. The final tableau provides the "best" trade-offs between the various corporate objectives.

Multiobjective techniques do not make unidimensional LP obsolete. In cases where one objective will suffice, unidimensional LP should be used because of its relative simplicity. In cases where unidimensional LP

will not suffice, multiobjective approaches may be considered. However, they carry with them additional computation and implementation complexities which may make their use prohibitive in many cases.

Control

The AAA Committee on Managerial Accounting (1970) recognized that a problem of consistency exists between the planning and control functions. It recognized three possible solutions:

(1) Modify the control system to become consistent with the planning system;

(2) Structure the control system around the planning system; or

(3) Dual measurement, (p. 8).

The second approach is probably the most usable in an LP context and is suggested by Dopuch, Birnberg, and Demski (1967).

Samuals (1965) was one of the first to suggest using LP to compute a variance based on opportunity losses. Demski (1967) developed an ex post accounting system which used LP as a basis for arriving at a planning variance and an opportunity loss variance (which measures the cost of not adapting plans to changing conditions).

There have been a number of additional attempts to structure the control system around the planning system. Most of these have been aimed at designing control subsystems that are consistent with the LP planning system. However, to date, no one has developed a completely integrated control system. Specific research efforts have been (in addition to those mentioned previously) Farag (1967), Onsi (1970), and Kaplan and Thompson (1971). These deal with transfer pricing, decomposition analysis, and overhead allocation. Each area will be discussed individually.

Transfer Pricing. Several writers have suggested that transfer prices should be based on shadow prices, i.e., on secondary opportunity costs. Farag (1967) feels that the transfer price should be equal to the direct cost plus the shadow price. If this method is used, and each division performs exactly as budgeted (using an LP model), then each division will exactly breakeven. Any deviation from the LP budget (except for technological improvements) will produce a loss. However, if a division improves its technical coefficients, it will show a profit. A problem with this system is that if the TC's are currently attainable, it is very likely that the divisions will normally operate at a loss. This may result in the lowering of aspiration levels and, thus, production.

Onsi (1970) has suggested a method to determine the transfer price of a division that manufactures two products of which only one is to be transferred (where the one not to be transferred has an outside market price). He assumes that none of the one transferred out will be produced and then uses LP to optimize the one with the outside market price. Once this is done, the shadow prices of the raw materials can be used in Farag's formula.

Finally, it is commonly stated that it is not permissible to optimize division A and then division B in succession since this will very likely produce suboptimal results. For interdivisional optimization, decomposition may be used.

Decomposition Analysis. There are different ways to apply the decomposition principle depending on the complexity of the problem. In general, there are interdivisional and intradivisional constraints. The interdivisional constraints are those imposed by top management. The

intradivisional constraints are those existing within the various divisions. Also, demand interdependence usually exists between divisions. That is, if A produces goods to be transferred to B, then A's demand is dependent on B's demand. The complexity of the problem will depend on the amount of demand interdependence and whether interdivisional constraints exist or not.

If interdivisional constraints exist, an iterative approach may be used. In this case, two "sets" of programs are formulated (interdivisional and intradivisional). The interdivisional program is solved first and its solution is used to generate objective functions for the intradivisional programs. The intradivisional programs are then solved and their solutions are used to add new columns to the interdivisional program. This process is repeated a finite number of times until an optimal solution is converged upon.

A simpler case of decomposition arises when there are no top management constraints. A example of this is given by Onsi (1970).

There are important motivational considerations that should be recognized when using decomposition. Godfrey (1971) has criticized decomposition as being a highly centralized decision making procedure. It is very likely that the company's plan based on decomposition will require some divisions to produce a mix that is suboptimal for them on an individual basis. The difference between their individual optimal and the company's optimal plan is a motivation cost. One solution is to subsidize the division for this cost so that it will not be penalized for operating for the benefit of the company as a whole.

It should be noted that advanced computer software has made it much easier to use techniques such as decomposition. For further

information on decomposition, see Baumol and Fabian (1964), Dantzig and Wolf (1960), Dantzig (1963), and Kormai and Liptak (1965).

Overhead Allocation. Kaplin and Thompson (1971) have formulated a model for overhead allocation based on shadow prices. Using their method of full costing, decisions based on full costed objects will produce the same set of decisions as those based on variable costing, i.e., the model allocates overhead in such a manner that the relative profitability is preserved. Their model will also provide an overhead subsidy to a complementary product when it is profitable to produce that product at a loss due to demand interdependency.

This concludes the consideration of specific LP implementation problem areas.

OPERATIONAL ACCOUNTING

Goldschmidt (1970, p. 173) found that "...the conventional full cost accounting systems failed to provide the required financial data for programming." Therefore, if managerial accountants are to include LP as an integral part of the MAIS, the MAIS will have to be modified to include an operational accounting subsystem.

Churchman and Ackoff (1955, p. 35) have defined operational accounting as "...the process of providing the kind of information that operations research needs for studying an executive's problem." Goldschmidt (1970) broadens the concept to include all types of operations research decisions. It seems particularly worthy of consideration as organizations redefine their data requirements while moving towards computerized data bases.

Jensen (1963) has formulated an operational accounting model which consists of a budgeted income statement based partially on opportunity costs. He also uses such new accounts as "Planned Opportunity Cost," "Actual Opportunity Cost," and "Variance from Opportunity Cost." His system provides for the proper classification of the necessary data for an operational accounting system. A system of this type may be a workable solution to many of the deficiencies mentioned earlier in this paper.

Will companies be willing to modify their current accounting systems to permit operational accounting? Goldschmidt (1970) found that in many cases where LP was successful, the companies were completely willing to introduce changes in their accounts to facilitate LP. Even if there is reluctance, the increased analytical capability made possible by the resultant computerized management information system should exert tremendous pressure for implementing operational accounting.

CONCLUDING REMARKS

This paper has considered a number of problems associated with the implementation of LP by the managerial accountant. It illustrates that a significant body of literature exists relating to the use of LP as a part of the MAIS. However, it also illustrates that if the practical problems associated with implementation are to be adequately addressed, an interdisciplinary approach to the literature and research effort is required (with industrial engineering being an especially fruitful source of guidance).

Further research is needed to more clearly define the exact data to be included in the model coefficients. Once this is done, effort can be directed to the area of modifying current accounting systems to include operational accounting subsystems which will furnish the needed data inputs. This latter research has a technical aspect, i.e., designing the subsystem, and a behavioral aspect, i.e., managing systems change.

There is little doubt that the managerial accountant faces a new environment of computerized systems. These systems make possible an integration and extension of managerial accounting information that has not been possible in the past. While this paper has only considered LP, the systems offer the capability to make a number of operations research techniques integral parts of the accounting information systems that provide management with information for planning, control, and decision making. Therefore, additional research may also prove productive in the area of implementing such techniques as simulation, network models, and game theory.

REFERENCES

American Accounting Association, Committee on Managerial Accounting, "Report of the Committee on Managerial Accounting," Supplement to the Accounting Review (1970), pp. 1-8.

Baumol, W. J. and T. Fabian, "Decomposition, Pricing for Decentralization and External Economics," Management Science (September 1964), pp. 1-32.

Cohen, K. J. and F. Hammer, "Optimal Debt Schedule for Municipal Bonds," Management Science (November 1966), pp. 161-66.

Charnes, A., W. Cooper, and L. Miller, "Application of Linear Programming to Financial Budgeting and the Costing of Funds," Journal of Business (January 1959), pp. 20-46.

Churchman, C. W. and R. L. Ackoff, "Operational Accounting and Operations Research," Journal of Accountancy (February 1955), pp. 33-39.

Dantzig, G., Linear Programming and Extensions, (Princeton Press, 1963), Chapters 22-24.

Dantzig, G. and P. Wolf, "Decomposition Principles for LP," Operations Research (February 1960), pp. 101-111.

Degarmo, P., "Applying a Modern Industrial Engineering Technique to Two Old Foundry Problems," Journal of Industrial Engineering (September 1966), pp. 449-53.

Demski, J. S., "An Accounting System Structured on a Linear Programming Model," THE ACCOUNTING REVIEW (October 1967), pp. 701-12.

Dopuch, N., J. Birnberg, and J. S. Demski, "An Extension of Standard Cost Variance Analysis," THE ACCOUNTING REVIEW (July 1967), pp. 526-36.

Edge, C. G., "The Profit Contribution of Linear Programming to the Management of a Forest Industry Company," CORS (July 1966), pp. 61-68.

Farag, S., Input-Output Analysis: Applications to Business Accounting, (University of Ill., 1967), pp. 88-120.

Garvin, W. W., J. Crandall, J. B. John, and R. A. Spellman, "Applications of Linear Programming in the Oil Industry," Management Science (July 1957), pp. 402-29.

Godfrey, J. T., " Short-Run Planning in a Decentralized Firm," THE ACCOUNTING REVIEW (April 1971), pp. 282-97.

Goldschmidt, Y., Information for Management Decisions, (Cornell University Press, 1970), pp. 173-208.

Hartley, R. V., "Operations Research and Its Implications for the Accounting Profession," THE ACCOUNTING REVIEW (April 1968), pp. 321-332.

Hiller, F. S. and C. J. Lieberman, Introduction to Operations Research (Holden-Day, Inc., 1973), pp. 3-12.

Jensen, H. G., Some Implications of the Cost Data Requirements of Linear Programming for Cost Accounting (Ph.D. Dissertation, University of Minnesota, 1963).

Kaplan, R. and G. Thompson, "Overhead Allocation Via Mathematical Programming Models," THE ACCOUNTING REVIEW (April 1973), pp. 352-64.

Killough, L. N. and T. L. Souder, "A Goal Programming Model for Public Accounting Firms," THE ACCOUNTING REVIEW (April 1973), pp. 193-206.

Koenigsberg, E., "Some Industrial Applications of Linear Programming," Operations Research Quarterly (April 1961), pp. 105-14.

Kormai, J. and T. Liptak, "Two Level Planning," Econometrica (January 1965) pp. 141-69.

Kornbluth, J. S. H., "Accounting in Multiple Objective Linear Programming," THE ACCOUNTING REVIEW (April 1974), pp. 284-95.

Lea, R. B., "Estimating the Parameters in Operational Decision Models: A Linear Programming Illustration," (Univ. of Texas: unpublished working paper, May 1971).

Lee, S. M., "Decision Analysis Through Goal Programming," Decision Sciences (April 1971), pp. 172-80.

Madge, D. N., "Programming an Integrated Lead-Zinc Metallurgical Complex," CORS (March 1966), pp. 14-22.

Mason, R., Jr., "Basic Concepts for Designing Management Information Systems," Information for Decision Making, 2nd, ed. A. Rappaport (Prentice-Hall, 1975), pp. 2-16.

Martin, A. D., Jr., "Mathematical Programming of Portfolio Selections," Management Science (January 1955), pp. 152-66.

Morton, C., "Linear Programming - An Application in an Indian Textile Mill," Operational Research Quarterly (May 1958), pp. 198-206.

O'Malley, R., "A Multiplant, Multiperiod Allocation Model for Cable Production," Journal of Industrial Engineering (November 1966), pp. 580-84.

Onsi, M., "A Transfer Pricing System Based on Opportunity Cost," THE ACCOUNTING REVIEW (July 1970), pp. 535-43.

Ross, M. H., "Depreciation and User Cost," THE ACCOUNTING REVIEW (July 1960), pp. 422-28.

Samuels, J. M., "Opportunity Costing: An Application of Mathematical Programming," Journal of Accounting Research (Autumn 1965), pp. 182-91.

Stasch, S., "Linear Programming and Space-Time Considerations in Media Selection," Journal of Advertising Research (December 1965), pp. 40-46.

Welch, H. and M. Florian, "An Application of Linear Programming to Wage Analysis," CORS (March 1970), pp. 28-37.