AD-A040 548 TEXAS UNIV AT AUSTIN CENTER FOR CYBERNETIC STUDIES F/G 12/2
PLANNING IN THE MULTINATIONAL FIRM: THE STRATEGIC OPERATIONS IN--ETC(U)
MAR 77 R L CRUM, D KLINGMAN, L A TAVIS N00014-75-C-0569
UNCLASSIFIED CCS-286 NL

| OF |
AD
A040548

END
DATE
FILMED
7-77

1.0 2.8 2.5 4.5 5.0 3.2 2.2 5.6 6.3 3.6 7.1 4.0 2.0

1.1 1.8

1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CENTER FOR CYBERNETIC STUDIES

The University of Texas
Austin, Texas 78712

Research Report CCS 286

PLANNING IN THE MULTINATIONAL FIRM: THE STRATEGIC OPERATIONS INTERFACE

by

R. L. Crum*
D. Klingman**
L. A. Tavis***

March 1977

*Assistant Professor of Finance, College of Business Administration, University of Florida, Gainesville, Florida 32611

**Professor of Operations Research and Computer Science, Department of General Business, BEB 600, University of Texas, Austin, Texas 78712

***Professor of International Finance, College of Business Administration, University of Notre Dame, Notre Dame, Indiana 46556

This research was partly supported by Project NR047-021, ONR Contracts N00014-75-C-0616 and N00014-75-C-0569 with the Center for Cybernetic Studies, and by OASIA Contract number 705-75-29 with Analysis, Research, and Computation, Inc.

CENTER FOR CYBERNETIC STUDIES

A. Charnes, Director
Business-Economics Building, 203E
The University of Texas
Austin, Texas 78712
(512) 471-1821

Abstract

Great environmental uncertainties have increased the importance of formal planning structures to assist multinational firms in adapting to a rapidly changing world. It is our belief that the type of information needed by multinational planners can best be obtained when strategies are superimposed on the operating system of the firm. In the past, fully integrated optimization planning structures were infeasible because of the enormous complexity of multinational companies resulting in extremely large models and very slow solution time -- if a solution could be obtained at all. This has led to non-optimization simulation modeling which provides some but not enough relevant information. With *Computer Implementation Technology* and *NETFORM* representations, a move to optimization procedures is feasible and desirable. The power of these procedures over simulation models is demonstrated in an application for the U. S. Treasury, where we show how the model can lend insight into important planning issues and develop hard cost information for soft constraints.

Introduction

Dramatic shifts in the world's eco-political system are challenging the very survival of the multinational firm. Inflation is a continuing phenomenon in the developed as well as the less developed countries; the lack of exchange rate predictability in the "dirty float" monetary system has totally disrupted virtually all multinational treasury functions; recent changes in financial reporting standards are exaggerating this disruption on U. S. balance sheets; awakening third world nations are becoming more determined and effective in controlling their internal business sectors and demanding a larger share of the fruits of world productivity; the deterioration of U. S. dominance is leading to more competition and restrictions among the developed western nations. The convergence of these disruptive trends in world events will soon fully challenge the remarkable versatility of multinational managers demonstrated so clearly in the past two decades.

Unfortunately, repetition of past, successful actions on the part of managers will fail in this new environment where their experience inventories no longer apply. The multinational firm is presently in a vise between national governments with greater power and desire for influence, and owners who are focusing more on economic performance in what they see as a threatening international environment. The multinational firm itself has become so complex -- as have its surroundings -- that anticipating the systematic impact of any action requires a formalized planning information system. Planning is clearly the key to corporate and managerial survival as well as to long-run profitability.

The strategic aspect of planning takes on added importance in a world of shifting power balances. With the disruption of product and financial markets, the interpretation of strategies in the context of the firm's operating environment is fundamental to their analysis, so recognition of the close ties between the strategic and operations dimensions of planning is an important component for both. Strategically established policies are based upon assumptions concerning their operating impact, but strategies are sterile until they are imposed on the firm's activities. *Effective strategic planning cannot be divorced from its operational implementation.*

Integration of these two dimensions into a multinational planning structure, therefore, entails providing meaningful information on the full impact of policies as they relate to all elements of the production, marketing, or financing components of the firm. Such a model must be amenable to testing many environmental scenarios and policy alternatives, while, at the same time, be complete enough to capture the interrelated complexities of the system. Also implied is the requirement of rapid solution time and the ability to collate and synthesize the various input and output data in a manner comprehensible to the analyst.

The techniques for building, solving, refining and analyzing computer-based planning models such as those required for this application have undergone a steady evolutionary development as computer hardware has changed. This evolution has recently spawned the embryo of two new and important technologies, *network computer implementation technology* and *NETFORM (network formulation) technology*

The first has emerged from recent research on new solution algorithms and implementation techniques for solving network problems [2, 3, 4, 8, 11, 12, 15, 17, 20]. The fruits of this research have dramatically reduced the cost of solving linear and mixed integer network-type problems. This cost reduction, significantly, has been entirely above and beyond any reductions afforded by changes in computer hardware or compilers. For example, the cost of solving network problems with 2400 equations and 500,000 arcs on an IBM 360/65 has been reduced from a conservative estimate of $10,000 in 1968 to $300 in 1976 by these advances. In addition, *network computer implementation technology* has stimulated the development of new modeling techniques for handling a multitude of problems that arise in applications of scheduling, routing, resource allocation, production, inventory management, facilities location, distribution planning, and other areas.

These new modeling techniques [10, 13, 14, 16] are mathematically and symbolically linked to network and augmented network structures and are called *NETFORM technology*. A major attribute of the *NETFORM technology* is that it allows users to conceptualize formulations of their problems graphically. The pictorial aspect of this technology has proven to be extremely valuable in both communicating and refining problem interrelationships without the use of mathematics and computer jargon. Thus it protects the non-technical person against technical legerdemain and exaggerated claims of model "realism." Another powerful attribute of this technology is that it often yields a model which can be solved as a sequence of linear network problems.

It is our opinion, based on considerable experience with the development and industrial implementation of *NETFORM* models, that most of the obstacles preventing utilization of optimization planning models by business are overcome by joining these two technologies. As an example of the product of this successful union, our purpose in this paper is to describe the computer-based multinational operations planning system that we developed for the U. S. Department of the Treasury [1] utilizing *NETFORM* and *network computer implementation technologies*. We emphasize the substantial power of the model to lend insight into important planning issues and show that this planning tool can be used to respond quickly to changes in the international environment.

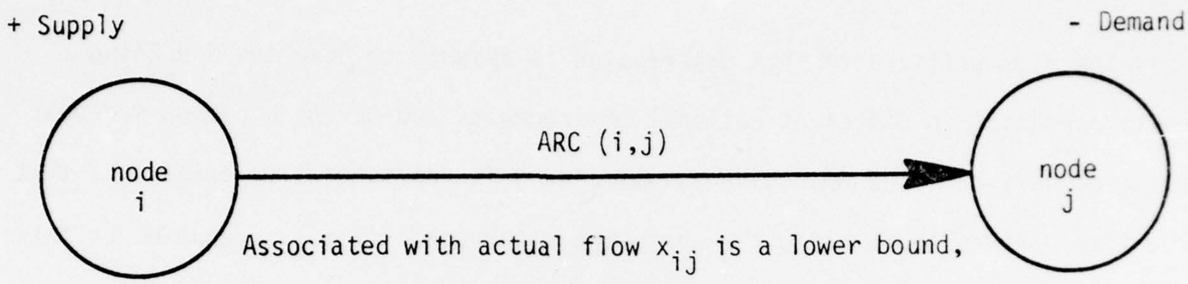
In the next section of the paper, we present a brief overview of the model. Since the major focus of the paper is on the planning process per se -- how large-scale models can be used in the planning process rather than the mathematical specification of model parameters and relationships -- the model description is necessarily restricted to only the critical elements and interrelationships. We then discuss in the context of the Treasury study recent developments in the environment of multinational firms, suggesting policy areas of particular current importance and demonstrating the power and type of information provided by the model. We conclude the paper with a discussion of the characteristics of the modeling process that facilitate implementation in an actual firm and how the model can be used as a policy-making vehicle.

The Planning Model

The firm utilized in this description is assumed to have two operating units operating in different national environments and having a common two-year planning horizon. The objective assumed for this representative example is that the firm desires to maximize the worldwide net revenue (total revenue minus total cost, where required return on equity is explicitly included as a cost) generated by the corporate system. The model structures the production-inventory decision for each subsidiary, intersubsidiary trade credit, transfer pricing, local and international money market investment and borrowing, dividends, royalties, fee payments, direct loans, and changes in internal capital in an intertemporal chance-constrained generalized network context. The uncertainties associated with subsidiary cash generation and exchange and interest rate fluctuations are included as stochastic parameters.

Each possible product or funds flow in the multinational system is modeled as a separate arc. An arc (i,j) connecting the amount of supply at node i (where supply is denoted as a positive quantity) with the demand at node j (where the demand is denoted as a negative quantity), can then be described in terms of five parameters. Defining L_{ij} and U_{ij} as respectively the lower and upper bounds on the amount of flow, x_{ij}, on the arc (i,j) (U_{ij} need not be finite), a multiplier, p_{ij}, is applied to the actual flow leaving node i, and c_{ij} is the unit cost of the flow x_{ij} from node i to node j. These relationships are presented graphically in Figure 1.

One observation is very important. If the objective function coefficient, c_{ij}, is a negative number, the model will want to ship as many units as is feasible over arc (i,j) since the objective is to minimize total costs and



Associated with actual flow x_{ij} is a lower bound, L_{ij}, an upper bound, U_{ij}, an objective function cost, c_{ij}, and a flow magnifier or reducer, p_{ij}.

Figure 1. GRAPHICAL REPRESENTATION OF NETWORK PARAMETERS

negative numbers are smaller than positive numbers. Thus, "costs" such as taxes and interest paid are modeled as positive c_{ij} and revenues such as interest received as a negative c_{ij}.

The model is broken down into three major subsections corresponding to the primary response elements of a multinational firm, with the arcs in each subsection tied together by common nodes. The operations network represents these common nodes and is used to tie the firm into an integrated system. The production subsystem determines the optimum level and mix of production, level of inventory, and sales at each facility in each time period. Production decisions are at least partially based on financial considerations, so an intertemporal financial resource allocation subsystem is incorporated into the model so that the financial links over time between the firm and the worldwide capital markets are specified. The cross-sectional financial resource allocation subsystem is likewise included to permit consideration of internal corporate flows to allocate liquidity and profits in the manner of greatest benefit to the overall corporate system. Of course, these three resource allocation subsystems are mutually interdependent, so the generalized network formulation permits the simultaneous consideration of the interaction of all subsystems to the overall goal of the firm.

The Operations Network

The differences in national factor endowments and economic structures of the various host countries lead to major differences in productivity and operating characteristics for the subsidiaries. Thus, the individual subsidiaries form the heart of the model.

In Figures 2, 3, and 4, it is seen that the three nodes and two arcs drawn with heavier lines are utilized to describe subsidiaries A and B in periods 1 and 2. Normal indenture provisions, standard industry practices and other restrictions will in some cases set minimum requirements for various components of working capital. Lower bounds on the arcs connecting a given subsidiary between two periods in time (labeled with an asterisk in Figure 2) represent the minimum stock of gross working capital that must be maintained to operate the subsidiary. Any funds in excess of this minimum amount can be treated as a residual to allocate among the components of the system in the most efficient manner. Moreover, the upper and lower bounds on each arc in the operations network allow management to store working capital in subsidiaries with favorable market outlooks and strong currencies (a relatively larger lower bound) or restrict the working capital investment in cases of uncertain political situations or weak currencies (a relatively smaller upper bound). The convergence at the master sink, representing the horizon value of the firm's working capital, is a device to insure that each subsidiary maintains an acceptable operating posture at the termination of the model.

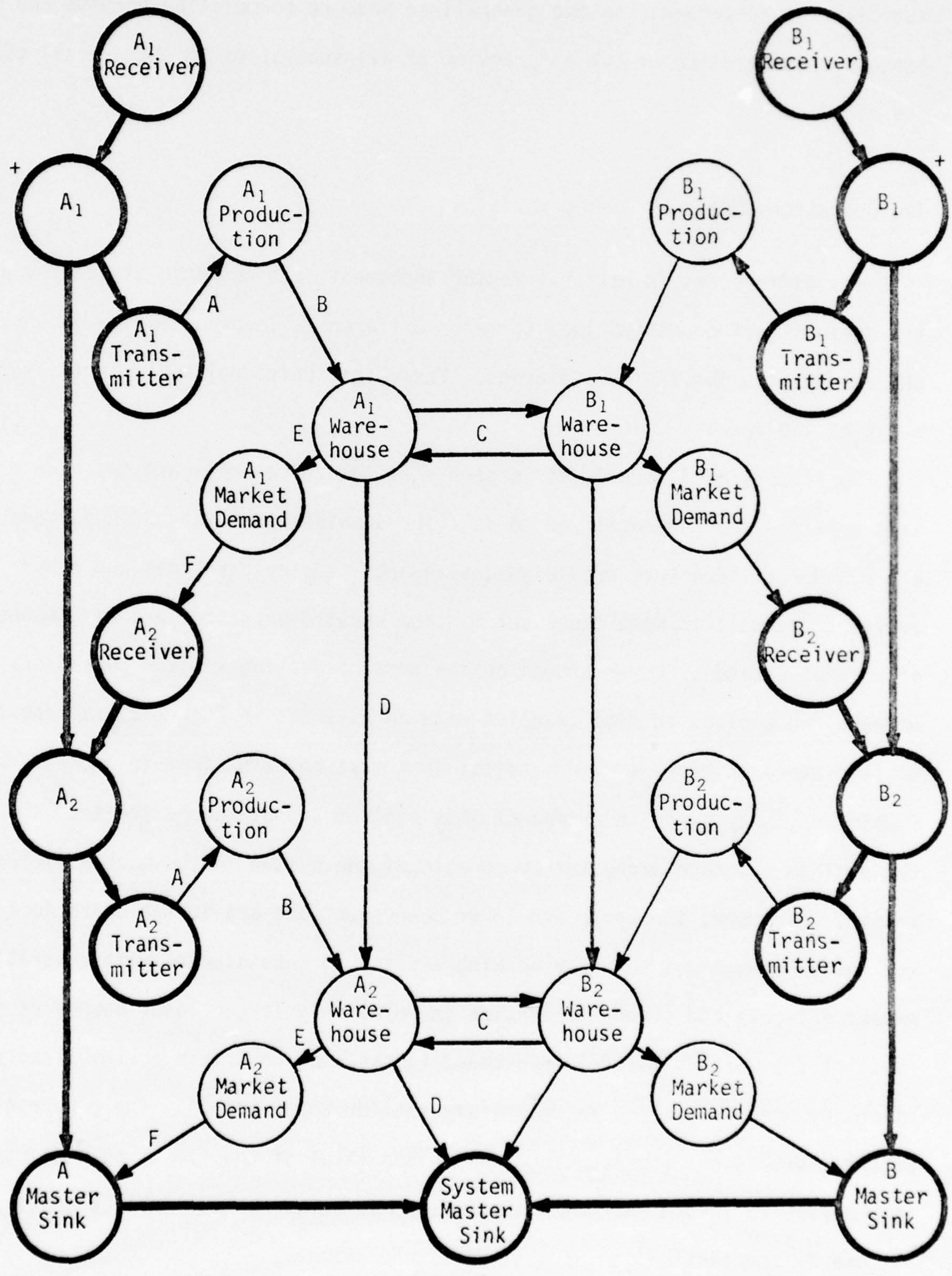


Figure 2. THE PRODUCTION SUBSYSTEM

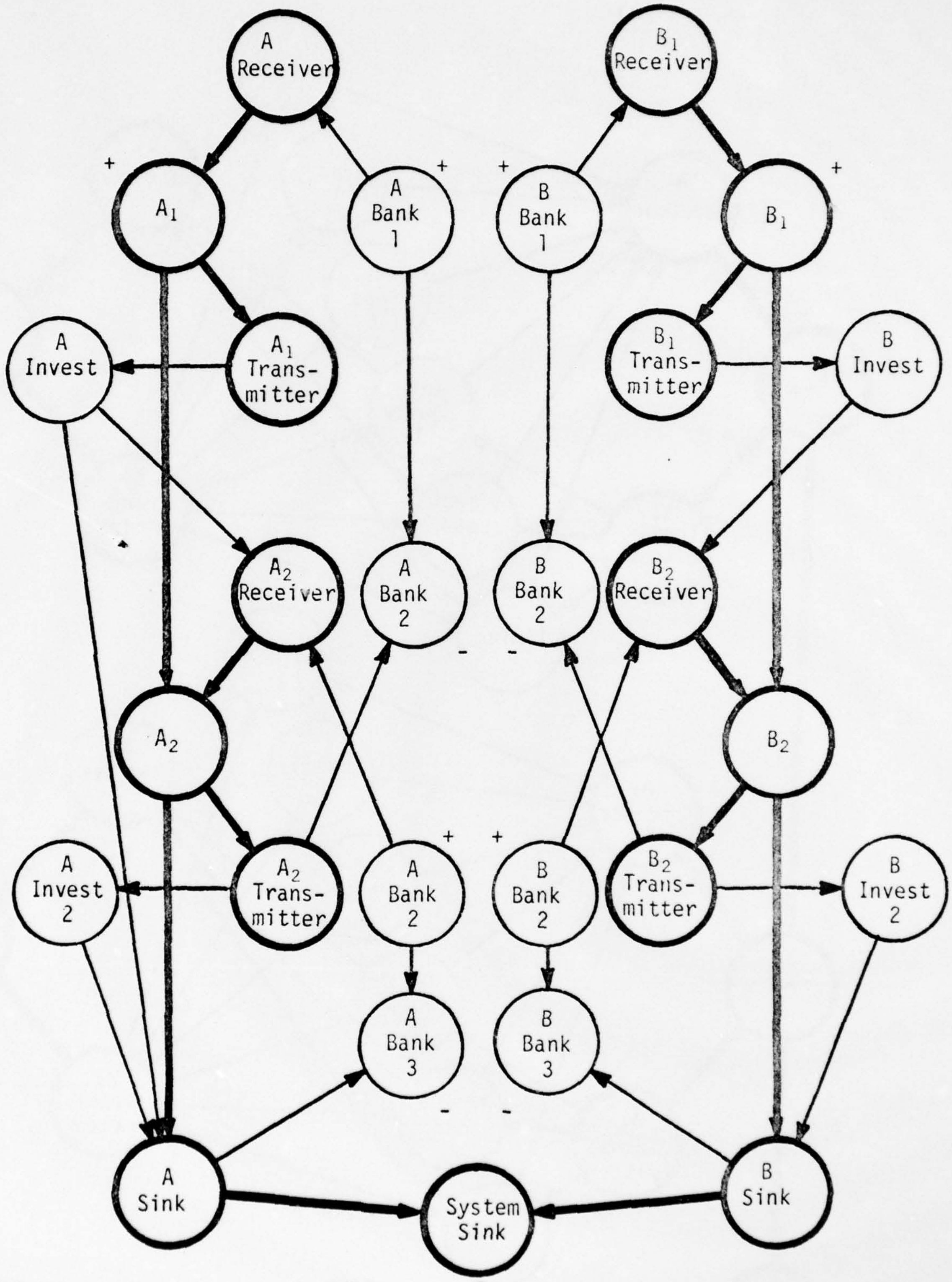


Figure 3. THE INTERTEMPORAL FINANCIAL RESOURCE ALLOCATION SUBSYSTEM

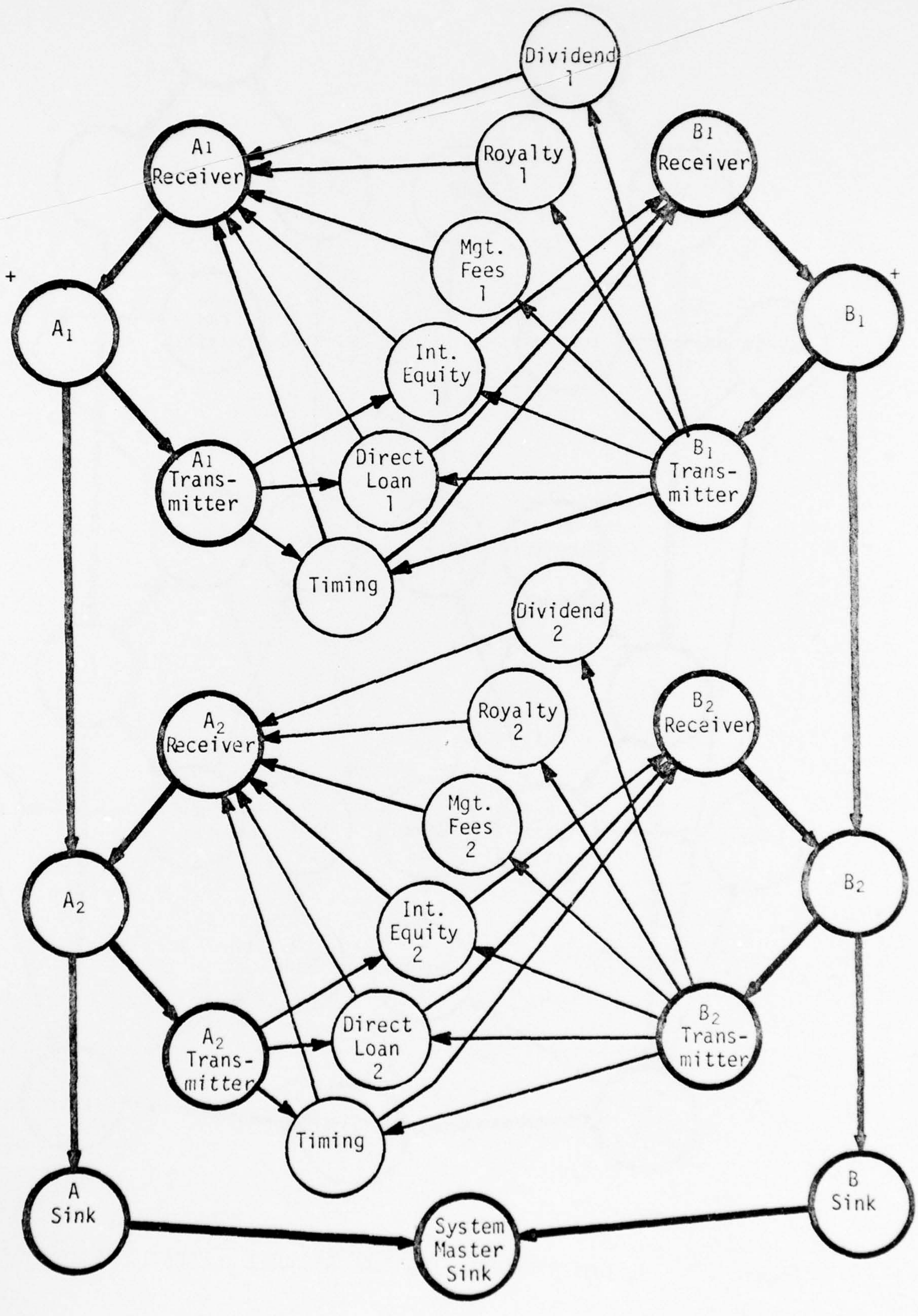


Figure 4. THE CROSS-SECTIONAL FINANCIAL RESOURCE ALLOCATION SUBSYSTEM

The Production Subsystem

One of the major factors influencing the location of corporate subsidiaries is the potential to exploit the factors of production for the benefit of the overall corporate system. Each potential production facility has different structural combinations of factor inputs and product distribution channels. The model must include these considerations so that location of production, level of production at each chosen facility, product distribution channels, and inventory carryover are integrated systematically as functions of market demand in each market segment served, cost of production and distribution, and the alternative opportunity cost of unsatisfied demand.

Production is included in the model in the manner shown in Figure 2. Assume that X dollars are allotted to subsidiary A production by the model. X dollars then flow along the arcs labeled with an A to the subsidiary production node where it has been converted to "product" by the p_{ij} parameter on the arc. A lower bound may be desirable on the A arcs to force a minimum level of production, and an upper bound represents production capacity. c_{ij} is the unit cost of production.

Once cash is transformed into product on the A arcs, it is available for distribution in the various marketing channels to "warehouses" serving different market segments. The arcs labeled with a B in Figure 2 represent the shipment of product from the production site to the home warehouse or distribution site, with the c_{ij} representing the distribution cost. Once at the warehouse, there are three alternatives. The product can be transferred to another market segment (or product from other markets transferred to this market) via the C arcs, it can be held in storage until the next period via the D arcs, or it can be sold in the marketplace via the E arcs. An upper bound is placed on the E arcs to represent maximum anticipated market demand.

There must be a way of introducing profits into the model so that the allocation will be based on profitability. That is, even though for subsidiary i it is profitable to serve market i, the incremental profitability of serving market j, calculated in terms of all costs, may be higher. In this case, market j will be served instead of market i until the marginal profitabilities are equal. Profits, therefore, are tied to the arcs, such that the costs are restated as incremental revenues. The proper cost for the E arcs is the net incremental contribution to the revenue of the firm by satisfying one unit of demand. This revenue is made available for use by the firm by transferring it to the next period subsidiary cash receiver node via the F arcs, where c_{ij} is the average receivable carrying cost.

The production subsystem shown in Figure 2 includes production and labor costs (regular and overtime), distribution costs, marketing costs, shipping costs, and the opportunity cost of unfilled demand. The production level for each product in each subsidiary and the distribution channels chosen are specified by the model, and the major production factors influencing the location decision are included explicitly.

The Intertemporal Financial Resource Allocation Subsystem

The multinational firm has access to worldwide capital markets, so the firm can borrow or lend in many different currencies to take advantage of structural rigidities in the world financial system. This does not mean, however, that the decision to build a factory in a particular country can be made independently of capital market considerations. When combined with techniques to reallocate funds within the system, certain locations may prove to be more advantageous than others. When production considerations are combined with capital market factors, the optimal operating policy may be quite different than if each decision area was considered separately. Thus, outside sources and uses of capital must be included explicitly.

Capital can be obtained from a variety of sources, within the host country and without, and even in countries in which no subsidiaries are located. In Figure 3 the acquisition of debt capital is shown as coming from a "bank" where the term is meant to signify various types of debt capital. The maximum amount of the loan is shown as the supply available at the bank loan node. The time of the loan is one period but is renewable at the end of the period. Demand at the bank repayment node equals principal plus interest due if the line is fully subscribed. A dummy arc connecting the bank loan node to the bank repayment node has p_{ij} equal to one plus the rate of interest so that if the loan is not fully subscribed, demand for repayment will be reduced. The amount repaid in this case will equal the amount actually borrowed plus the accrued interest on that amount. The interest cost is transferred to the objective function via the c_{ij}. Loans of longer maturity could also be included, but are excluded here to simplify the exposition. Likewise, more sources of debt, each with its own characteristics, are available to each subsidiary, but again for simplicity, only one per subsidiary is included.

If, instead of excess demand there is a surplus of cash, the model incorporates elements that represent short-term investments. They are structured as wholly within the local economy, but multiple investment possibilities, some of which are in countries other than the host country, can also be modeled. The investment node collects the excess funds for investment, perhaps adjusted for transactions costs, and determines the maturity structure of the short-term portfolio. Return on the investment is included on the maturity arcs with the cash impact imbedded in the p_{ij} and the revenue impact transferred to the objective function by the c_{ij}. The system is structured as a series of single-period investments, except for subsidiary A which has a two-period option.

The Cross-Sectional Financial Resource Allocation Subsystem

When the multinational corporation is viewed as an integrated system, liquidity can be allocated internally among the subsidiaries to meet the goals of the firm. However, since there are really several entities operating in different host environments and subject to different constraints, there are limitations on the movement of funds within the system. There are six major methods generally available to a multinational corporation for shifting capital internally:

1. shifting funds by dividend payments,
2. shifting funds by royalties,
3. shifting funds by management fees,
4. varying the timing of intrasystem receivables and payables collections, and transfer pricing,
5. extending direct intrasubsidiary loans, and
6. changing the internal equity position.

All six can be represented with the same general structural characteristics, the major differences coming from the interpretation of the cost and flow parameters and the unique constraints attached to each method. Figure 4 contains the network representation of the cross-sectional financial resource allocation subsystem.

Funds can be shifted between elements of the firm in the form of dividends, either by paying dividends and shifting the funds to the owners, or by delaying dividends thus keeping the liquidity in the subsidiary. The model will distribute an aggregate amount of dividends to the owner(s) without regard to the number of shares owned, but in proportion to the relative ownership of each.

Royalties are payments made by a subsidiary to another element of the firm for use of patents, processes, or other technical know-how. Host government agencies watch this channel carefully so that it is not abused. If the host country perceives that contrary to government policy, royalties are being used as a conduit for channeling profits out of the country, restrictions may be forthcoming.

Payment for services rendered, such as the subsidiary's share of centralized management functions, is included in management fees. Thus, it is in some sense similar to royalties and is treated in much the same way by host government officials. When using this device to allocate funds, care must be taken to maintain a justifiable posture, otherwise the payments may be regarded as dividends. Exactly the same procedure and qualifications apply to the modeling of management fees that apply to royalties.

In the situation where there is a physical exchange of merchandise between subsidiaries of a company, alteration of the credit terms by speeding up or retarding the settlement of the accounts and by varying the transfer price can be used to shift liquidity from one subsidiary to another. For example, if there is a desire to concentrate liquidity in subsidiary A at the expense of subsidiary B, A could delay payment of accounts payable to B, and subsidiary B could prepay its payables to A (A's accounts receivable from B), and/or the transfer price from A to B could be increased.

The final two systems by which funds can be shifted internally are through direct loans and changes in the equity investment in subsidiaries. These two systems permit two-way flow between various elements of the firm. Care must be taken in specifying bounds on these flows because of their political sensitivity, particularly in Third-World nations and in countries that are experiencing balance on payments problems.

Planning in the Multinational Environment

For the Treasury analysis mentioned earlier, an interactive two-period planning model of a representative electronics firm consisting of a U. S. holding company with producing subsidiaries in the U. S., France, Mexico, and Taiwan was formulated. Corporate data were drawn from various Commerce Department sources, specialized manufacturers policy manuals, audited financial reports, and other sources of information on this industry. For non-firm specific data such as tax rates, interest rates, exchange rates, tariffs, and transportation costs, sources such as the Federal Reserve, the International Monetary Fund, and the Internal Revenue Code were used. The response of the system to various exchange rates, selling prices, raw materials cost and availability, and interest rates was analyzed.

The model indicates the best financing-marketing-production decisions in terms of funds and product flow patterns for any specified objective function and constraint set. The constraint set is imposed externally by the environment as in the case of economic or governmental requirements, or by management to reflect strategic considerations. Through post optimality analysis or rerunning the model for various constraint configurations, management may analyze the sensitivity of the firm to various environmental scenarios and strategic plans.

The ease in imposing upper and lower bounds on each fund or product flow provides the connector between the strategic and operations dimension of planning. In production, for example, if no limits are placed on the flow of goods among subsidiaries (beyond their capacity limits) or between production and marketing sites, the model will suggest an optimum production-marketing-financing pattern on a centralization basis. If, in a given country, the minister of trade indicates concern over the lack of exports, management can readily determine the marginal cost of satisfying the minister through post-optimality analysis or by imposing a lower bound on the international product flows from that subsidiary. In financing, the bounds may arise from the concern of the minister of finance over local borrowing to replace funds that had been provided by the parent. In marketing, it could be a need to push local facilities to inefficient capacity in order to cut back on imports. These are the kinds of operating decisions that fall within the envelope of multinational centralization and power strategies and which can be investigated with an interactive planning model such as this. The costs of strategically determined soft constraints provide one of the few sources of hard information for strategic-planning.

Other constraints that can be investigated by the model result from negotiations with host country groups, often in conjunction with a governmental agency.

The model's contribution in this case lies in providing cost information for alternate negotiating positions. It can generate the cash flow impact of facilities expansion, long term financing, or any other operating policy.

Liquidity, another strategic decision, is maintained on a firm-wide basis. The ability to cover cash emergencies at one point in the system from far away sources provides an advantage to the multinational firm over its uninational competition. Optimal liquidity positioning depends on the availability and location of operating cash in the system and on governmentally imposed restrictions on funds movements, but it takes an integrated model to sift through the various alternatives.

In each of these examples, the cost impact of an isolated decision or event can be measured. Given the complexity and uncertainty characterizing the multinational environment, a less formal model could not trace these impacts through the interconnecting links. Moreover, in each of these uses, the ability to impute costs -- available only with an optimization model -- is critical. "Simulation" models simply cannot provide this type of information.

A decision that has caused great recent upheaval, and one where the strategic-operations interface is particularly important but difficult to capture, is exchange policy. The problem lies in the unpredictable, sporadic intervention in the exchange markets by central banks, the many alternatives available to the firm for dealing with these varying rates, and the fact that exchange rates in some way touch most of the decisions of a multinational firm.

Multinational firms must *convert* cash from one currency to another to support their operations and periodically *translate* their assets denominated in many currencies into a single reporting currency. Thus, there are two identifiable components to exchange policy: (1) the covering of operating and financing flows in the forward exchange market, and (2) the hedging strategies to offset translation losses.

The decision to cover an anticipated cash flow in the forward exchange market is a risk-return trade-off where management accepts the risk of converting at an unknown future spot rate, or insures against that uncertainty through a forward exchange contract. This insurance may be costless. Where it is not, the multinational firm has the alternative of not moving these funds at all or transmitting them though other channels in addition to covering them in the forward markets. Thus, analysis of a single forward cover decision involves the full cash flow of the firm and can only be done in the context of an integrated model.

The second component of the exchange strategy is hedging. Given a forward cover policy and optimal operating and financing cash flow patterns, management must establish a policy relative to its exposed assets. The requirement for this policy arises from the periodic need to translate the records of the firm into a single reporting currency.

Attention has recently been focused on this issue with the promulgation of Financial Accounting Standards Board (FASB) Bulletin No. 8. Broadly speaking, this bulletin mandates that most current assets (except inventories carried at cost), current liabilities, and fixed liabilities will be translated at current exchange rates. As a currency changes, a firm will experience accounting gains and losses as the translated value of these assets shifts with exchange rates. Under a system of floating exchange rates, the value of currencies, and thus the value of translated current assets, can be expected to fluctuate more than under the old Bretten Woods fixed rate system. A second, perhaps more important, requirement of FASB Bulletin No. 8 is that exchange gains and losses cannot be offset against a reserve.

Thus, the full impact of the exchange variation in balance sheet items is carried to the income statement at the time of translation. In this way, developments in the exchange markets combine with the new accounting standards to magnify the translation exchange impact on the financial reports of multinational firms.

This reporting impact of exchange variation does not necessarily have an *economic* consequence at the time of the translation. In the case of an affiliate's current assets designated in local currency, the only impact of an exchange rate change on the local value of these assets would result from the interaction between the exchange rate and the local economy. The direct exchange impact would not occur until the investment in these assets is eventually removed from the operating cycle and remitted to the parent in some form at an indefinite future time. The exchange rate at that unspecified future point may well have moved in a very different direction -- particularly under a flexible rate system.

Thus, the translation exchange variation (record keeping) impact of an affiliate's activities can be independent of its economic impact, at least in the reporting period. Even though economic theory tells us that it is the economic impact that it important, managers attempt to offset this accounting impact in order to minimize the risk that owners associate with variable reported earnings. In the absence of a systematic planning model, the firm would decrease its cash, non-affiliated receivables, or, in some cases, inventories denominated in currencies that are expected to depreciate. These operating adjustments could well reduce the firm's profitability. For exchange market hedging the firm would take a position in the forward exchange market with the anticipation of liquidating that position at maturity in the spot market. For money market hedging, the firm would enter into a form of uncovered interest arbitrage where funds are borrowed in one currency for investment in another with the repayment converted at the future spot rate. These financial hedging activities generate their own speculative cash flows to offset a potential translation loss that itself is not known at the time the hedging is undertaken.

With the model, hedging decisions are treated on a post-optimality basis. The model measures exposed assets at the end of the planning period when all working capital is translated to the master sink. Management can analyze the impact of an operational hedging policy by changing the boundaries on these end-of-period balances and comparing the systemic economic cost with the change in the distribution of potential reported exchange losses. Analysis of hedging in the financial markets would be conducted outside of the optimization process but from parameters that are available in the model -- interest rates, spot rates, forward rates, and the distribution of future spot rates. The best available hedge would be compared to the distribution of translation losses implied by the model solution.

In all of the tests that we conducted with the model, the overall response of the system supports the hypothesis one would propose from international economic theory, but, the sensitivity of these flows to changes in the firm's environment and the ability of the firm to offset detrimental environmental shifts through adjustment of the product-funds flows pattern was surprising. For example, when the dollar was devalued, return on investment (ROI) increased even though demand was inelastic. When interest rate relationships were changed, the firm shifted its borrowing and investing locations with little overall earnings impact. With demand-pull and cost-push inflation combined with devaluation imposed on the system, the firm, again shifted production levels to maintain profit levels. These sensitivity tests also highlighted the intertemporal connections. The timing of flows was very sensitive to environmental changes. Thus, it is seen that the worldwide corporate system can change its reaction to external events to maintain business as usual, but the ways in which it must react are not obvious. Simply reacting to environmental events on an isolated basis rather than on a systematic basis drastically reduces the profitability of the firm.

The Model-Manager Interface

Up to this point we have described how a mathematical computer optimization model can be used to enhance the planning process of multinational firms. Although described only at a very superficial level, it should be obvious that the model outlined in this paper is quite large and extremely complex. It has long been recognized that the robustness and analytical potential of mathematical programming procedures can be utilized to structure such highly complex decision environments and to ascertain quickly and efficiently the dominant set(s) of actions for achieving an explicit objective(s), but few of these models have fit the management process. In this section of the paper we explore the ramifications of this type of model on the firm. That is, we investigate the reasons why large-scale optimization modeling systems are not often used in the strategic planning process, and show why the Computer Implementation Technology embodied in the model discussed in this paper overcomes these problems.

Our experience, gained from the Treasury study and other applications, indicates that the lack of real-world utilization can be largely attributed to three primary factors. First, most of the models that have appeared in the academic literature are algebraically elegant and extremely complex. The basic difficulty thus became the inability to achieve adequate computational efficiency. This caused companies to surrender to expedient but less than fully satisfactory solution processes of an ad hoc nature such as simulation. Such "quasi-optimizing" approaches, while extensively used today, do not allow valid comparisons between alternative solutions. As input parameters are changed, the user cannot fully predict if differences of the solutions are due to different parameter values or to inability of the model to sift through the multitude of feasible solutions and find an optimal one.

Another obstacle to the use of complex algebraic models, gleaned from 20-20 hindsight, stems from the fact that solutions of such models are merely a numbers in/numbers out game which tells *what* but not *why*. That is, regardless of the complexity of the models employed, their solution can only be used to gain insights about the decisions to be made and not to provide "the answer". The "answer" (decision) must be made by an individual, possibly aided by insights gleaned from using the model. Unfortunately, solving a model once does not provide adequate insight on how a system responds to environmental changes. To garner such insights, the model must be iteratively solved using a systematically developed sequence of strategic reaction scenarios. Once these scenarios have been solved, then insights can be acquired. But these insights must be coaxed out by a laborious synthesis of the solutions blended with experience of the analyst.

The third factor hindering the use of large-scale optimization planning models is behavioral. Before a decision maker can be expected to utilize a mathematical model, it must reflect the essence of the decision process *as he views it*, and he must understand the underlying relationships. Managers are distrustful of solutions that from come a "black box." This means that the decision maker should participate in designing and/or implementing any model; but since models usually involve a series of mathematical equations to specify the desired relationships and most managers are not trained (or inclined) to think in terms of equations, there are communication problems between the model builders and users. All too often this leads to models that the manager does not understand or appreciate and which do not reflect the necessary elements of the decision process.

It has been our experience, based upon numerous successful applications of network related models, that the combination of NETFORM representations and network computer implementation technology can effectively neutralize these three problems in most cases. Once an individual learns to visualize problems in network-related frameworks, the initial "recognition" of many problems is made far easier. This change of orientation by which problems are directly visualized and represented as NETFORMS has highly beneficial effects along several dimensions. First, management scientists are able to use these NETFORMS to explain their models to managers more effectively. Second, the non-scientific user can be more easily taught how to formulate his problem via diagrams and pictorial representations. The ambient effects of these advantages make it possible for management scientists and managers to interact more fully, thereby leading to clearer mutual understanding of the problem formulation and of the potential insights which could be attained from using the model. Third, network-related formulations are often amenable to solution by algorithms which utilize graph operations in place of algebraic operations. These algorithms are at least fifty times faster than state-of-the-art commercial linear programming codes.

Thus, the computer implementation technology and NETFORM representations that are utilized in this multinational strategic planning model overcome these problems and make the potential for implementation in an actual firm quite high. With an interactive computer system coupled to an efficient problem generator and report writer, playing the "what if?" game suggested in this paper should be easy and efficient. Our experience indicates that this type of *interactive NETFORM planning system* has far fewer implementation problems and much higher management acceptance and confidence than other optimization and even simulation systems.

References

1. Analysis Research, and Computation, Inc., "Large Scale Models of Multinational Companies," ARC Technical Report, P. O. Box 4067, Austin, Texas 78765.

2. R. Barr, F. Glover, and D. Klingman, "Enhancements of Spanning Tree Labeling Procedures for Network Optimization," Research Report CCS 262, Center for Cybernetic Studies, The University of Texas at Austin, 1976.

3. R. Barr, F. Glover, and D. Klingman, "The Alternating Basis Algorithm for Assignment Problems," Research Report CCS 263, Center for Cybernetic Studies, The University of Texas at Austin, 1977.

4. G. Bradley, G. Brown, and G. Graves, "Design and Implementation of Large Scale Primal Transshipment Algorithms," Technical Report NPS55BZBW76091, Naval Postgraduate School, Monterey, California, 1976.

5. A. Charnes, and W. Cooper, *Management Models and Industrial Applications of Linear Programming*, Vols. I and II, Wiley, New York, 1961.

6. R. Crum, "Cash Management in the Multinational Firm: A Constrained Generalized Network Approach," Working Paper, The University of Florida, Gainesville, Florida, 1976.

7. R. Crum, and L. Tavis, "The Multinational Dimension of Short-Term Funds Management," Presented at the 1975 Conference on Working Capital Management in Advanced Technological Societies, University of Illinois.

8. J. Gilsinn and C. Witzgall, "A Performance Comparison of Labeling Algorithms for Calculating Shortest Path Trees," NBS Technical Note 772, U. S. Department of Commerce, 1973.

9. F. Glover, J. Hultz, and D. Klingman, "Improved Computer-Based Planning Techniques," Research Report CCS 283, Center for Cybernetic Studies, The University of Texas at Austin, 1977.

10. F. Glover, J. Hultz, D. Klingman, and J. Stutz, "A New Computer-Based Planning Tool," Research Report CCS 258, Center for Cybernetic Studies, The University of Texas at Austin, 1976.

11. F. Glover, D. Karney, and D. Klingman, "The Augmented Predecessor Index Method for Locating Stepping Stone Paths and Assigning Dual Prices in Distribution Problems," *Transportation Science*, 6, 2, (1972), 171-179.

12. F. Glover, D. Karney, and D. Klingman, "Implementation and Computational Study on Start Procedures and Basis Change Criteria for a Primal Network Code," *Networks*, 4, 3, (1974), 191-212.

13. F. Glover, and D. Klingman, "Network Applications in Industry and Government," Research Report CCS 247, Center for Cybernetic Studies, The University of Texas at Austin, 1975.

14. F. Glover, D. Klingman, and C. McMillan, "The NETFORM Concept," Research Report CCS 281, Center for Cybernetic Studies, The University of Texas at Austin, 1975.

15. F. Glover, D. Klingman, and J. Stutz, "The Augmented Threaded Index Method for Network Optimization," *INFOR*, 12, 3, (1974), 293-298.

16. F. Glover, and J. Mulvey, "Equivalence of the 0-1 Integer Programming Problem to Discrete Generalized and Pure Networks," MSRS 75-19, University of Colorado, Boulder, Colorado, 1975.

17. R. Helgason, J. Kennington, and H. Lall, "Primal Simplex Network Codes: State-of-the-Art Implementation Technology," Technical Report IEOR 76014, Department of Industrial Engineering, and Operations Research, Southern Methodist University, Dallas, Texas, 1976.

18. S. Robbins, and R. Stobaugh, *Money in the Multinational Enterprise*, Basic Books, Inc., New York, 1973.

19. D. Rutenberg, "Maneuvering Liquid Assets in a Multinational Company: Formulation and Deterministic Solution Procedures," *Management Science*, Vol. V, No. 10, June 1970, B-671 - B-684.

20. V. Srinivasan and G. Thompson, "Accelerated Algorithms for Labeling and Relabeling of Trees with Applications for Distribution Problems," *JACM*, 19, 4, (1972), 721-726.

21. L. Tavis, R. Crum, and D. Klingman, "Implementation of Large-Scale Financial Planning Models: Solution Efficient Transformations," Research

Report CCS 267, Center for Cybernetic Studies, The University of Texas at Austin, 1976.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Center for Cybernetic Studies The University of Texas	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Planning in the Multinational Firm: The Strategic Operations Interface

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research rept.

5. AUTHOR(S) (First name, middle initial, last name)

R. L. Crum
D. Klingman
L. A. Tavis

33p.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1977	28	21

8a. CONTRACT OR GRANT NO. N00014-75-C-0569, 0616 and OASIA 705-75-29 b. PROJECT NO. NR047-021 c. N00014-75-C-0616 d.	9a. ORIGINATOR'S REPORT NUMBER(S) Center for Cybernetic Studies Research Report CCS-286 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Naval Research (Code 434) Washington, D.C.

13. ABSTRACT

Great environmental uncertainties have increased the importance of formal planning structures to assist multinational firms in adapting to a rapidly changing world. It is our belief that the type of information needed by multinational planners can best be obtained when strategies are superimposed on the operating system of the firm. In the past, fully integrated optimization planning structures were infeasible because of the enormous complexity of multinational companies resulting in extremely large models and very slow solution time -- if a solution could be obtained at all. This has led to non-optimization simulation modeling which provides some but not enough relevant information. With Computer Implementation Technology and NETFORM representations, a move to optimization procedures is feasible and desirable. The power of these procedures over simulation models is demonstrated in an application for the U. S. Treasury, where we show how the model can lend insight into important planning issues and develop hard cost information for soft constraints.

DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0101-807-6811

406197

Unclassified
Security Classification

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Networks						
Generalized Networks						
Financial Planning Model						
Corporate Planning						
Multinational Firm						