CORPORATE PLANNING MODELS: WHAT LEVEL OF ABSTRACTION?

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1. Overview

This paper considers the problem of appropriate design for a corporate planning model. Two models are described which illustrate the range of choice available concerning level of detail. The first, an accounting level model, is simple to develop but may not be responsive to the changing environment in which most companies operate. Thus, it may have limited predictive capability. The second, an operating level model, while capable of validly representing the company operations, may be overly difficult and expensive to develop, maintain and use.

2. Statement of the Problem

A large number of firms are considering, in the process of developing, or have implemented corporate planning models as an aid to financial decision making. The development of a corporate financial planning model is often the first application of management science techniques to a company's financial function. Its success is, therefore, critical.

The level of abstraction of such a model is an important design alternative. The selection of the level of abstraction should be guided by the intended purpose of the model and the results expected from it. Too often, the task of developing a corporate financial planning model, becomes a primary goal. The problems with which management is concerned are overlooked.

Additionally, the resources available and the needs for validity must be considered. If too much detail is represented in the model, the cost of development and validation may be excessive. To the extent there is too little, the model may not validly represent the changing environment facing the financial executive. Thus, it is important to discuss the relative merits of the available alternatives and this is the purpose of this paper.

3. What Is a Corporate Financial Planning Model and Its Purpose

First, in order to provide a common basis for our discussion, we briefly define what we mean by a corporate financial planning model. "A model is a simplified representation of a system." Models are constructed and used in order to make inferences about the system. They, unlike the system, can be easily manipulated in order to study changes in the operation of the system which result from changes to its inputs.

Many types of systems can be modeled. They range from the total operation of an economy to a department within a small company, from the circulatory system within the human body to a diagram of the fire exits of an airplane.

More specifically, a corporate financial planning model is a representation of a company's operations. It permits an executive to modify inputs and other parameters which describe the company in order to estimate the effect of these modifications on the company's performance. The outputs are usually expressed in terms of familiar financial statements and operating statistics.

We have defined two levels at which the abstraction of a financial planning model can be measured. These are called

(a) the accounting level
(b) the operating level.

Accounting level models are most often designed to aid in solving two major problems. The first problem is the task of developing a profit plan or a budget on a regular basis (e.g. annual cycle). In large diversified, divisionalized companies, the difficulties involved in piecing together the highly detailed plans of dozens or even hundreds of planning units can be extreme. The needs of the corporate parent to have simplified consolidated financial summaries for "planning" purposes is increasingly being met by accounting type models. In truth, these models act more as information compilers. They can consolidate, aggregate and simplify the task of obtaining useful information. They are also extremely valuable in instituting and maintaining control in the profit planning or budgeting process.

One large U.S. paper company which has developed such a model is comprised of many divisions each with a detailed budgeting system. The data output was so voluminous that the real information content of the system was hidden. The financial planning model they developed aggregated and consolidated the inputs and resulted in meaningful financial planning information at the divisional and company level. The computerized system furthermore provided for input and change of statistics only on an authorized basis. Control of the profit planning process was achieved.

The second problem area for the application of accounting models is in developing tools to meet the needs of "planning" in a more real sense. Planning

is the process of defining, evaluating and selecting alternatives. The model-compiler described above provides little help in this process since it relies on manual techniques for developing and relating information. This is tedious, time-consuming and subject to errors.

Simple mathematical models, on the other hand, can be highly useful. At the accounting level, mathematical models relate aggregated categories of variable costs or other accounts to explanatory variables, dollar sales; for example. Fixed costs may be described as a function of the length of the accounting period. The result is a model of a financial statement responsive to changes in the explanatory variables. The critical point to be made is that the effort in preparing the final impact of an alternative is greatly reduced. The manager as the real planner in any business can define the relatively few parameters required. The parameters are, in fact, among the key statistics he uses in running his business. With the time-consuming drudgery removed from the task of preparing plans, the manager is able to review many diverse alternatives.

Models constructed at the operating level are generally more complex than the two kinds of accounting level models just discussed. Operating level models represent and integrate the firm's physical operations as well as its accounting procedures. The practical differences in accounting level and operating level models are in terms of the detail in which the production, distribution and marketing functions are represented. The most important difference is that operating level models are models of cause and not effect. Changes in operations are reflected more faithfully.

Operating level models are difficult to categorize. They may be developed using simulation or mathematical programming. They may incorporate time intervals of one month, one week, one day, or one hour. They may describe at the lowest level individual physical operations in a plant or the plant as a whole. However, again, the most important consideration is the purpose for which the model is to be developed.

Two uses of models of the operating level variety can be distinguished. The first use is in aiding and making operating decisions. The second use is concerned with strategic management planning. Illustrative of such a model is an enterprise simulation model of a meat packing firm. The model represents the facilities and activities associated with beef slaughtering operations. Pork, lamb, veal, by-product and feed lot operations are also included. Live animals are classified by weights and grades. Production facilities are characterized in terms of the number of animals per hour, the type of operations performed and payroll cost in dollars per day, etc. Processing operations are identified as: primal, boning, data pack, pretendering, etc. By-product yields and cut-out data are expressed in the form of yield tables which indicate the percentage of live weight going into each product. The average cost associated with each processing operation is also represented. Unpredictable variations, for example, in grades, yields and prices are represented in the form of chance variation based on random numbers.

Investigative use of the model under alternative assumed or real conditions of live animal availability and prices and product demand and prices offers a means of evaluating operating strategies and general policies. Allocation of production in plant scheduling is one need served by the model.

The determination of suitable live buying policies for specified conditions is also an important usage. Transportation policies can be developed. The model is also useful in defining and establishing reliable values for critical parameters against which plant performance can be measured.

The use of such a model for strategic management planning is more concerned with identifying preferred alternatives. The implication of closing down a plant can be evaluated. Capital resource allocation can be investigated perhaps resulting in three to five year investment commitment plans. The impact of newly available or hypothetical technology can be evaluated. Acquisition candidates can be evaluated in heretofore uncommon ways. For example, evaluation may be accomplished in terms of the effect of new distribution logistics required by the acquisition.

The two sections which follow describe and discuss in greater detail an accounting level model and an operating level model.

4. Accounting Level Models

Corporate financial planning models which represent a company's operations at the accounting level are discussed in this section. Although the reader is probably most familiar with this type of model we briefly illustrate its essential feature with the following example:

A major diversified corporation has undertaken the development of a comprehensive financial planning model system. The modeling system approach was selected for its ability to consider many alternatives in a short span of time. While planning had previously been emphasized throughout the company, in reality planning consisted of preparing the financial results of the first set of assumptions formulated. From the corporate financial viewpoint this was considered inadequate.

The model system is comprised of many separate and distinct pieces of logic. Each of them is required to model different business areas and their individual components. The following description is of only one piece of the Fresh Meats Division logic.

The model was designed to incorporate the existing manual planning procedures into the logic. The same basic logic was replicated and used to project Income Statements for each department within a plant, e.g. beef, pork, lamb.

The basic input factors required for each plant department i and each time period j were as follows:

Average weight per animal ($AVEWT_{ij}$)
Head slaughtered ($HEAD_{ij}$)
Realization or gross income per cwt. (GI_{ij})
Live price ($PRICE_{ij}$)

The income model projects the Income Statements for each monthly period by applying variable an and fixed cost factors. Variable cost factors were comprised of the following categories:

Raw material ($PRICE_{ij}$)
Labor and burden ($LABOR_{ij}$)
Other direct exp. ($OTHER_{ij}$)

Total variable cost was, therefore

$$TVC_{ij} = AVEWT_{ij} * HEAD_{ij} * (PRICE_{ij} + LABOR_{ij} + OTHER_{ij})$$

Fixed expense factors were comprised of the following categories:

Local overhead ($LOCAL_i$)
Depreciation ($DEPREC_i$)
Local buying expenses (BUY_i)
Corporate overhead ($CORP_i$)
Interest ($INTR_i$)

Each of the fixed expense factors were expressed as weekly rates. The number of weeks per month was explicitly represented in fixed cost calculations as ($WEEKS_j$).

Total fixed cost was, therefore

$$TFC_{ij} = WEEKS * (LOCAL_i + DEPREC_i + BUY_i + CORP_i + INTR_i)$$

Net income is calculated as total shipments less variable and fixed costs as follows:

$$NET\ INCOME_{ij} = HEAD_{ij} * (PRICE_{ij} * AVEWT_{ij} + GI_{ij}) - TVC_{ij} - TFC_{ij}$$

Income projections for plant departments were made in the past on the basis of head throughput and "realization". The income projections made in this manner on a manual basis were not used to make operational or even strategic decisions by plant department management. They were used primarily as a control tool. In model form, however, and in conjunction with each of the models (income and asset models) for all of the other divisions, strategic decisions are facilitated at the corporate level.

The resulting income and asset projections are highly useful in determining amounts and timing of cash flows, corporate financing needs of divisions, and corporate capital capacity for capital expenditure programs.

The model just described consisted of relationships which express values for independent variables in terms of dependent variables. In general, the types of relationships which need to be developed for such a model would be of three types. These are:

a. Definitional Relationships

These relationships arise from accounting conventions or physical identities. An example might be the relation between a tax provision and income. Income under $25,000 per year is taxed at 22%, while income over $25,000 per year is taxed at 48%. Thus, the relationship between tax provision and income is expressed as illustrated below. In practice, of course, the relationship is not nearly so simple.

$$TAX\ PROVISION = \begin{cases} .22*INCOME, & \text{IF INCOME} < 25,000 \\ 5500 + .48*(INCOME - 25000), & \text{IF INCOME} \geq 25,000 \end{cases}$$

Definitional relationships are usually easy to develop and, in many cases, require little or no data analysis.

b. Empirical Relationships

Empirical relationships are based on the use of historical data to describe the past correspondence between two or more variables. An example is the relationship between raw material costs and sales. If, on the basis of past data, raw material costs are consistently about 40% of sales for a particular organizational unit, the formula

$$RMCOST = .40 * SALES$$

would be an example of an empirical relationship. These types of relationships often require statistical analysis to ascertain the numerical parameters involved.

The use and development of empirical relationships involves two special difficulties. First, the historical data which is available may not be descriptive of current or future relationships. That is, the correspondence between the variables may reflect modes of operation no longer current. This could be reflected in either a change in the numerical parameters which measure the degree of the relationship or in the structure and nature of the relationship itself. The second difficulty with empirical relationships is that the method of operation to which the data corresponds may represent low standards of performance. In such cases, the model will produce plans which do not encourage improved performance nor reflect the results possible from better management control. For reasons we discuss later, both of these types of difficulties can often be avoided with models at the operating level.

c. Normative Relationships

The third type of relationships are normative. in the sense that they express how variables should interrelate rather than how they have been related in the past. They generally result from management performance standards, e.g. top management may insist inventories be less than five days sales. They may, however, also result from empirical analysis. For example, assume the historical data describing the relationship between inventory and sales in several organizational units is no longer valid. How then should the model relate sales to inventory? By examining data for all units we may discover that the ratio of inventory to sales is "explained" by the purchase lead time. Such a relation is exhibited in Figure 1. The observed relationship can then be used for those units where the data are not valid. This is done by estimating the purchase lead time and determining the resultant ratio of inventory to sales.

Let us next discuss the relative advantages and disadvantages of accounting level models. First, the advantages.

a. Accounting level models can often utilize existing and available software systems. These systems permit either time sharing or batch mode use at service bureaus or on the user's machine. The systems usually provide a capability for file creation, maintenance, editing, consolidation, information retrieval and report preparation. Some of the systems also have a modeling capability or user constructed FORTRAN routines can be easily integrated.

b. Accounting level models are easy to construct. Their short calendar time and low development are important advantages to companies not willing or able to commit themselves to major efforts.

c. Finally, accounting level models are

easy to "sell". The financial executive can understand the model and verify its validity. As a result, he is more apt to accept and use it.

On the other hand, accounting level models possess certain disadvantages. Among these are:

a. The relationships built into the model, because they do not model the physical operations, may become obsolete if there are changes to the company's way of operation. This is especially true for growing companies in a changing environment. We call this effect the Chinese baseball syndrome. The game of Chinese baseball is identical in almost all respects to the American game of baseball. There are nine players on each side, three outs to an inning, four balls and three strikes to a batter, and so forth. There is only one difference. After the ball leaves the pitcher's hand and before it reaches the catcher's glove, the team in the field can move the bases to wherever they desire. The analogy to planning models is a simple one. Often, while the model is being built and afterwards, the physical operations of the company are changed, i.e. the bases are moved on the model builder. A model which does not represent directly physical operations can lead to errors. As an example, consider a firm which has 80 regional warehouses. If these are cut to 32 the relationships which estimate distribution costs will be wrong. If the model was at the operating level, i.e. the distribution system was being simulated, the input data could be adjusted and the model would remain valid.

b. In many instances the empirical relationships which form the elements of an accounting level model lead to extrapolations of trends which are inappropriate. In other words, the magnitude of future data may be outside of that available historically. This is especially worrisome when linear relations have been used.

c. A final disadvantage is that accounting level models may lead to inproper planning. This is because of their simplistic, deterministic nature. Consider the following example. Assume a company has

Production capacity = 100 units/week
Demand - 400 units/four weeks

An accounting level model which considers a four week time period and plans capital expenditures based on the need to meet increases in demand would miss the point of a model which is more detailed in considering the operating environment. The numbers below illustrate why this would be the case.

Production capacity per four weeks = 400 units
Demand per four weeks = 400
Capacity needed = 0
Inventory cost = 0
Lost sales = 0

With the four week time period the ups and downs of demand are washed out. As a result, it appears there are no holding or penalty costs and capacity is balanced with demand. As a result, new investment would not yield financial returns to the company. With a weekly time period, however, the following may occur.

	Week				
	1	2	3	4	Total
Production	100	100	100	100	400
Demand	80	130	90	110	400
Inventory	20	0	10	0	30
Lost Sales	0	10	0	0	10

Here we see demand sometimes exceeds capacity. As a result inventories must be accumulated to meet peaks and, when they are insufficient, lost sales accur. The result: there would be a return to increased plant investment.

5. Operating Level Models

An operating level model represents more completely the operations of a company than is the case with an accounting level model. They generally involve the use of operations research and other similar techniques to simulate or optimize the manufacturing and distribution activities which lead to the accounting results. We present an example of this type of model in order to show how it encompasses more detail than is the case with an accounting level model. Figure 2 describes a study recently completed by MATHEMATICA which involved the initial development of this type of corporate model. Think of the compnay as a multinational producer of automobiles. The real company, the name of which we will not mention, was not in the automobile industry.

Each major product group of the company is represented by a linear programming model. Examples of the product groups might be Chrysler cars, Dodge cars, Plymouth cars, and so forth. There is some interaction between each, especially in major component production but these interactions were relatively minor and treated after the linear program solutions as illustrated in Figure 2.

The programming models were used to determine monthly component production levels, the sourcing pattern of components to assembly plants, the production levels at the plants and the supply patterns for plants to sales areas. Figure 3 illustrates these flows.

Each product group linear programming model determines a production plan which satisfies capacity and demand constraints and minimizes the total variable costs of production and distribution. The details are summarized below.

DIMENSIONS:

- o T = time
- o I = finished products
- o A = major components
- o K = sales areas
- o J = assembly plants
- o S = component sources

DECISION VARIABLES:

- o Component purchase or production and shipping quantities (ASJT)
- o Finished product assembly quantities (IJKT)
- o Finished product shipping quantities (IJKT)
- o In-process component inventories (AJT)

- o Assembly plant finished product inventories (IJKT)
- o Finished product inventories (IKT)
- o Unsatisfied demand (IKT)

OBJECTIVE FUNCTION:

- o Revenue
- o Finished product assembly and shipping costs
- o Component production and shipping costs
- o Taxes and rebates
- o Inventory costs
- o Administrative costs

CONSTRAINTS:

- o Minimum production levels for each plant
- o Maximum capacity at each plant
- o Product sub-groups maximum capacity
- o Breakpoints in administrative costs
- o Product assembly ratios
- o Component source capacities
- o Unsatisfied demand maximums
- o Finished product inventory balance at assembly plants
- o Finished product inventory balance at sales areas
- o Component inventory balance
- o Inventory limits

When production plans are obtained for each product group they are adjusted for interaction. Only final products such as engines, axles, transmissions, and so forth are considered in the linear programming models. To obtain a further breakdown in production items the major component flows are broken down into secondary component flows. This is the purpose of the explosion boxes shown in Figure 2. For example, a transmission is broken down into housings, gears and so forth.

Production and purchase timing considerations are taken cognizance of throughout the computation. For example, the linear programming model considers that a demand in the twelfth month in sales area X must be satisfied out of production shipped in month 9 and its components in month 7. Once the timing of production and shipping is known, it is possible to develop algebraic models at an accounting level which determine costs of goods sold, freight in, freight out, etc. and measure the cash flow implications of the production and distribution plan. From this pro forma financial statements can be produced.

The model has been used to provide evaluations of several important management strategy alternatives. In particular, it has considered problems related to (a) the production and financial implications of closing down a plant, (b) the impact of a substantially higher share of market in several sales areas and, (c) measurement of the effect on operating plans of the United Kingdom's entry into the European Economic Community (Common Market). In each case results were compared to a base case run. The output reports were those familiar to both production and financial executives of the company.

Finally, let us compare the advantages and disadvantages of this type of model to the accounting level model previously discussed. First, consider the advantages.

a. Operating level models permit the user to represent greater detail in terms of time, products, facilities and so forth. They are models of cause rather than effect. As a result operating models are more sensitive to changes in operating practice and, therefore, less susceptiable to the Chinese baseball syndrome.

b. Operating level models are useful for a greater variety of management applications than is the case with accounting level models. For example, assume a capital expenditure program involving several millions of dollars is proposed. The program would lead to increased capacities and efficiencies in the production of certain products. Financial management must estimate the associated return on investment. With an operating level model the user needs as inputs the new capacities and operating costs. The model will compute production levels, distribution patterns, etc. New estimates of costs of goods sold would be generated and return on investment computed. With an accounting level model the impact of the new investment on operating costs would have to be calculated outside the model - often difficult if not impossible to do.

c. In many cases the data requirements of operating level models are easy to obtain. For example, an input to an operating level model may be a table of transportation rates based on cwt. shipped from each plant to each distribution center. These data are published tariffs and easily available. An accounting level model, on the other hand, would need the average cost of distribution between locations. Such data may not exist within the company and would need to be synthesized from accounting records.

d. Finally, operating level models do an excellent job of integrating the manufacturing, distribution, marketing and finance functions within the company since these activities are directly represented. Thus, the developed system is more truly able to do corporate, as opposed to financial, planning.

On the other hand, there are several serious disadvantages of operating level models. We next mention these.

a. Operating level models are cumbersome. They require large amounts of input data (the shipping costs example mentioned above is illustrative) and computer run times are generally longer than with accounting level models. As a result of the need to maintain or create a large data bank and to have available a large computer budget the model may not be used as much, if at all.

b. Operating level models are expensive and difficult to develop. The types of relations and calculations performed are significantly more complicated than the three types of relationships (definitional, empirical and normative) discussed for accounting level models. This causes the development time to be longer and requires skills in operations research which may not be available or are expensive to acquire.

c. Finally, operating level models are less likely to succeed. This is a result, to a large extent, of the issues discussed above. They are larger and more difficult technically. As a result the risks are greater.

6. Summary

The preceding discussion has identified two levels of abstraction appropriate to the design of corporate financial planning models. Models which

illustrate each level have been presented and their relative advantages and disadvantages discussed. In practice a model will generally incorporate both extremes. All models will contain accounting type relations and important subparts will, at least to some extent, model physical operations. It is hoped that this paper has provided the reader with greater insight into why and when the additional detail of an operating level representation is needed.

USING EMPIRICAL DATA TO DEFINE NORMATIVE RELATIONSHIPS

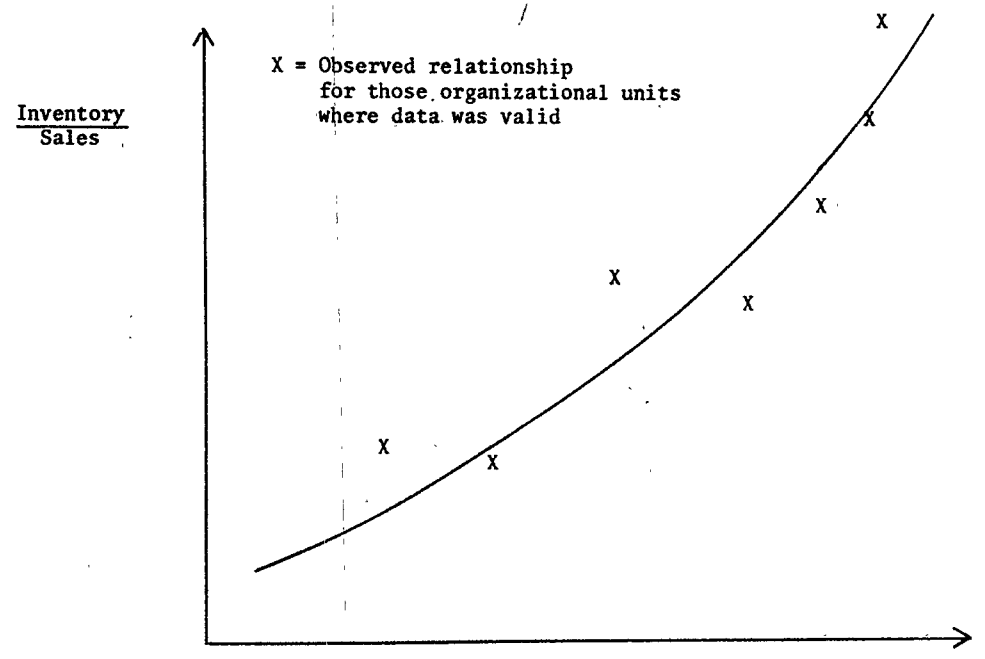

Figure 1

LOGICAL OVERVIEW OF AN OPERATING LEVEL MODEL

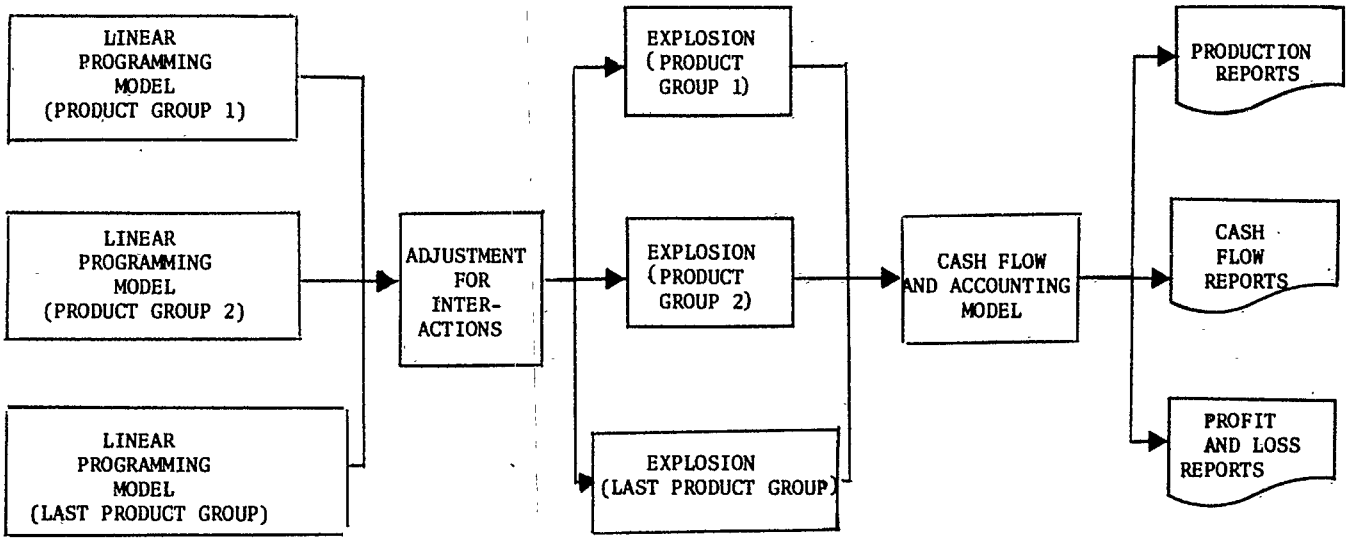

Figure 2

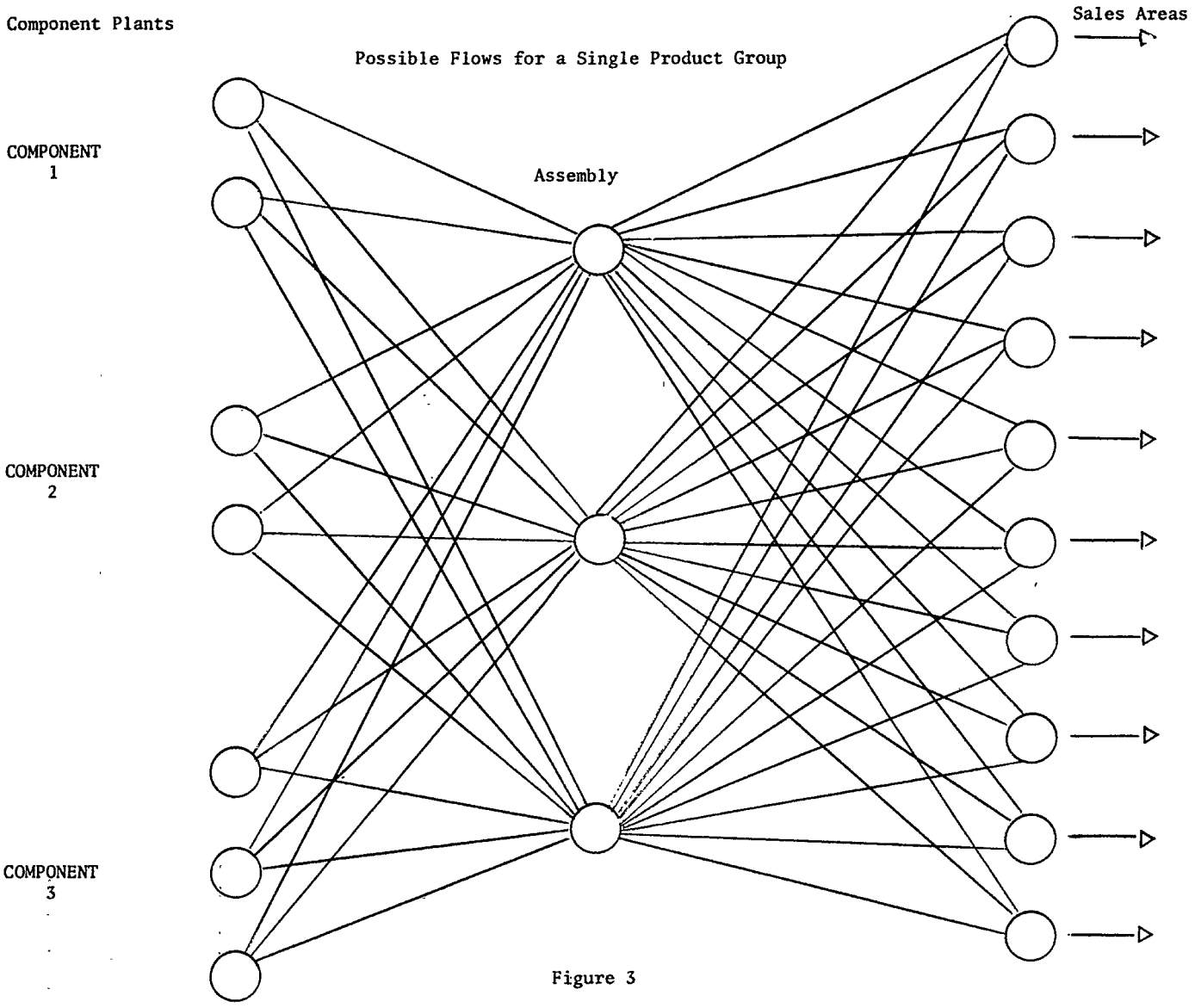
Component Plants
Possible Flows for a Single Product Group
Sales Areas
COMPONENT 1
Assembly
COMPONENT 2
COMPONENT 3

Figure 3