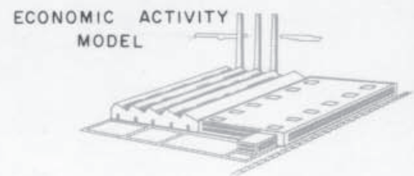
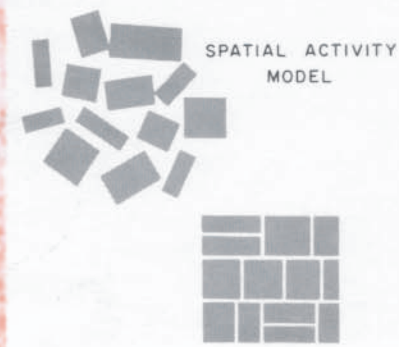
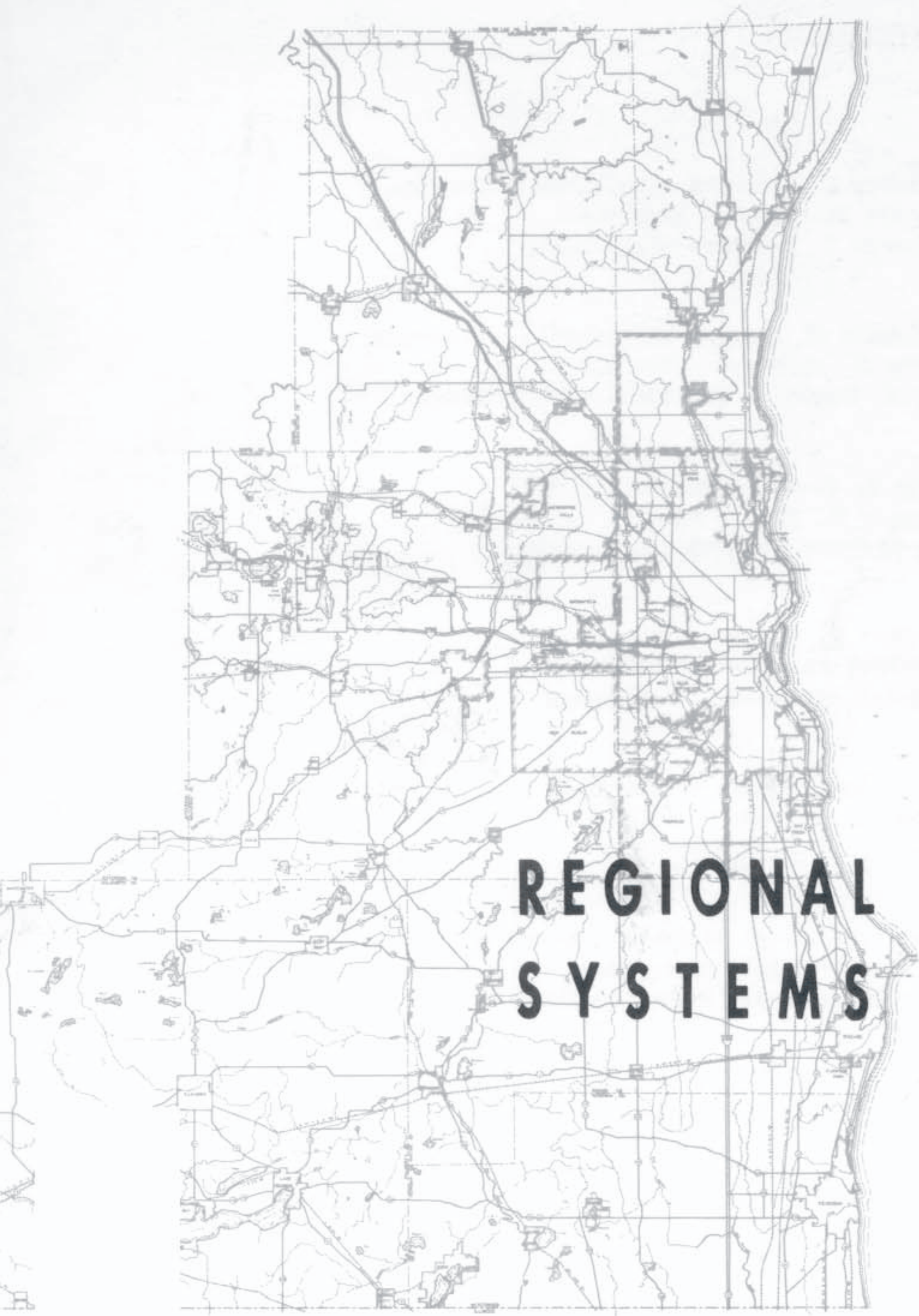
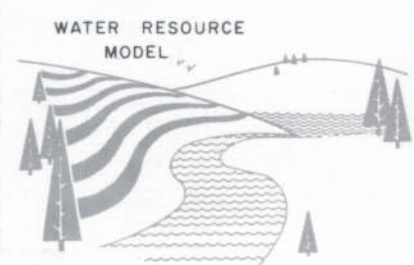
PLANNING REPORT NO. 1



# REGIONAL PLANNING SYSTEMS STUDY





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# REGIONAL PLANNING

# SYSTEMS STUDY

# REPORT

The preparation of this report was financed in part through an urban planning grant from the Housing and Home Finance Agency, under the provisions of Section 701 of the Housing Act of 1954, as amended.

MARQUETTE UNIVERSITY

FOR THE

SOUTHEASTERN WISCONSIN REGIONAL

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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# STATEMENT OF THE EXECUTIVE DIRECTOR

This report presents the results of a study conducted under contract by the College of Engineering of Marquette University for the Southeastern Wisconsin Regional Planning Commission. This study was one of a series performed under Urban Planning Grant No. Wis. P-6 (G) from the Housing and Home Finance Agency. The study began in March of 1962 and was completed in December of 1962.

The report is quite unusual for a planning report in that it neither presents the results of data collection nor recommends specific plans. It does, however, establish a framework for both data collection and plan formulation.

The mathematical models described in the report serve to define the requirements for future data collection and analysis programs in regional economic forecasting and development, in population forecasting, and in land use-transportation and water resources planning. In the past, the establishment of such data requirements for planning has been largely of an intuitive nature. With a mathematical model, it is possible to establish a logical and detailed set of data requirements consistent with the application involved.

Models also serve in plan formulation as testing vehicles for the evaluation of proposed plans. With a model it is possible to test the effectiveness of a plan in the complex environment of the model which simulates the real life situation. This makes it possible to quantitatively test complex system plans and thereby formulate practical and workable long range plans for such complex systems of facilities as transportation, water supply, sewerage and drainage networks.

The timing of the regional planning systems study was quite fortunate. The models developed in this study will now provide the framework for data collection and analysis and plan development in the Commission's regional land use-transportation study, the river watershed planning studies and other regional planning programs.

K. W. Bauer
Executive Director

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# PREFACE

This report presents the results of a study conducted under contract by the College of Engineering at Marquette University in conjunction with the Southeastern Wisconsin Regional Planning Commission. This study was one of a series performed under Urban Planning Grant Contract No. Wis. P-6 (G) from the Housing and Home Finance Agency.

Acknowledgment is extended to Professor Arthur C. Moeller and Mr. Henry Thompson, research assistant, of the Department of Electrical Engineering of Marquette University for their contributions to the study. Further acknowledgment is also expressed to Mr. Sanford S. Farness and Dr. Kurt W. Bauer, former director and present director of the Southeastern Wisconsin Regional Planning Commission, for their interest and constructive comments throughout the study program. The basic analysis effort and the preparation of the final report were completed under the direction of Kenneth J. Schlager, now chief systems engineer for the Commission.

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## CHAPTER I

# INTRODUCTION

### A. GENERAL

In March of 1962, the Southeastern Wisconsin Regional Planning Commission contracted with the College of Engineering of Marquette University to develop a preliminary design of a regional planning system using operations research, systems engineering and electronic data processing techniques. This system would eventually be used to assist government officials, planners and engineers in the orderly and economic development of the region and providing for the planning and design of regional transportation and water systems.

The preliminary design of this system has encompassed only the first stage of a two stage development process. This first stage has resulted in the preliminary formulation of a series of mathematical models of the region and a delineation of the data requirements necessary to make the models operable. Final development and testing of these models will require statistical information about the region. In the second stage of the program, emphasis will be placed on data collection and processing techniques to provide the needed information. Since the first stage of the program was concerned only with preliminary model formulation, the major portion of this report consists of a description of these models. A basic description of each model with a minimum of mathematical detail is presented in the main text. Detailed descriptions of each model with a listing of all equations and data requirements are included in the appendices. Prior to a presentation of these models, a brief exposition of the philosophy of the approach seems appropriate.

The primary purpose of planning is to improve decision-making in order to achieve certain selected objectives. Regional planning is particularly concerned with decisions that affect the development of a geographic region.

A geographic region changes as a result of explicit or implicit decisions that result in actions leading to subsequent growth or decline.

Decision-making is a three stage process comprised of:

1. Information collection and interpretation.
2. The decision itself.
3. The action resulting from the decision.

The outcome of any decision or series of decisions is determined by the individual effectiveness of each of the above stages. What information was available to provide the basis for the decision? What was the logic used in making the decision, and how well was the action resulting from the decision carried out? Improvements in decision-making depend primarily on better information and better decision-rules for utilizing this information.

The above decision process sequence is usually accepted with little discussion. Problems arise, however, in the implementation of the basic concept in terms of real-life everyday decisions. The most common fallacy results from the assumption that the overall problem is solved in the sequence listed above. Invariably, initial efforts are concentrated on gathering huge quantities of data with the vague hope that improved decision-making will surely result. This approach is illogical for the reason that no meaningful data can be gathered until the decisions to be made are clearly understood.[1] Data is the fuel of the decision-making furnace, but this furnace is quite particular about the kind of fuel it will burn. We must design the furnace before we can specify the fuel.

Why is it necessary to first determine the nature of the decisions to be made? And why can this determination not occur in the process of gathering data? The answer lies in the complex inter-

[1] It is also important to realize, however, that data collection may be based on a logical framework developed in a previous study. Many transportation studies have used traffic assignment models that were judged to be valid in earlier studies.

relationship that exists between individual decisions. No decision is ever made in isolation. The results of any decision always interact with other decisions. This interrelationship may be illustrated by a pair of diagrams. In Figure 1 the basic relationships between information, decision and action are illustrated.[2] Information on past actions is used as the basis for further decisions which in turn lead to new actions.

Most decisions are not this simple, of course. The information used in making the decision is often the result of many past decisions. An example of such an interrelationship is shown in Figure 2. Each decision is based upon information (shown by the dotted lines) of other decision-action combinations. An individual decision will be modified as a result of many other decisions. Even this diagram is greatly oversimplified since most decisions utilize many sources of information in their final formulation. This complexity tells us that we must understand the structure, that is, the internal relationship, of the system before we can specify data requirements. It is quite easy to conceive the difficulties involved in determining the informational needs of even a simple system as is shown in Figure 2 without an understanding of the decision-action relationships involved.

To cope with the above problems of planning and its consequence--decision-making--the Southeastern Wisconsin Regional Planning Commission has emphasized a study approach that determines data-information requirements after the structure of the decision-making process has been developed. This development takes form through the formulation of a number of mathematical models that are used to simulate activity in the region on an electronic digital computer.

Most laymen and even many technical people know digital computers primarily as data processing machines or as aids in scientific computations. Indeed, many companies producing this equipment designate it as a "data processing system" in recognition of its use in processing large quantities of data into meaningful information. There is little doubt that the primary application of digital computers to date has been in the automation of clerical operations, and such computer applications will be quite important in regional planning where large quantities of data will need to be processed.

Another less well known use of digital computers is that of system simulation. A mathematical simulation model represents a system as a set of equations which are programmed for a digital computer. When the model is "run" on the computer it "acts like" the real life system. Static, often called iconic, models are familiar to all of us. A photograph is a model of a person, object or scene in that it "looks like" what it represents. Such a model, however, is static; it does not change with time. A simulation model is dynamic in that it "acts like" the system it represents. The flow of water may be used as a model for the flow of electric current or vice versa.

In this case, it is desired to construct a model of the activities taking place in Southeastern Wisconsin in order to better understand and influence through decisions and actions the development of this geographic region. Through the use of a model it will be possible not only to understand the region, but also to test the effects of alternative decisions and policies before critical commitments are made. In this way, it will be possible to minimize reliance on "intuitive" decision-making so characteristic of the past.

B. MODEL SELECTION AND DESIGNATION

In developing any mathematical model, it is first necessary to determine its area of application. A model used to decide on the location of a freeway will be quite different from one used to determine public policies necessary to stimulate economic development. In other words, it is necessary to first determine the kind of questions which will be put to the model. These questions will determine the degree and kind of detail which will have to be built into the model. The nature of these questions for applications in this region are discussed in the last section of this chapter.

Since both planning and decisions concerning development of the region will be made at different levels, it seems obvious that no one model will suffice for all applications. For this reason a set of autonomous but interrelated models must be developed for the region. The models presently under development are:

[2] J. Forrester, Industrial Dynamics, John Wiley, New York, 1961.

# INFORMATION FEEDBACK SYSTEM

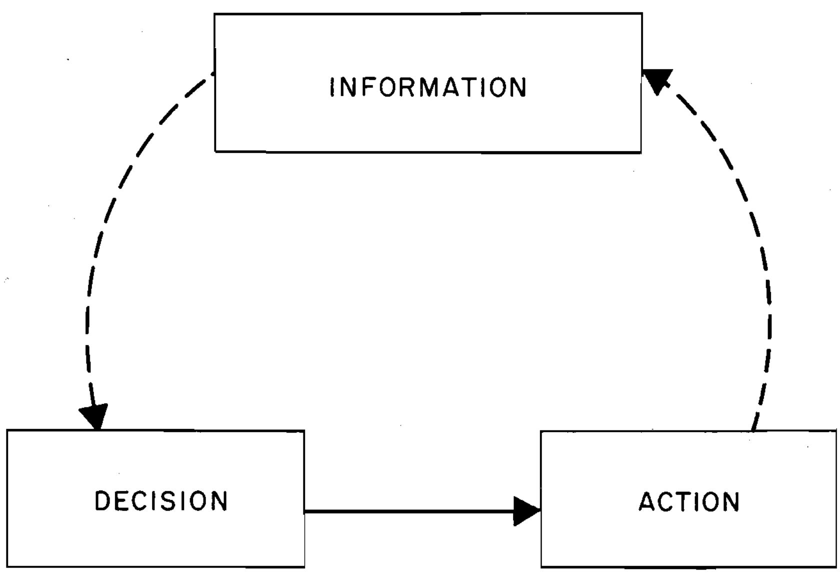


FIGURE 1

# DECISION-ACTION INFORMATION FEEDBACK NETWORK

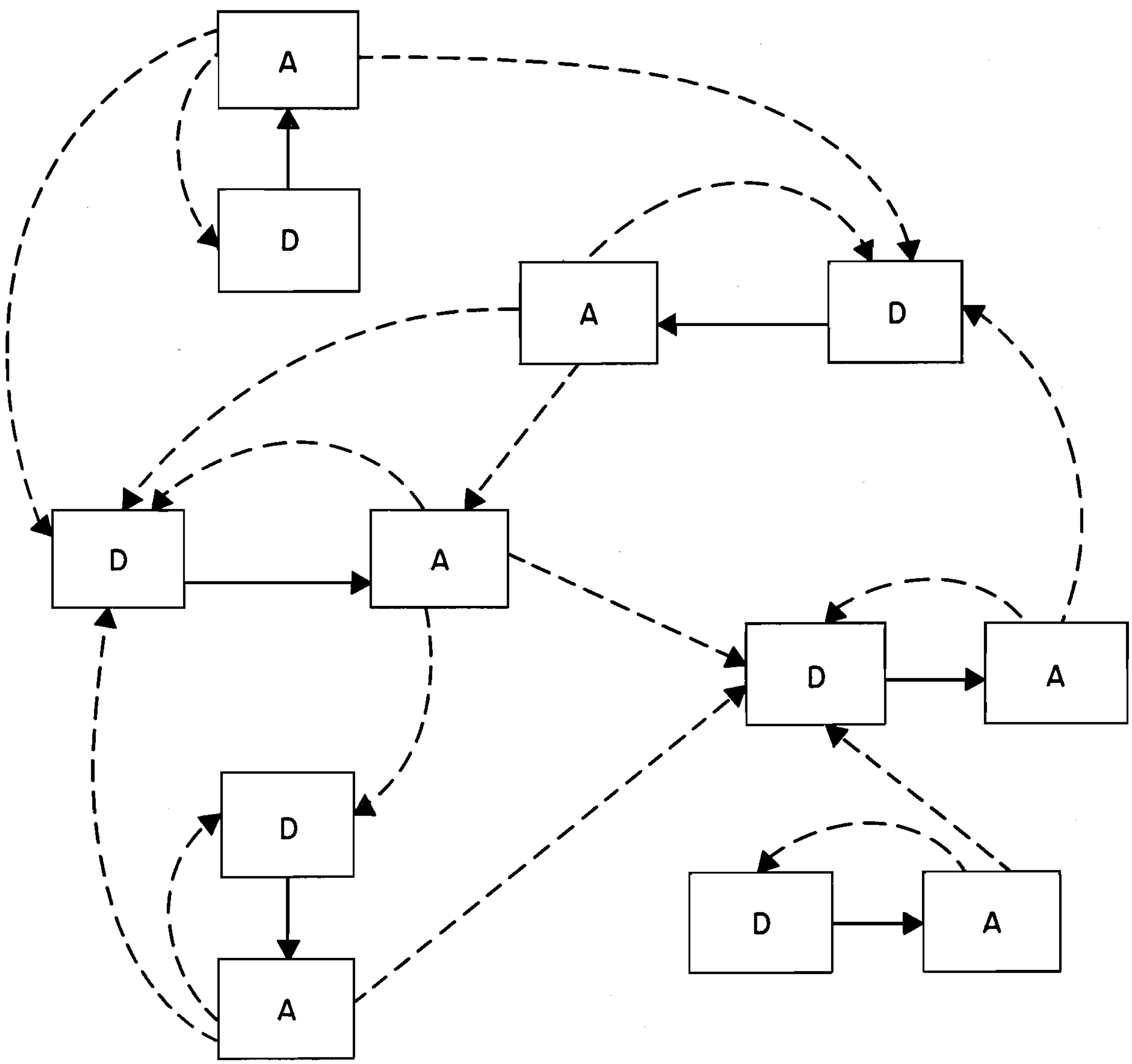


FIGURE 2

1. Regional Activity Model
2. Spatial Activity Model
3. Transportation System Model
4. Water Recource System Model

The regional activity model is a functional model representative of the primary activities of the region. Flows of goods, services, money, capital equipment and information are represented in the model to simulate the activities of industry, households and government in the regional economy. Population growth is specifically represented in the model as a basic element in the development of all of the other sectors. Technically, the model is a dynamic input-output simulation model. It is dynamic in that it simulates the changes in the regional economy with time; input-output, in that it treats of the purchase and sales transactions between sectors both within the region and with the rest of the world. The model is a simulation model in that it generates or simulates a history similar to that of the real-life economy with time. This model, to be described more fully in Chapter II, should be most useful in understanding and modifying, if necessary, the forces making for the growth or decline of the region.

The regional activity model just described is spaceless because it considers all activities of the region to be concentrated at a point. For many decisions concerning development, such as decisions concerning economic growth, this model is quite sufficient.

Many regional problems and decisions, however, are concerned with the spatial location as well as the over-all level of an activity. Major expenditures by the governments of the region in transportation, water resources and other public facilities are vitally affected by the spatial distribution of residential, industrial, governmental and commercial activities. Basic spatial patterns and their dynamic changes with time are incorporated in a spatial activity model which distributes the functional activities of the regional activity model to areal locations within the region. The many interrelated factors influencing future land use development are included in this spatial model. Like the regional activity model, this spatial model may be run on a computer to test the effects of alternative policies on the future development pattern of the region.

The first two models are interrelated as shown in Figure 3. The regional activity model develops outputs of functional* activities that are distributed to areal locations by the spatial activity model. The spatial activity model in turn generates demands for regional services such as transportation and water systems that are developed in the next series of models. The spatial model should find its primary use in determining the decisions and actions necessary to attain a desirable future spatial pattern of land use in the region. The model will simulate the future results of any given set of land use development policies.

One of the primary effects of the spatial land use pattern represented in the spatial activity model is a demand for spatially-oriented services such as transportation (highway and transit), and water-sewerage systems. As shown in Figure 3, the spatial model provides an input to the service models in the form of demands for services. The spatial pattern is in turn affected by the services themselves in a feedback fashion. This concept is easily understood since all land development is greatly affected by the existence of roads, sewer, water and other services.

The service models are the working models of the planning system since they may be directly used in the design and operation of regional transportation and water resource systems. The decisions possible with these models are detailed planning decisions affecting the type and location of facilities. Simultaneous simulation using the spatial and service models allows for a detailed analysis of land use and service system relationships.

## C. DATA PROCESSING SYSTEM DESIGN

As previously explained, the regional planning system is being developed in two stages: the model construction stage and the data processing system design stage. Discussion so far has emphasized model construction since all effort to date has been concentrated in this area. Model development will result in requirements for information needed for decision-making in regional

* Functional is used here to signify activities with no designated spatial location within the region.

# RELATIONSHIP OF REGIONAL MODELS

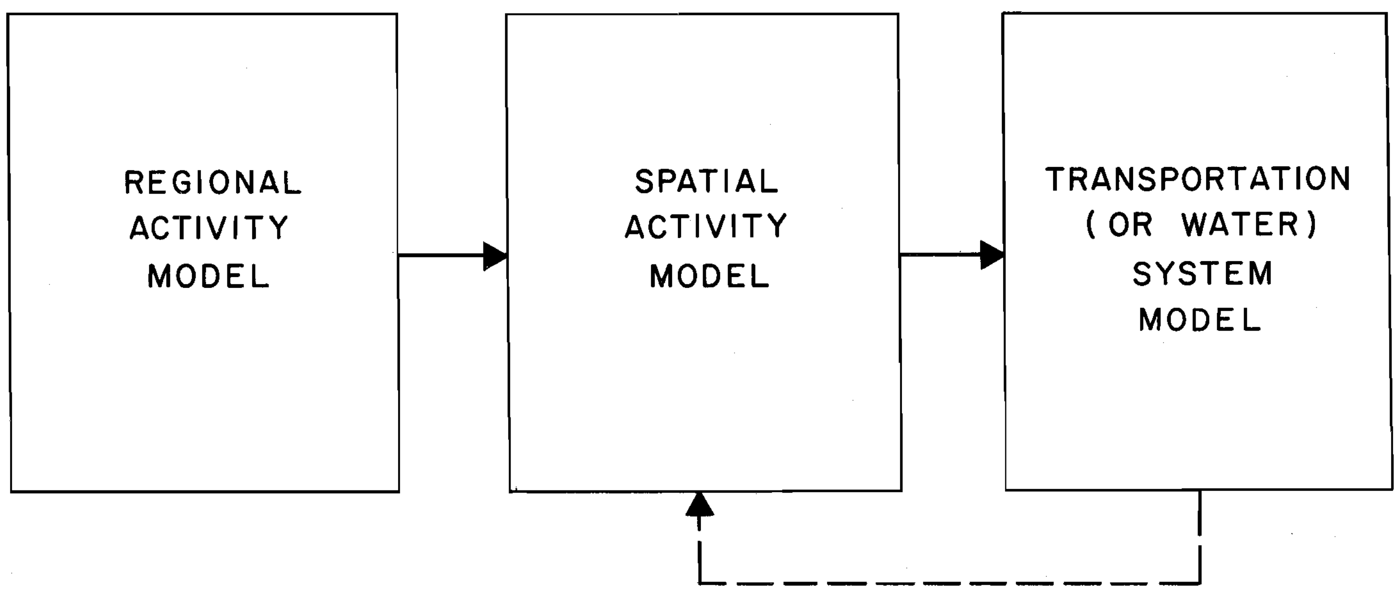


FIGURE 3

planning. These informational requirements must then be translated into a system suitable for collecting, processing and evaluating this data. The final output of this second stage will be a data processing system that will include:

1. Procedures and formats for data collection;
2. Data manipulation programs;
3. Procedures and program for information file storage and retrieval.

The information provided by the data processing system will be the basis for initial and continuing planning using the regional functional and spatial activity models and the transportation, water resource and other design models.

D. MODEL APPLICATIONS

The primary application of the regional activity model will be in economic development. One of the most critical economic problems facing this region in the coming years will be the maintenance of a rate of economic growth sufficient to provide jobs for the region's expanding population. Alternative combinations of private and public investment policies to achieve such growth may be tested in the regional activity model. The results of these tests may then be presented to public and private decision-makers to provide the basis for a program of economic development in the region.

Spatial activity model applications will emphasize the land-use pattern in the region. The relationship between land-use patterns and the availability of transportation, water, sewer and private utility facilities has been established.[3] Since facilities planning directly influences the future land use pattern of the region, it is very important that the desirability of future patterns be established by experimental simulation tests with the spatial activities model. It may well be that the future land-use pattern implied by current facilities planning policies does not represent the best over-all interests of the community. The community through its elected officials should, therefore, be given an opportunity to evaluate the benefits and costs of alternative future regional patterns.

Transportation and water resource system models are more technically oriented in their application. The engineer, as well as the planner and public official, is directly concerned with the implications indicated by these models since they are useful in detailed design as well as in general planning. The financial and land use effects of design decisions in these areas, however, make them of interest to the community as a whole.

[3] Alan M. Voorhees, Development Patterns in American Cities, Highway Research Board, 1961.

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# CHAPTER II

# REGIONAL ACTIVITY MODEL

## A. GENERAL

The regional activity model portrays the flows of goods, services, people and money that comprise the regional economy. It consists of a series of equations that express the relationships between these interacting flows within and outside the region.

A simplified representation of these flows is shown in Figure 4. In the lower half of the diagram the intra-regional flows are illustrated. Consumer goods and services are produced in the industrial and business sectors and distributed through the wholesale-retail trade sector to households. Industry also produces for itself in the form of producer goods and services. The great percentage of both producer and consumer goods flow out to other regions, but some remain within the region for utilization by local households, government and industry.

The household sector receives wages, salaries and other payments from business and government which enable it to purchase goods and services from business, pay taxes to government and save money which is invested through financial institutions.

Government receives taxes from business and households, borrows money from financial institutions and purchases goods and services from business. In the upper half of the diagram the extra-regional economy is shown. Since this region is noteworthy as a producer of capital goods, the most important flows are from regional producer goods suppliers to business outside of the region. Lesser flows of goods travel to the national household sector and the federal government.

A simulation model embodying the flows depicted in Figure 4 would be useful for an over-all understanding of the regional economy, but it would lack the detail needed for a sufficient understanding of the structure* of the region.

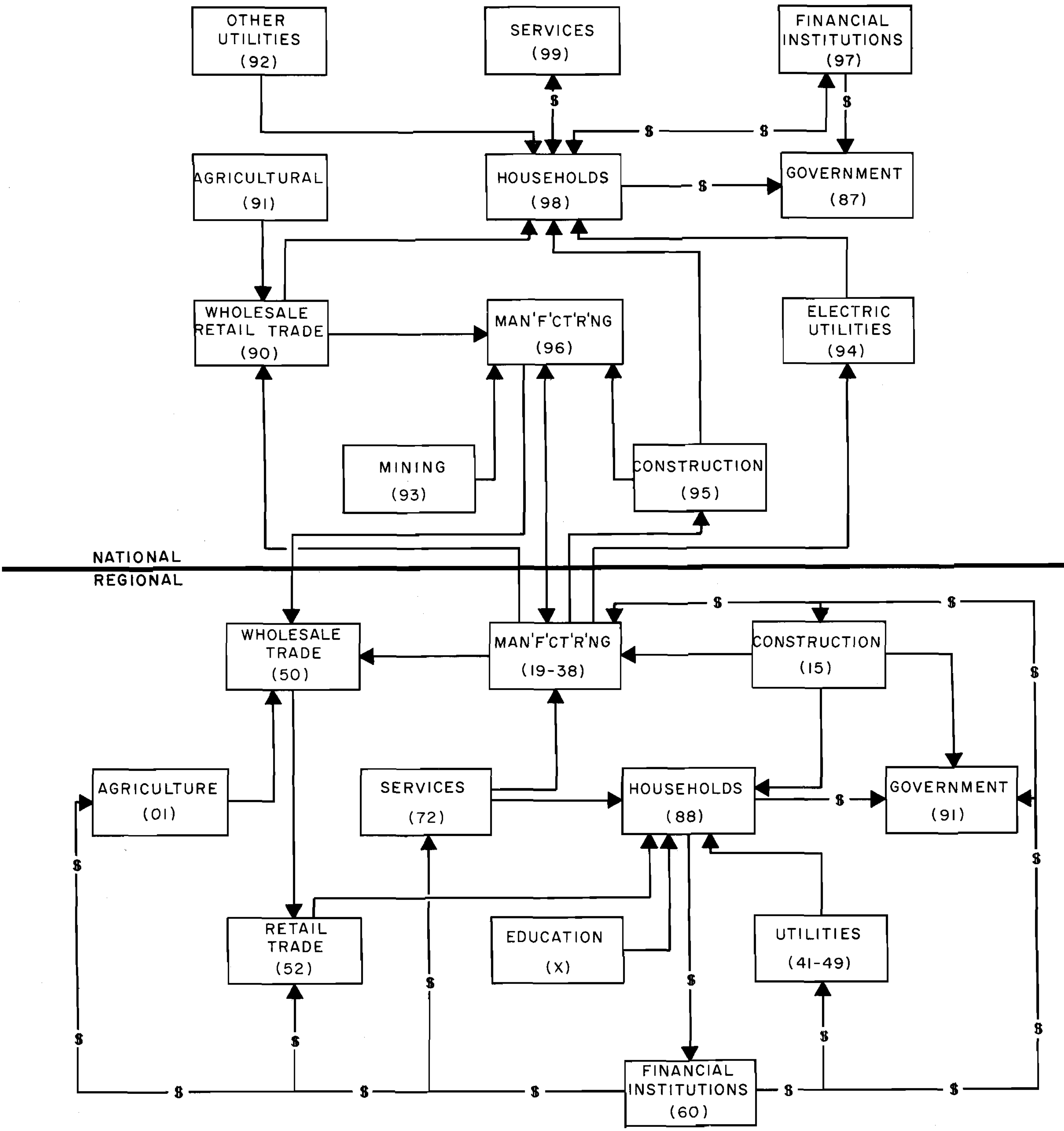
To understand the forces contributing to growth or decline, a knowledge of the structure of the regional economy is vital. A region specializing in industrial machinery (capital goods) such as this one has very different problems from one specializing in consumer products. For this reason, the specific economic structure of the region must be explicitly included in the model.

Structural economic relationships are best developed in an input-output model. Fundamentally, an input-output model is one that specifies the detailed flow of goods between different industries. As an example, the aluminum industry supplies metal to the automobile industry, the electric utility industry, as well as the construction industry. The aluminum industry in turn receives power from electrical utilities. Such transactional relationships are usually depicted in an input-output table as illustrated in Figure 5. The producing industries are listed vertically and the purchasing industries horizontally in the table. The positions in the table contain the transaction ratios between the intersecting industries at that point. Such a table depicts transactions at a given point in time and is essentially static. Since a dynamic simulation model is desired, it is necessary that the simple transactional relationship be replaced with a block of equations that represent the actions of a particular industry over time. In other words, the features of the simplified simulation flow model of Figure 4 with an input-output structure will be combined to produce an input-output simulation model. Such a model will be capable of simulating the operation of the regional industrial complex over time.

Confidence in the probable future usefulness of the regional activity model is enhanced by a brief review of related model developments. As previously stated, the regional activity model is a fused combination of an input-output framework in a dynamic simulation model. Both of these two elements have been highly developed in previous applications.

* The structure of this system, as used here, is the internal framework of the commodity and money flows between different industries.

# SIMPLIFIED REGIONAL ACTIVITY MODEL DIAGRAM




**NOTE:** Flow interconnections are suggestive only since flows exist to some extent between all sectors.

FIGURE 4

# INPUT-OUTPUT TABLE (ISARD, page 328)

| INDUSTRY PURCHASING / INDUSTRY PRODUCING | AGRICULTURE & EXTRACTION | LIGHT MANUFACTURING | HEAVY MANUFACTURING | POWER & COMMUNICATIONS | TRANSPORTATION | TRADE | FINANCE, INSURANCE, RENTALS | BUSINESS, PERSONAL SERVICES | EDUCATIONAL, BASIC SERVICES | CONSTRUCTION | HOUSEHOLDS | ALL OTHERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGRICULTURE & EXTRACTION | $0.28 | $0.21 | $0.06 | $0.05 | $0.04 | $0.01 | $0.02 | $ — | $0.04 | $0.18 | $0.06 | $0.09 |
| LIGHT MANUFACTURING | 0.06 | 0.28 | 0.04 | 0.01 | 0.02 | 0.02 | 0.01 | 0.14 | 0.15 | 0.04 | 0.20 | 0.13 |
| HEAVY MANUFACTURING | 0.01 | 0.02 | 0.33 | 0.01 | 0.03 | 0.01 | — | 0.09 | 0.01 | 0.18 | 0.03 | 0.09 |
| POWER & COMMUNICATION | 0.01 | 0.01 | 0.01 | 0.11 | 0.03 | 0.02 | 0.08 | 0.04 | 0.02 | — | 0.01 | 0.02 |
| TRANSPORTATION | 0.03 | 0.02 | 0.02 | 0.02 | 0.05 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.03 | 0.03 |
| TRADE | 0.02 | 0.02 | 0.01 | — | 0.02 | — | 0.02 | 0.03 | 0.05 | 0.09 | 0.12 | 0.05 |
| FINANCE, INSURANCE, RENTALS | 0.04 | 0.01 | 0.01 | 0.01 | 0.03 | 0.05 | 0.07 | 0.05 | 0.04 | 0.02 | 0.12 | 0.05 |
| BUSINESS, PERSONAL SERVICES | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.07 | 0.01 | 0.04 | 0.02 | 0.03 | 0.03 | 0.02 |
| EDUCATIONAL, BASIC SERVICES | — | — | — | — | — | — | — | — | 0.01 | — | 0.10 | 0.04 |
| CONSTRUCTION | — | — | — | 0.04 | 0.06 | — | 0.10 | — | 0.01 | — | 0.10 | 0.04 |
| HOUSEHOLDS | 0.40 | 0.25 | 0.34 | 0.58 | 0.58 | 0.63 | 0.53 | 0.46 | 0.50 | 0.40 | 0.01 | 0.28 |
| ALL OTHERS | 0.14 | 0.16 | 0.17 | 0.16 | 0.12 | 0.18 | 0.15 | 0.14 | 0.13 | 0.02 | 0.29 | 0.17 |
| TOTAL | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

*a* – Rounded to nearest cent. Dashes indicated inputs less than one-half cent per dollar output.

*Source:* "Methods of Regional Analysis: an Introduction to Regional Science" *by* Walter Isard

FIGURE 5

Input-output analysis was pioneered by Leontief[4] and has been applied on both a regional and a national level in this country and in Europe. A national input-output table was developed by the U.S. Department of Labor in 1947. Less comprehensive tables have been formulated for some metropolitan areas in the United States. A much more intensive effort has been made in Europe where an input-output model has formed the basis for French economic planning and is now being extended to the other Common Market countries.

Dynamic simulation models have received increased emphasis in recent years because of the advancing technology in electronic digital computers. The larger memories and higher speeds of current computers make dynamic simulation models of great size and complexity practical. Simulation models have been extensively developed for both military and industrial applications. The regional activity model here is based upon simulation models developed by Professor Jay Forrester and his associates at the Massachusetts Institute of Technology.[5] A number of company-level and industry-level simulation models have been developed under Professor Forrester. One of these models depicting the dynamic operation of the copper industry[6] is similar in its basic structure to the industrial sectors of the regional activity model. Essentially, the regional activity model is an interconnected set of industrial simulation models in an input-output framework.

## B. MODEL ORGANIZATION

The regional activity model will be comprised of a set of sectors consistent with the major industries of the region. Since structural understanding is desired, it is important to single out the crucial industries in the model.

The following sectors were selected for representation:

1. Agriculture (includes mining, a minor industry in the region)
2. Construction
3. Manufacturing
   a. Foods
   b. Printing and Publishing
   c. Primary Metals
   d. Fabricated Metals
   e. Machinery
   f. Electrical Machinery
   g. Transportation Equipment
   h. Other Manufacturing
4. Utilities (Electricity, Gas, Water, Communication and Transportation)
5. Wholesale Trade
6. Retail Trade
7. Financial Institutions
8. Services (other than those included in other sectors)
9. Education
10. Government (Local, State and Federal)
11. Households

The manufacturing sectors listed above include all of the major industrial employers in the region. The "other manufacturing" sector actually represents about 24 per cent of total manufacturing employment. All of the economic activity of the region is included in the above sectors. The household sector includes the population characteristics of the region as well as consumer spending.

[4] W. W. Leontief, The Structure of the American Economy, 1919-1939, Oxford University Press, New York, 1951.

[5] Forrester, Op. Cit.

[6] K. Schlager, A Systems Analysis of the Copper and Aluminum Industries, An Industrial Dynamic Study, M.S. Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1961.

The extra-regional economy is also subdivided into sectors. A greater degree of aggregation is used in the external sectors since the objectives of the analysis differ in this area. Principal emphasis will be placed on industries such as manufacturing, electrical utilities, mining, construction and other primary customers receiving the output of the region. The sectors include:

1. Agriculture
2. Mining
3. Construction
4. Manufacturing
5. Electrical Utilities
6. Other Utilities (including Railroads and other Transportation)
7. Wholesale and Retail Trade
8. Financial Institutions
9. Services
10. Government
11. Households

The first five sectors listed are the chief customers for the producer durables produced in the region. The other sectors serve to complete the external economic system. Foreign imports and exports will be handled as external inputs to the model.

For each of the above sectors two classes of equations must be developed:

1. Equations which relate each sector to other sectors (external relationships)

2. Equations which describe the internal operation of the sector (internal relationships).

To develop a basic understanding of the model, the general nature of these external and internal relationships will be explained in this section. A detailed description of all of the sectors of the model is included in Appendix I. Many of the sectors are similar in their basic structure, and they may be examined as a class with some comment on individual peculiarities. Other sectors, such as the household sector, differ significantly and must be considersd individually.

C. EXTERNAL RELATIONSHIPS

The external equations of the model specify the origins of the inflows and the destination of the outflows from each sector. The format of these equations is quite simple. The sales of any sector are comprised of the purchases of other sectors. Total sales of any sector are expressed as the sum of sales to intra-regional and extra-regional customers. For each of these two markets, total sales outflow of any sector is expressed as the sum of the sales to each of the other sectors. Sector sales in turn are determined by the total purchases of the other sectors, the inter-sector coefficient and the market share of the industry in this region. As an example, 40 per cent of the annual purchases of electrical utilities in the nation may be for electrical equipment of which 30 per cent comes from this region. Separate equations are used for raw materials and capital equipment.

Each sector will have two equation sets to express its output relationships with other sectors. One will sum intra-regional sales; the other extra-regional sales. The input relations of each sector are reflected in the output equations of the other sectors.

The sectoral flows of materials, goods and capital equipment are supplemented by flows of money. In many cases, money flows are in the opposite direction from goods flows. In such instances, money flow equations would, in essence, duplicate material-goods-equipment flows and would contribute little to our understanding of the system. In the case of government and financial institutions, however, money flow is primary; and it will be treated as a separate flow sequence. The approach will be the same as in the flow of goods except that the external financing and tax flows will replace raw material purchases and capital expenditures in the outflow summation.

With the external equations developed, a complete system of inter-connected "black boxes" are defined where the black boxes are the primary sectors of the model. It is now necessary to examine the contents of these black boxes.

## D. INTERNAL RELATIONSHIPS

### 1. General

The internal equations express the manner in which the inputs of each sector are converted into the outputs just described. These equations concern the timing as well as the quantity and value (cost) of these outputs. The relationships characteristic of a manufacturing sector will be first described. Modifications to this basic format for agriculture, construction, the utilities, services and trade will then be presented. The sector equations for financial institutions, education, government and households differ to such a degree that they will be described separately.

### 2. Manufacturing Sector

The internal equations of a manufacturing sector are developed in five subsectors:

a. Production
b. Marketing
c. Personnel
d. Finance
e. Plant and Equipment.

The production subsector equations provide for the control of product flow from initial raw material through work in process to finished goods.

The marketing equations encompass the reception and shipping of orders. Unfilled orders, finished goods, inventories and average sales are all a part of this subsector which monitors the distribution of the product.

Personnel equations account for the employment and layoff of hourly and salaried personnel. These flows are closely related with production flows in the production subsector.

Both short term and long term money flows are included in the financial subsector. Current costs and expenses, dividend payments and external financing are all expressed in the model equations. These formulations are intimately related to all of the other manufacturing subsectors since the activities of these subsectors directly affect fund flows.

The investment process is symbolized in the plant and equipment subsector. Both capacity changes and modernization are depicted in the simulation. Decision rules in this subsector are of a long term nature and establish capacity limits for the production subsector and cost coefficients for the financial subsector.

### 3. Other Equivalent Sectors

The agricultural, construction, utilities, wholesale trade, retail trade and service sectors are similar in format to the manufacturing sector just described. All but the trade and service sectors include a production subsector. This subsector in construction and utilities differs primarily in the absence of a finished goods inventory since these industries do not carry finished goods stock in the same sense as manufacturing. The agricultural production subsector is almost identical except for the constants used to implement it.

The marketing, personnel, financial and plant equipment subsectors exist in each of the other sectors as in manufacturing, differing only in detail.

### 4. Financial Institutions Sector

Financial institutions serve as intermediaries in the flow of funds from savings into investment. Commercial banks, savings banks, savings and loan associations, stock-bond exchanges, credit unions, finance companies and insurance companies are all represented in the model.

Funds flow into this sector from the household, business and government sectors. A minimum legal reserve of funds is maintained within the sector and the remaining money flows back to the other sectors for:

1. Business plant, equipment and working captail;
2. Household home mortgages and installment purchases;
3. Government debt financing.

The equations describing the outflows of funds to the various business, household and government sectors are similar to the sales equations of the manufacturing sector in that the money acquired by the other sectors is divided among the various money suppliers through the use of market share coefficients.

The internal structure of the sector contains a personnel subsector and a "plant" and equipment subsector similar in format to those in manufacturing.

5. Education Sector

The structure of the education sector has much in common with the manufacturing sector. Subsectors for personnel, finance and facilities (like plant and equipment) are included in the format. The production and marketing subsectors of manufacturing are replaced by a student subsector that is directly related to the population subsector of the household sector. Students of various age groups progress through the sector as in real life, finally entering the labor market at different grade levels of the system.

The personnel subsector accounts for teaching, administrative and service personnel and is directly affected by the output of graduates of the education sector itself.

6. Government Sector

The intra-regional government sector encompasses state, local and local-federal governmental activity while the extra-regional government sector programs the complete role of the federal government. Governments play a dual economic role as producers of public services such as education and police protection, and as public consumers of goods from the business sectors. Some public services are included in other sectors such as education and water-sewer utilities. Others, such as police-fire protection, are included within the governmental sector itself.

Tax receipts flow into the government sector from the household and business sectors. External debt funds flow in from the financial institutions. In the case of the federal government, the stock of money is managed through the Federal Reserve System through its control of bank reserves and government securities.

Expenditures of funds flow to one of four destinations:

1. To other sectors supported by public funds, e.g., education;
2. To business sectors furnishing supplies, facilities and services to the government, e.g., construction;
3. To the household sector in the form of wage-salary and transfer payments;
4. To the financial institutions as interest and debt retirement payments.

The personnel and facilities subsectors are as previously described in the education sector.

7. The Household Sector

The household sector subdivides into two primary subsectors:

1. Household Consumption
2. Population.

In the household consumption subsector, money inflows from wages, salaries, dividends and interest are channeled to expenditures and savings. Expenditures are subdivided by the source industry in the sales equations of the selling industry. Savings are classified according to the destination (commercial banks, insurance, etc.) in the financial sector and are transferred to that sector. The financial status of liquidity and debt is currently maintained.

Real and personal property of a durable nature is accounted for in terms of its financial value. Expenditures in this area are related to the current capacity use of existing housing as well as regional income.

The population subsector contains a detailed current inventory of population according to five-year age groups. Births, deaths and net migration flow is simulated to continuously up-date the population record. Auxiliary information on race, educational level and occupation is also included. This subsector is intimately related with household consumption within the sector and employment in all of the other sectors.

## E. DATA REQUIREMENTS

Two classes of information are needed to implement the operation of the model after the equations have been developed. One class of information, technically known as initial conditions, provides the starting point for model operation. To simulate the operation of the regional economy from 1962-1972, we must first know the state of the system in 1962. Typical initial conditions would be the current employment, average level of production and the capitalization of a given industry.

The second class of information needed are the constants or coefficients involved in the equations. For the external equations, these constants are the percentages of sales of industry A to industry B and the market share of industry B that is located within the region. Internal equations require a number of constants that determine the nature of production, marketing and financial controls within the industry.

Initial testing of the model to ensure internal consistency and operability has used approximate data for both initial conditions and constants. The second phase of the program will determine the data to be used in the actual operation of the model.

## F. MODEL VERIFICATION AND TEST

A useful model must be a valid model. To be valid, the model must act like the real life system. It is not essential that it reproduce historical data in detail, but it must indicate a strong structural similarity to the system it is simulating. The key test of its validity relates to its capability in improving the effectiveness of regional economic decisions.

After initial formulation and debugging, a series of model verification test runs must be performed. At this stage, the lack of adequate data in many areas has severely restricted test conclusions, but it has been possible to use rough-estimate data to establish confidence in the model. After the second stage of the program has been completed and accurate data is available, rigorous tests of model validity will be possible.

## G. SENSITIVITY ANALYSIS AND USE IN REGIONAL PLANNING

With the validity of the model established, an extensive sensitivity analysis will be performed on the model. Various parameters, singularly and in combination, will be varied to determine the effect of certain variables on the over-all operation of the system. The results of the sensitivity analysis provide an extremely important frame-work for use of the model in planning.

At this point the model will be ready for active use in plan formulation in the region. The model must then be clearly explained to planning and administrative officials in order that a detailed program of plan tests may be formulated.

## H. CURRENT STATUS

During the first stage of the program, a preliminary version of the regional activity model has been formulated and tested. Each sector type in the model has been tested on the IBM 704 digital computer. An interconnected test of all of the sectors was not possible due to the lack of input-output data. Input-output data now being gathered by the Southeastern Wisconsin Regional Planning Commission and the State Department of Resource Development on the P-6 economic study should permit a complete model test by June of 1963.

## CHAPTER III

# SPATIAL ACTIVITY MODEL

### A. GENERAL

The regional activity model described in the previous chapter provides a functional spaceless representation of the activities in the region. This model includes a detailed description of the socio-economic structure of the region and provides a means for testing alternative decisions and their effects on the future growth of the region. Although this regional activity model is useful in the determination of the basic elements of functional growth, it is not directly applicable to planning problems involving transportation or water resource systems which require a space dimension. A second planning model, the spatial activity model, is necessary to distribute regional activities over space.

Basically, the spatial activity model must encompass the dynamics of land use. The factors that influence land use change must be included in the simulation model. Land use descriptions must include not only the factors that generate landuse change itself, but also those factors that generate demand for space-oriented services such as transportation and water resources. Ultimately, the primary use of this second model will be in determining possible future land use patterns in the region.

Lynch in a recent article[7] considered three factors as being critical to the spatial form of a metropolis. The first factor was the magnitude and pattern of structural density and condition (the state of obsolescence or repair). The second was the transportation system or pattern of circulation. The third factor was concerned with the location of critical central activities such as work, shopping and recreational locations. These central activities are in critical interaction with the rest of the spatial system. If we are to model the dynamic patterns of this region we must discover and formulate in quantitative terms the forces affecting pattern changes of these critical factors.

### B. MODEL ORGANIZATION

Land use changes occur as a result of individual decisions made by persons or groups of persons. The spatial activity model must incorporate the factors that influence these decisions since an understanding of the forces generating future land use patterns is essentially an understanding of these decision processes.

These basic decision processes differ for various categories of land use. Three categories of land use are included in the model:

1. Primary uses involving only a few decision makers. Industrial, regional commercial, regional institutional, regional recreational, regional governmental and urban renewal land uses are in this category.
2. Primary uses involving a large number of decision-makers. Only residential land use fits this category.
3. Secondary or service uses. These uses develop as a result of service activities needed for the primary uses. Local commercial, local recreational and local governmental land uses are in this category.

The order of presentation above is quite significant since the first class of primary use is basic in that it largely determines the employment pattern of the region which in turn greatly influences the second class of primary use (residential) and the many service land uses. A number of classifications of land use are enumerated in the model. These classifications and their symbols are listed below:

[7] Kevin Lynch, "The Pattern of the Metropolis", Daedalus, Winter 1961, and Proceedings of the American Academy of Arts and Sciences, Volume 90, No. 1.

1. Residential (R)
2. Industrial (I)
3. Regional Commercial (RC)
4. Regional Institutional (RI)
5. Regional Governmental (RG)
6. Regional Recreational (RR)
7. Urban Renewal (UR)
8. Local Commercial (LC)
9. Local Governmental and Institutional (LG)
10. Local Recreational (LR)
11. Transportation and Utility Facilities (TF)
12. Farm (F)
13. Vacant (V) (will be classified by development potential)
14. Miscellaneous (M)

Each of the above types will be described in terms of the following classes of parameters:

1. Parameters relating to the intensity of usage (population density, building density, retail sales, etc.)
2. Parameters relating to the quality of population and buildings (age, income, land-building value, etc.)
3. Parameters relating to space-location and transportation facilities (accessibility) with respect to other sites.
4. Parameters relating to other services (water, sewer, etc.)

The equations of the model express the relationship between the above parameters and how they change over time. The rationale for the equations in each of the three primary categories of land use will be described in the subsequent paragraphs of this chapter. A complete set of model equations is included in Appendix II.

Land use parameters in the spatial activity model will be specified for areal subdivisions of the region designated as zones. Zonal areas will vary from a section (one square mile) or even larger in rural areas to quarter sections or even blocks in densely populated urban areas. For each zone the model will simulate and record the parameters of land use as they change over time.

## C. RESIDENTIAL LAND USE

Residential land use models are more highly developed than those of other forms. The work of W. G. Hansen[8] is particularly noteworthy in that he has developed a model and evaluated its performance in a number of cities. Although the forecast errors of his initial model are still larger than is desirable, his efforts represent an advance over previous intuitive procedures.

Hansen's model considers two primary variables as determinants in land use change. The first of these is vacant land; the second is accessibility. The manner of incorporation of vacant land as a variable limits the application of the model to undeveloped land. Accessibility is a measure of the travel time to other zones offering employment, shopping and social opportunities. The growth in any zone, G, is expressed as a function of the vacant land available in the zone and the accessibility to other zones as compared to the total vacant land and accessibility of other zones in the region, or as:

$$\frac{G_i}{G_R} = \frac{V_i f(A_i)}{V_i f(A_i) + V_j f(A_j) + \ldots V_n f(A_n)};$$

Where:
$G_i$ is equal to the residential growth in zone i (population or dwellings)

$G_R$ is equal to the residential growth in the region or subregion.

8 Walter G. Hansen "Land Use Forecasting for Transportation Planning" in Highway Research, Bulletin 253, Washington, D.C.; 1960.

$V_i$ is the vacant developable land in zone i.

$A_i$ is a measure of accessibility in zone i.

Using the above equation, Hansen estimated the residential growth (increase in dwelling units) in Washington, D.C. between 1948 and 1955. Comparison of the model forecast with the actual increase in dwelling units revealed that about 75 per cent of the estimates were within 50 per cent of the actual growths. This level of inaccuracy, while encouraging, is still too large for transportation or water resource-system facility planning.

An improved spatial activity model must consider factors other than transportation and vacant land. In fact, more recent research on the development patterns of cities by Vorhees indicates that transport accessibility is declining in importance as a major factor in urban development because travel time differences between one location and another have been drastically reduced by the advent of freeways.[9]

To improve the accuracy of the spatial activity model a number of changes and extensions to the Hansen model are proposed here:

1. The primary inputs to the model such as economic activity and population growth will come from the regional activity model. Use of these inputs will introduce social and economic factors not considered in the Hansen Model. Spatial growth in a zone will be directly tied to general economic conditions, family income and social effects such as the color line.

2. The model coefficients will be determined by analysis of past growth over short time increments. These time increments will correspond to the time increments to be used in the simulation model. Sampling over many short time intervals should lead to the development of a better knowledge of the structure of the system. Multiple linear regression analysis techniques will be used.

3. Additional factors such as water and sewer service, rail service, land value and local tax rate will be included in the model as may be indicated by the results of the regression analysis.

The first of the above changes stems from an objective to relate land use changes to over-all economic growth in the region. The other changes are necessary to convert the basic model of Hansen into a true simulation model. The residential portion of the model is described in detail in Appendix II.

## D. COMMERCIAL, INDUSTRIAL, GOVERNMENTAL AND URBAN RENEWAL LAND USES

All of the land uses designated in the title of this section are determined by the actions of a relatively small number of decision-makers. The most difficult categories of land use forecasting are those in which a single decision can greatly affect the over-all result. A decision to build a large plant may be made by a few men or even one man, and it is difficult to foresee the forces motivating him in this decision. Here there are no averaging effects as in the residential model with its multitude of decision-makers.

In addition most of these uses are critically dependent upon the outputs of the regional activity model. It is quite possible that new industrial construction may be negligible if Milwaukee's machinery industry is depressed. Even if a normal growth takes place, local companies may decide to expand either in other regions or at their present site or at a new site within the region.

For all of the above reasons, land uses of this category must be approached on a project basis by industrial or governmental function. A specific industry along with its companies - such as electrical machinery - must be studied in terms of its basic growth, its desire to expand locally or elsewhere, and its approach to on-site expansion versus a new site expansion. The basic growth will be an output of the regional activity model. The split between other-region expansion, on-site expansion and new site expansion construction must be learned from detailed analysis of the major industries.

[9] Alan M. Vorhees, Development Patterns in American Cities, Highway Research Board, 1961.

A model has been developed by Hansen for industrial land use similar to that used for the residential land use previously explained. At this time, however, it is doubtful that such a model would be little better than an intuitive approach until the regional activity model outputs are available and more is learned about the plant location methods used by local industry.

Although the above approach may seem quite complex, its importance can hardly be overestimated. Although industrial land use comprises only a small proportion of the total land use pattern, its importance arises from the impact it has on residential distribution. The Hansen model demonstrates that employment accessibility is a key factor in the locational pattern of residential land use. Should industry in Milwaukee, Racine and Kenosha abandon its central locations and move to the suburbs the entire settlement pattern of the region could change radically.

Regional commercial land uses- banking, insurance, central offices- must also be handled on a project basis.

Governmental locations of parks and facilities must be approached in a similar fashion. Urban renewal projects are a special case but their location should be more predictable with the degree of planning now required on these projects by the HHFA.

Model investigations will make full use of a recent study completed by Professor Norbert J. Stefaniak of the School of Commerce, University of Wisconsin-Milwaukee.[10] This study includes the historical background and rationale for present plant locations together with requirements for alternate industrial locations. This study will serve as a starting point for industrial land use model formulation.

## E. SERVICE LAND USES

Certain land use categories exist as service functions to residential areas. Each residential area must have local schools, shopping centers, streets and governmental functions such as police and fire protection. The percentage of land devoted to these service functions is fairly stable so that such uses are best expressed as a percentage of residential land.

Local commercial land would therefore be determined as follows:

C111.K = (CC111) (RL111.K)
C111 - commercial usage, zone 111, square miles
CC111 - commercial constant, zone 111
RL111 - residential land, zone 111, square miles

Transportation and utility facilities land usage can also be expressed as a percentage of residential usage in a predominantly residential zone. In an industrial, commercial, or farm zone it is expressed as a percentage of the predominant usage.

TF111.K = (TC111) (RL111.K)
TF111 - Transportation and utility facilities usage, zone 111
TC111 - Transportation and utility facilities constant, zone 111

Educational and other governmental service uses will be determined in a similar manner.

## F. FARM LAND USES

Farm land use throughout the region is declining and growth in other land uses is almost always at the expense of farm usage. For this reason, the farm land use decline rate is best expressed in terms of the sum of other land usage increases.

F111.K = F111.J + DT/C111(O-RL111.JK - IL111.JK - . . . .)
F111 - Farm usage, zone 111, square miles.
C111 - Land usage coefficient to account for street, commercial and other land uses.

10 Norbert J. Stefaniak, Industrial Location Within the Urban Area, University of Wisconsin School of Commerce, Madison; 1962.

## G. DATA REQUIREMENTS

The principal data requirement difficulties in the model arise from zonal definitions. Although much of the required socio-economic data is available from the federal census, it is available by census tracts, most of which are too large to be used for model zones. Additional surveys using statistically selected samples will be needed to supplement census data the necessary land use data. It would be well if zonal boundaries could be established to coincide with data collection for urban renewal and other activities of local governments within the region.

## H. MODEL TESTING AND USE IN PLANNING AND DESIGN

The same development sequence used in the regional activity model of initial formulation, debugging, validity verification and sensitivity analysis will be applicable to the spatial activity model. The ultimate purpose of model application will be the determination of development policies necessary to attain any one of a number of possible future spatial activity patterns in the region. Such spatial activity patterns are essential inputs to the facilities planning models.

## I. CURRENT STATUS

All of the spatial activity model sector types have been tested on the IBM 704 computer. Synthetic data was used in these tests which were aimed at a verification of the internal consistency of the model. No attempt was made to relate model results to past land use changes in the region. The complete lack of relevant data made such tests impractical at this time.

During the next stage of the program, data collection and analysis will be directed toward the determination of relevant model coefficients for more extensive application of the model to the entire regional land use pattern.

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## CHAPTER IV

# TRANSPORTATION SYSTEM MODELS

### A. GENERAL

It was not an objective of this study to develop all of the models required for the regional land use-transportation study to be undertaken by the Southeastern Wisconsin Regional Planning Commission. Extensive research and application of transportation models has taken place in previous transportation studies in other metropolitan areas. The weak elements in these studies were usually centered in the economic and land use areas covered by the regional and spatial activity models of this study. Transportation models of trip generation, zonal interchange (origin - destination), mode and route choice were usually highly developed in all of the more recent studies. New transportation studies would do well to make use of the hard earned experience of these earlier studies. It might well be said that if as much attention had been paid to the regional economic and spatial activity patterns as had been devoted to traffic characteristics only minor improvements to previous study techniques would be required in this region.

Notwithstanding all of the work previously accomplished in previous transportation studies, in the areas of mode and route choice there is still a wide divergence of opinion as to the best approch. Further reservations could be expressed concerning the lack of an over-all structure interrelating the above stages into a common pattern. Improvements are also needed in system design once the travel demands are known. In many transportation studies, the major part of the effort is devoted to predicting future traffic demands and little time or effort is given to alternative system designs. In the final phases of this study, it was decided to investigate some alternative approaches to transportation system design to remove some of the discussed shortcomings before the time pressures of the proposed land use-transportation study make consideration of alternatives difficult.

The system design approach that seems to offer the greatest promise of alleviating most of the difficulties mentioned is that of electrical network analysis or linear graph theory. In the following paragraphs, the manner in which the network analysis concept could interrelate the design of the transportation network and make possible the consideration of optimal networks will be described.

### B. TRANSPORTATION SYSTEM DESIGN AND ELECTRICAL NETWORK THEORY

Research conducted by Grecco and Breuning[11] has demonstrated the basic feasibility of the application of network analysis to the determination of zonal interchange. In the electric network analogy, transportation demands or pressures are equivalent to voltages. These demands (voltages) are determined from land use, income and vehicle ownership data during the trip generation phase of the study in the standard manner. These voltages result in actual traffic flows (currents) in the network which are a function of the travel time resistances in the network. This distribution is usually determined between the zonal areas previously referred to in the spatial activity model. In the usual case alternate routes will be available between the same two zones and parallel circuit paths each having their own resistance (travel time) may be designated. Comparisons with the gravity and electrostatic models have been made in zonal interchange computations, and the results were encouraging.

The real benefits of the electrical network approach, however, do not derive from simplification of zonal interchange computations. It is true that some saving in computation costs and increase in accuracy might result in comparison with iterative gravity model computations. These savings might extend to a possible reduction in the amount of origin-destination survey data needed to achieve a given traffic forecast accuracy. Such a reduction could be extremely significant in reducing the cost of regional and metropolitan transportation studies.

[11] W. L. Grecco and S. M. Breuning, "Application of System Engineering Methods to Traffic Forecasting", Highway Research Board; 1962.

The real benefits, however, not emphasized by Grecco and Breuning, may derive from the improvement of transportation system design which the electrical network approach offers. All of the stages of transportation planning may be encompassed in a single integrated frame work. Trip generation provides a pattern of zonal demands (voltages) which are distributed between zones, modes and routes as a balanced electrical network. System design involves the modification of the values and topology of the resistance network. Alternative system designs may be analyzed entirely within the framework of network analysis. It will even be possible to consider alternate land use effects through variations in the voltage matrix of the network. The network construction method would seem to be decidedly superior to the present approaches which combine gravity model zonal interchange determination with least time route choice and completely independent analytical methods of system modification.

System design using electrical network theory is further enhanced by the relationship that exists between an electrical network in equilibrium and the optimal solution of a mathematical programming problem. Dennis[12] has demonstrated that certain linear programming problems have a direct physical analogy in an electrical network containing voltage sources, current sources and ideal diodes. If the voltage and current sources are set to values corresponding to the data of the programming problem, the optimal solution may be found by simply measuring currents and voltages at appropriate points in the network, that is, the electrical network automatically forms a current distribution which forms an optimal solution to the programming problem. This relationship can provide a powerful tool in transportation system design.

Another important and related consequence of this analogy is the promise it holds for interrelating the design of transportation facilities (highways, mass transit, etc.) with the traffic operation of these systems. With network capacities established, the network solution will be optimal for the operation of the existing system. In other words, the network solution will define the best performance to be expected from the system in traffic operations. Alternative changes in capacities may be concurrently considered with changes in operational procedures.

In the past, the planning of transportation facilities was often quite isolated from the problems of traffic operation. Even today, with the emphasis on metropolitan transportation studies to meet future demand, little consideration is usually given to the decision rules and techniques for operating these facilities. Design is considered only in terms of providing so much capacity. System effectiveness will always depend on both the capacity of the basic facilities and the decision rules or operating procedures for using these facilities. It still seems, that despite all the studies and complex design of multi-lane freeways, the traffic engineer is left with the problem of operating the system after it is designed.

The final phase of this study will be concerned with investigating the basic feasibility and techniques of the network approach to transportation system design. Significant progress in this area has already been made by Grecco, Breuning, Dennis and personnel at the Rand Corporation.[13]

## C. CURRENT STATUS

The network approach to transportation system design is being tested on a small network in the City of Waukesha, Wisconsin. The availability of origin-destination traffic planning land use data, together with previous application of this data by the State Highway Commission,[14] using a gravity model for interzonal transfer and a least time model for traffic assignment, provide a basis for comparison with the network technique. Tests of the model in Waukesha are scheduled for completion by June of 1963. At that time, it will be possible to evaluate the effectiveness of the proposed model and its probable usefulness in the regional land use-transportation study.

[12] J. B. Dennis, Mathematical Programming and Electrical Networks, Technology Press and John Wiley, New York; 1959.

[13] L. R. Ford, Jr. and D. R. Fulkerson, Flow in Networks, Princeton University Press, Princeton, New Jersey; 1962.

[14] M. Rothenburg, A Traffic Analysis of the Waukesha Thorough-fare Plan, The State Highway Commission of Wisconsin; 1961.

## CHAPTER V

# WATER RESOURCE SYSTEM MODEL

### A. GENERAL

The flow nature of water supply and waste-water disposal systems make them particularly well suited to the system simulation approach. The analogy between the flow of water and flow equations is direct, and model test results may be directly compared with water flow measurements.

Fundamentally, a water system model will represent water in quantity, quality, time and place. Surface and ground sources of supply will be represented in a spatial zonal framework along with multi-purpose municipal, industrial and agricultural uses. Man-made structural installations and equipment may be represented in their functions of modifying the quality, quantity or time-place location of water.

The model will be used to determine requirements for new facilities and operating rules of regional metropolitan and local water systems. Compromises between the demands of conflicting needs for flood control, municipal and industrial water supply, waste-disposal and other uses may all be determined in model experimentation.

Application of system simulation models to the design of multi-unit multi-purpose water resource systems was inaugurated by the Harvard Water Program at the Harvard University Graduate School of Public Administration.[15] In this five year study program, system simulation design was compared with conventional intuitive and analytical design techniques. Although this program used as its experimental example a "western-type" river basin system in which power generation, irrigation and flood control were the major uses considered, the design techniques are equally applicable to water systems in urbanizing regions, such as Southeastern Wisconsin. The Harvard Water Program is a splendid example of theoretical and applied research and provides an excellent background for regional water system design projects.

### B. MODEL ORGANIZATION

The fundamental surface water system entity is a river basin or watershed. Storm drainage and waste disposal are usually accomplished within this fundamental river basin system network. In an urban area, however, the river basin unit is often modified by complex area-wide water supply and sewerage systems that encompass a number of river basin complexes. In the Milwaukee area, for example, most of the water supply originates in Lake Michigan, and the metropolitan sanitary sewerage system terminates in Lake Michigan, but both the water supply and sanitary sewerage systems overlap several river basins. Only storm drainage seems to conform strictly to river basin boundaries. This complex nature of water flows in the region make it necessary to select the areal zone as the basic unit of the model.

In a particular zone all of the supplies and uses of water may be portrayed. Ground water and surface water together with a central areawide water supply will provide the sources of supply. Agricultural, domestic and industrial consumption and waste-disposal carriage will provide the demand.

Water supply sources will be treated as inputs to the zone. A typical zone might have the following supply inputs:

1. Precipitation
2. Surface water flows
3. Ground water
4. Municipal water from an areawide system.

[15] Arthur Maas et al, Design of Water Resource Systems, Harvard University Press, Cambridge, Massachusetts; 1962.

These inputs will be characterized in terms of both quantity and quality. The second and fourth inputs will be the outputs of adjoining zones, while the first and third will be generated internally. Precipitation will be treated as a random process based upon the hydrologic cycle as expressed in long term precipitation records. The surface water inputs will have seasonal and longer term fluctuations as in the actual system and will be based upon long term gauging records. Ground water supply inputs will be a function of the water table level which in turn is affected by the natural recharge through the hydrologic cycle.

The characteristics of the zone will modify the quantity and quality of the zonal inputs. Structural characteristics will vary widely, but a complex zone might contain the following uses:

1. Withdrawal (consumptive) uses. (Many agricultural domestic and industrial uses, soil moisture and evaporation fall in this category.)
2. Non-withdrawal - flow uses
   a. Domestic carriage
   b. Industrial waste carriage
3. Non-withdrawal - on-site uses
   a. Recreation
   b. Navigation
   c. Wild life ecology
4. Withholding uses (flood Control)
5. Ground water table level
6. Water treatment (modifies quality)
7. Water inventory facilities (dams, reservoirs that modify time-place-quantity parameters.)

The outputs of the zone will be modified in quantity and quality from the inputs. Withdrawal uses will have reduced the quantity of the inputs. Waste control flow uses will have degraded the quality of the water inputs. Water treatment will have improved the quality, and water dam or reservoir facilities will have stored water for future use. Surface, ground or municipal system outflows serve as inputs to adjacent zones.

The regional water system model will be composed of a large number of zonal segments. Each zone receives inputs which are transformed and transmitted to other zones in a complex input-output network structure.

Most of the zones will be similar in their equation structure since domestic uses will predominate. Differences will occur in zones where major industrial users or treatment plants are located. Other differences will result from ground water characteristics and large surface water locations. Even when the equation structures are similar, the numerical value of the equation parameters may vary widely from one zone to another.

With the model formulated, it will be possible to test a wide variety of system changes using the simulation model. To understand the nature of these changes, a better understanding of the nature of water problems is required.

## C. WATER PROBLEMS AND SYSTEM SIMULATION

The water problem is one of matching water demand and water supply in quantity, quality, time and place. Three major groups of problems exist in achieving this supply-demand balance:[16]

1. Water Quantity
   The water supply demanded may consistently exceed the available supply.
2. Timing Discontinuities
   Fluctuation in supply may not correspond with fluctuation in demand so that water is not available at the time and place needed.
3. Water Quality
   The quality of the water may not be acceptable for its intended uses.

[16] E. A. Ackerman and G. O. Loef, Technology in American Water Development, Resources for the Future, Inc., Johns Hopkins Press, Baltimore, 1959.

Most water management projects have the objective of alleviating one or more of these three problems. Dams and retention basins are built to alleviate the effects of timing discontinuities by storing water for future use. Artificial ground recharge systems are used for the same purpose. Water treatment facilities are used to improve water quality. Techniques and methods to reduce evaporation of water in reservoirs are means used to increase the average supply. All of these projects and others are interrelated in their effects on the total system. This complex interrelation of supply and use make it necessary to use a simulation model in system evaluation. The alternative is a project-by-project approach to evaluation which can never accomplish the balanced-interrelated system needed.

Experimental evaluation of the water system using a simulation model will provide integrated answers to:

A. The type, capacity and location of needed water equipment and facilities
B. Priority rules for scheduling conflicting water uses
C. The timing of water control decisions.

The striking advantage of system simulation analysis is that it can evaluate any proposed project in terms of its cost and benefit effects on the entire system. In such analysis, it can consider systems in a detail feasible with no other approach to the problem. The Harvard Water Project has demonstrated the basic feasibility of system simulation in water resource systems. Time and competent technical effort is needed, however, to apply this approach to actual complex water systems. A sample set of model equations for a typical zonal subdivision is shown in Appendix III.

## D. RECOMMENDATIONS FOR FUTURE APPLICATIONS

The unique pioneering nature of the application of system simulation models to regional water resource systems would make it seem both possible and desirable to seek assistance for such application through a research-planning grant. The nature of such actual application would both advance and complement other work now underway elsewhere.

Since the technology involved in water resource systems is quite extensive and diverse, it will be necessary to obtain the cooperation of a number of governmental and industrial organizations in such application. The governmental agencies might include:

1. U.S. Geological Survey
2. U.S. Public Health Service
3. U.S. Corp of Engineers
4. Soil Conservation Service
5. State Department of Resource Development
6. State Conservation Department
7. State Committee on Water Pollution
8. State Soil and Water Conservation Committee
9. Metropolitan Sewerage Commission of the County of Milwaukee
10. State Board of Health
11. State Public Service Commission

These agencies, along with the many companies developing and manufacturing equipment and constructing water system installations, could provide the descriptive detail and data sources needed in model development. Even with all of this assistance, however, it is likely that additional water quantity and quality measurements will need to be made to completely implement the model for system design.

Primary cooperation will be required with the U.S. Geological Survey. The data collection program of this federal agency within the region should be coordinated with the requirements of the system model. Model requirements will indicate the locations where real-time data can best contribute to improving model validity. The recent augmented program suggested by U.S.G.S. to the regional planning commission could well form the basis for a combined data collection-system simulation model program.

It is important to emphasize that this water system project can not only contribute in a major way to development of this region, but also can make a major contribution to the advance of water systems planning and technology.

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## CHAPTER VI

# RETROSPECT AND PROSPECT

The first stage of the regional planning system study program has been concerned with the preliminary formulation of mathematical models for regional planning in Southeastern Wisconsin. A proper perspective of the usefulness of these models in regional planning is best gained by relating them to current and future programs of the commission. For this reason, this final chapter of the report is devoted to the relationship of this study to the over-all planning program of the Southeastern Wisconsin Regional Planning Commission.

The initial objective of this study was to develop a complete system of regional planning models and the data collection and processing procedures to implement the use of these models. Time and budgetary limitations made it advisable to accomplish this objective in the two-stage program described previously in this report. The first stage, now completed, provided for the preliminary formulation of the mathematical models; the second for a data collection and processing system to implement the practical use of the models.

Three of the four mathematical models - the regional activity model, the spatial activity model and the transportation model - will be continued under the regional land use-transportation study now being developed by the commission. Further development of the fourth model, the water system model, is dependent on additional financial support from outside organizations. With such support, the water system model could be interrelated with the watershed planning programs now getting underway in the region.

Initial mathematical model development under the HHFA P-6 program has provided:

1. The framework for a regional data collection and processing program for general regional planning;

2. Specific models for use in economic, land use, transportation and water resource planning and development.

Model development on this study has been coordinated with the other P-6 planning studies on economic structure, population, natural resources and public utilities which will provide preliminary data for further model testing and development.

Two additional features of the regional planning models should be understood for a proper appreciation of their future use. First, it is important to emphasize the pioneering nature of this program. In no other regional or urban planning program have mathematical models been used as extensively as in Southeastern Wisconsin. The most significant previous attempt of this kind has taken place in the Penn-Jersey Transportation Study. The emphasis here was on a regional growth model similar in objective though not in structure to the spatial activity model. Even here, however, there was no attempt to develop a functional economic model similar to the regional activity model. Such a development probably was not considered within the scope of a regional transportation study.

Any attempt at pioneering in new methods of regional planning involves certain risks. While it is important to re-emphasize that none of the models are new in a research sense since each of the models has been tried in other applications, the combination of the models and the actual model equations are new, having never been applied to regional planning prior to this time.

Difficulties in the further development and use of these models in regional planning are possible in two areas:

1. Difficulties in obtaining the data required to apply the models.

2. Difficulties in obtaining sufficient accuracy in the model representation of the real life system.

The first difficulty is inherent in the use of any model of this kind and has often been a handicap in the application of such models in the past. Recent experience on the P-6 economic structure study indicates, however, that input-output data is available from regional firms, and this data can be and is being obtained through company interviews. This is not to minimize data collection and interpretation difficulties since some of the internal data may yet present problems, but initial experience does give cause for optimism.

The question of model validity and accuracy will never be answered until the model has been tested and compared with historical records, but general experience with industrial simulation models of lesser scope indicates that such models can be extremely useful in the fulfillment of their primary purpose: as an aid in the determination of policies for the attainment of a desired pattern of regional economic or regional land-use development.

This model application must not be confused with a second but quite different possible application - that of forecasting future regional economic (or land use) activity. In this second application, it is highly likely that the models will prove to be superior to techniques involving extrapolation of current trends or approaches which assume that industries in this region will follow national trends. Even a perfect model will be limited in its forecasts, however, by unforeseen changes in activities outside the scope of the model.

A second major feature to be recognized is that the regional planning program can be successful even though the models should not provide the highest level of performance in all respects. It is firmly believed that even a partial degree of success in the application of these models to regional planning will provide new opportunities for understanding and therefore shaping the development of the region. Nonetheless, it must be recognized that the very admirable objective of pioneering new methods of regional planning must not jeopardize the need to satisfactorily complete the transportation, water resource and other studies in the region on schedule. To prevent the possibility of such a delay, data collection and processing are being designed to allow for conventional methods of analysis as well as the systems simulation approach.

More specifically, economic data collection and analysis will allow for a conventional economic base (and structure) study and projections in addition to providing data for the regional activity model. Land use data will allow for conventional projection approaches in addition to its use in the spatial activity model. Transportation and traffic data may be applied to the same traffic assignment models used in the Chicago and Pittsburgh transportation studies as well as providing the basis for a new transportation network model. Water resource planning may be conducted on a statistical and intuitive basis without the benefit of a water systems model.

In each of the above model applications, the planning models have a potential for significantly increasing the benefits of regional planning, but in each instance satisfactory completion of the program is possible without them. At a minimum economic, land use, transportation and water resource studies comparable in quality to those completed in other areas will result. Beyond this minimum, significant contributions to the advancement of regional planning are possible.

## APPENDIX I

# REGIONAL ACTIVITY MODEL DESCRIPTION

### A. GENERAL

The model equations will be explained in the following sector sequence:

1. Manufacturing Sectors
2. Model Sectors similar in basic format to the manufacturing sector, i.e., agriculture, construction, utilities, services and trade
3. Education Sector
4. Financial Institutions Sector
5. Government Sector
6. Household Sector
7. Extra-regional Sectors

The manufacturing sector is first described because of its basic function in the region and because it served as the initial point in the development of the model equation format. The extra-regional sector equations will be presented without comment except in instances where they differ substantially from the intra-regional equations.

The equation format is based upon the use of the DYNAMO compiler developed at the School of Industrial Management of the Massachusetts Institute of Technology. DYNAMO is a computer compiler that enables the systems analyst to write the model equation in a conventional form. The compiler translates these equations into the computer language of the IBM 704 or IBM 7090. The model is basically recursive in nature, and the equations are difference equations. In DYNAMO three successive time periods are designated as J, K and L. WIP.K means the work in process at time K, the current time. IN.JK means the inflow between times J and K, i.e., the time interval JK. Except for these time subscripts, DYNAMO equations are difference equations in an algebraic format. The code number to the left of each equation designates the type of DYNAMO equation. For additional information on DYNAMO, the reader is referred to Forrester's book[17] or the user's manual by Pugh[18].

### B. MANUFACTURING SECTORS - INTRA-REGIONAL

1. General

Since all eight of the manufacturing sectors of the model are identical in format only one, Electrical Machinery Manufacturing (SIC36), will be described here. The equations for the other sectors will only be referenced.

The external relationships will first be described and then the internal relationships of the sector.

2. External Relationships

The external equations of the sector designate the destination of the output of the sector, inside and outside the region.

| | | | |
|---|---|---|---|
| 7R | S36.KL | = | ES36.K + IS36.K |
| | S36 | - | Total sales, sector 36 |
| | ES36 | - | Export sales, sector 36 |
| | IS36 | - | Internal sales, sector 36 |
| 17A | ES36.K | = | (S3696) (E3696) (ERP96.JK)+. . . . |
| | | + | (S3694) (E3694) (EEP94.JK)+. . . . |
| | S3696 | - | Ratio of sales of 36 to 96 (external manufacturing) |
| | E3696 | - | Region's market share of 3696 sales |

17 J. Forrester, <u>Industrial Dynamics</u>, John Wiley, New York; 1961.

18 A. L. Pugh III, <u>Dynamo User's Manual</u>, M.I.T. Press, Cambridge Massachusetts; 1962.

| | | |
|---|---|---|
| ERP96 | - | Raw material (or components) purchases by 96 (external manufacturing) to be used in the assembly of products |
| S3694 | - | Ratio of sales of 36 to 94 (external electric utilities) |
| E3694 | - | Region's market share of 3694 sales |
| EEP94 | - | Expansion purchases by 94 used as capital equipment for production of power. |

The first equation expresses total sales as the sum of export and intra-regional sales. The second expresses external sales as dependent on the customers' purchases, the inter-sector coefficients and the regional market share. Raw material-component purchases are separately considered from capital equipment purchases. The internal sales equation has similar definitions.

17A IS36.K = (S3635) (I3635) (RP35.JK)+. . . .
(S3638) (I3638) (EP38.JK)+. . . .

I3638 - Internal market share

The complete set of equations will link the electrical machinery sector (36) to all other sectors with which it conducts transactions.

3. Internal Relationships
   a. General
      The internal equations are classified in the following subsectors:
      1) Production
      2) Marketing
      3) Personnel
      4) Finance
      5) Plant and Equipment
   b. Production
      Purchased material and components (RP36) are accumulated in the raw material inventory (RI36) out of which they flow into production and then to finished goods inventory.

| | | |
|---|---|---|
| 1L | RI36.K=RI36.J+(DT)(RP36.JK-RMU36.JK) | Raw Material Inventory |
| 40R | RP36.KL=RG36.K+(1/TR36)(RD36.K-RI36.K) | Raw Material Purchased |
| 40A | PD36.K=SS36.K+(1/TI36)(ID36.K-FG36.K) | Production Desired |
| 51A | PI36.K=CLIP(PD36.K,PE36.K,PE36.K,PD36.K) | Production Initiated |
| 12A | PE36.K=(PEV36.K)(PE36C) | Production Possible |
| 12R | RMU36.KL=(RFG36)(PI36.K) | Raw Material Used |

   c. Marketing
      The marketing equations define the reception and processing of sales orders. New orders accumulate in unfilled orders (U036) and are later shipped (GS36) from finished goods inventory (FG36). Smoothed Sales are determined from a moving time average of past orders. The desired levels of finished (ID36) and raw material inventories (RD36) are determined as functions of smoothed sales.

| | | |
|---|---|---|
| 1L | U036.K=U036.J+(DT)(S36.JK-GS36.JK) | Unfilled Orders |
| 20A | G36.K=U036.K/SD36 | Goods to be shipped |
| 1L | FG36.K=FG36.J+(DT)(PI36.JK-GS36.JK) | Finished Goods Inventory |
| 3L | SS36.K=SS36.J+(DT)(1/TS36)(S36.JK-SS36.J) | Smoothed Sales |
| 20A | F36.K=FG36.K/DT | Finished Goods Possible to be shipped |
| 51R | GS36.KL=CLIP(F36.K,G36.K,G36.K,F36.K) | Goods Shipped |
| 12A | ID36.K=(SS36.K)(FGC36) | Finished Goods Inventory Desired |
| 12A | RG36.K=(SS36.K)(RFG36) | Raw Goods Purchases Desired |
| 12A | RD36.K=(RG36.K)(RMC36) | Raw Material Inventory Desired |

   d. Personnel
      Direct (factory wage) personnel is a function of the production rate and indirect (salaried) personnel level is dependent on smoothed sales.

| | | |
|---|---|---|
| 20A | DP36.K=PI36.K/DPC36 | Direct Personnel |
| 20A | IP36.K=SS36.K/IPC36 | Indirect Personnel |

# MANUFACTURING SECTOR
# PRODUCTION SUBSECTOR

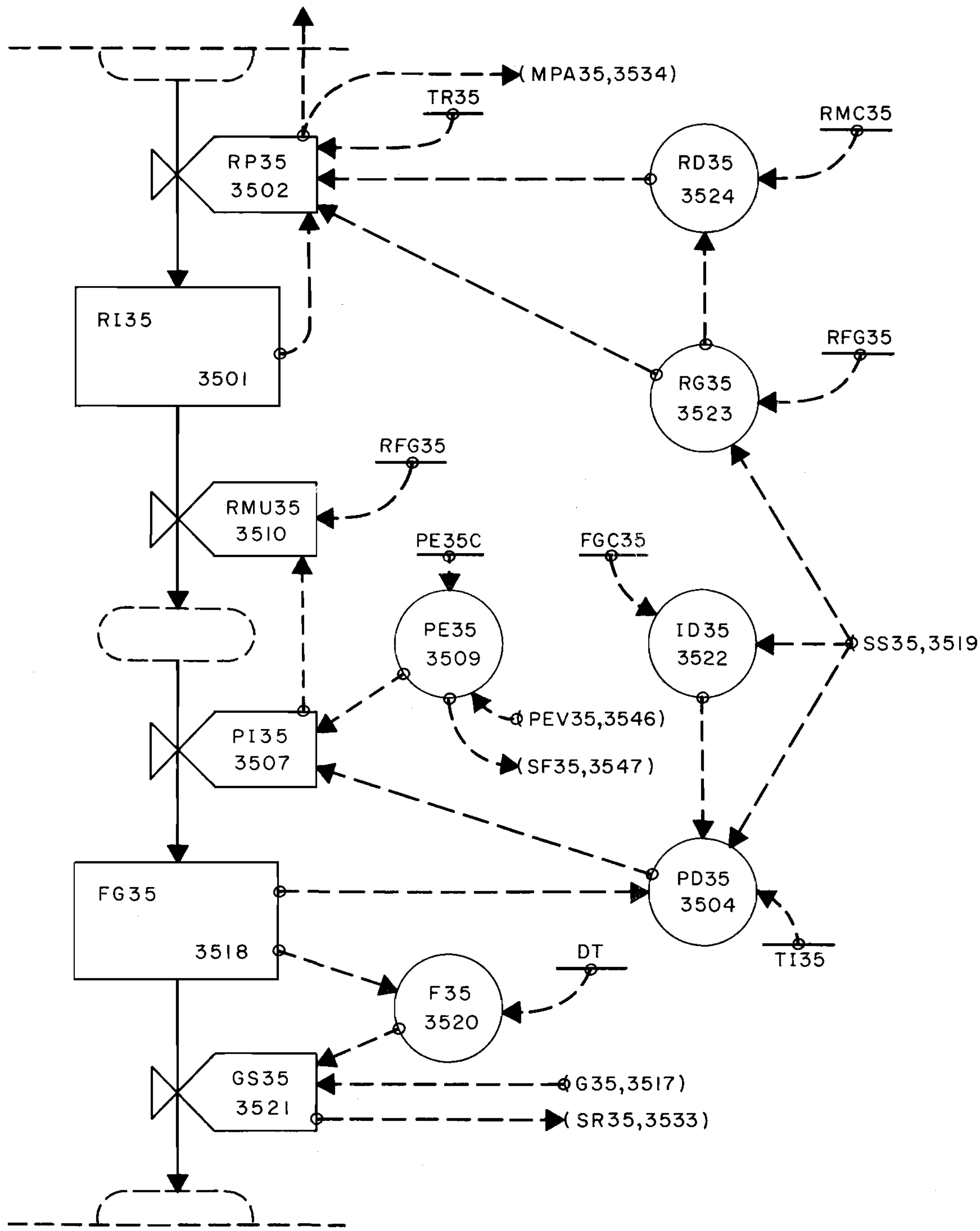


FIGURE 6

# MANUFACTURING SECTOR
## MARKETING SUBSECTOR

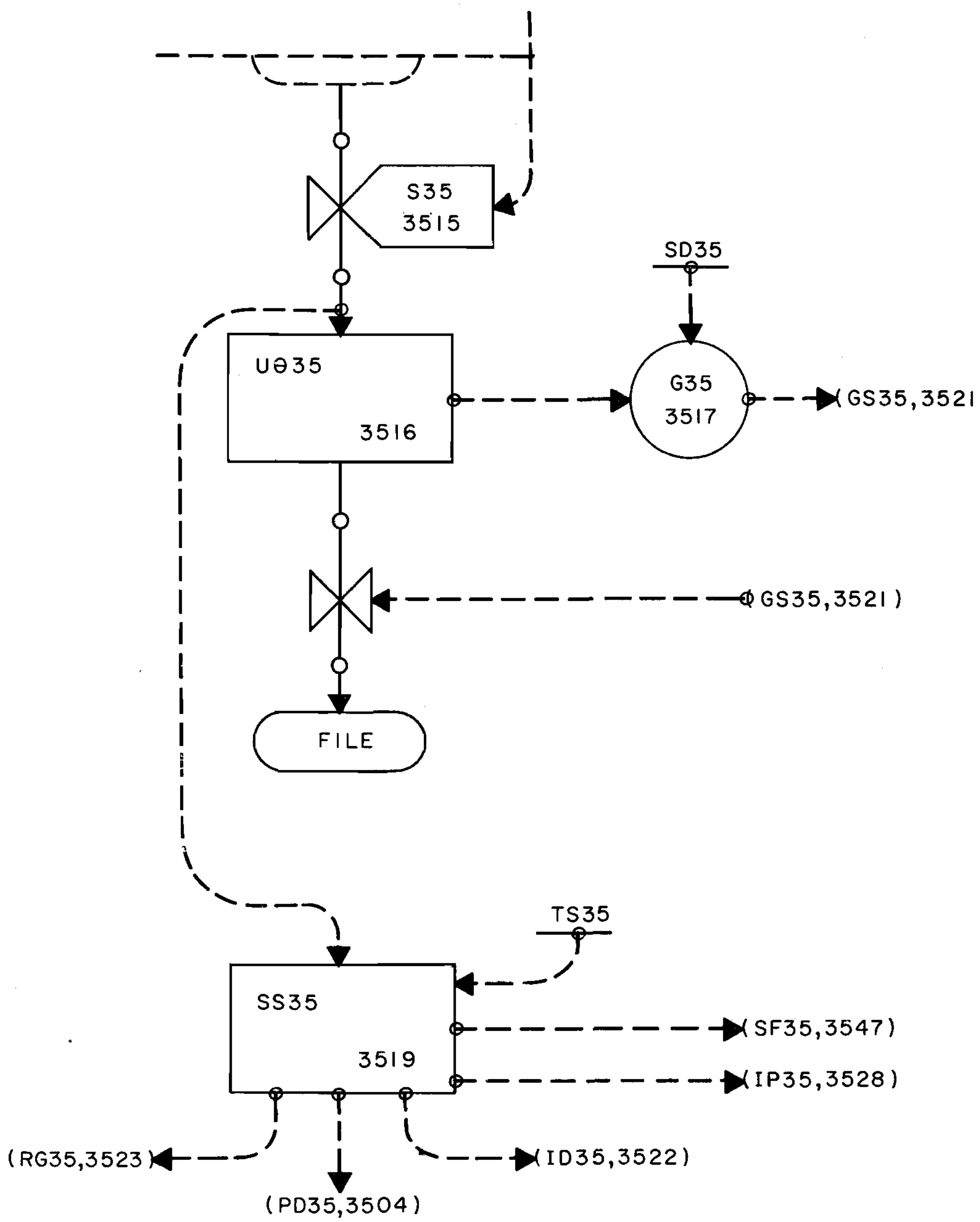


FIGURE 7

# MANUFACTURING SECTOR
## PERSONNEL SUBSECTOR

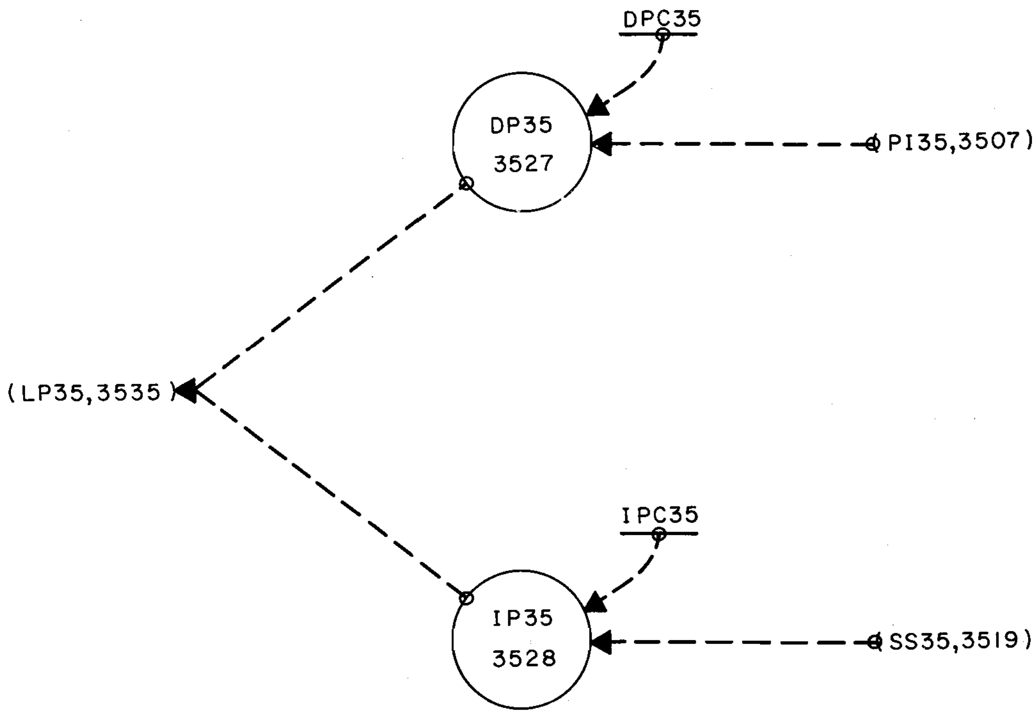


FIGURE 8

e. Finance

The central focus of this subsector is on the cash level (which would also include bonds and other liquid securities). Cash level (CA36) is changed by operational (short term) cash flows (OP36) and external financing.

| | | |
|---|---|---|
| 1L | CA36.K=CA36.J+(DT)(OP36.J+EF36.J) | Cash |

Operational flow is positive - adding to cash balance - from revenue obtained from goods shipped (GS36) and negative - reducing cash balance for raw material purchases (RP36), labor wage-salary payments (LP36), interest and debt retirement payments (IAD36), tax payments (TP36), capital expansion payments (EP36), and dividend payments (DIV36).

| | | |
|---|---|---|
| 11A | OP36.K=GS36.JK-RP36.JK-LP36.JK-IAD36.JK-TP36.JK-EP36.JK-DIV36.JK | Operational Cash Flows |
| 12R | LP36.KL=(WR36C)(DP36.K+IP36.K) | Labor Payments |
| 14R | IAD36.KL=DR36.K+(IR36C)(DBT36.K) | Interest and Debt Payments |
| 1L | DBT36.K=DBT36.J+(DT)(EDF36.JK-DR36.J) | Debt Level |
| 12R | EDF36.KL=(DER36)(EF36.K) | External Debt Financing |
| 51A | EF36.K=CLIP(-OP36.K,O,MNP36.K,OP36.K) | External Financing |
| 12A | DR36.K=(DBT36.K)(CDR36) | Debt Retirement |
| 12R | DIV36.KL=(DIR36C)(PO36.K) | Dividend Payments |
| 12R | TP36.KL=(PO36.K)(TAXC) | Tax Payments |

Labor payments depend on the wage-salary rate (WR36C) and the number of direct personnel (DP36) and indirect personnel (EP36). Interest and debt retirement payments depend on the debt retirement rate (CDR36) and the interest rate (IR36C) and the debt size (DBT36). Dividend and tax payments depend on the profits (PO36) and tax-dividend (TAXC) (DIR36C) rates.

f. Plant and Equipment

Plant and equipment are procured to replenish obsolescent and depreciated property. The plant and equipment value (PEV36) level is increased by expansion payments (EP36) and reduced by depreciation (DE36). Expansion payments depend on expansion rate (ER36), which is a function of operating profit (OP36) and the level of sales (SL36).

| | | |
|---|---|---|
| 12R | DE36.KL=(DEP36)(PEV36.K) | Depreciation |
| 13R | EP36.KL=(ER36.K)(PEV36.K) | Expansion Payments |
| 1L | PEV36.K=PEV36.J+(DT)(EP36.JK-DE36.JK) | Plant and Equipment Value |
| 44A | SF36.K=(SS36.K)(MSC36)/PE36.K | Sales Figure |
| 7A | SL36.K=SF36.K-1.0 | Sales Level (+ or -) |
| 20A | E36R.K=SL36.K/EAT36 | Expansion (+ or -) |
| 51A | PO36.K=CLIP(OP36.K,O,OP36.K,O) | Positive (+) Operating Profit |
| 51A | E36P.K=CLIP(E36.R.K,O,E36R.K,O) | Expansion (+) |
| 51A | ER36.K=CLIP(E36P.K,O,OP36.K,MNP36.K) | Expansion Rate |
| 12A | MNP36.K=(-CA36.K)(FCU36) | Minimum Net Profit |

4. Initial Conditions

The initial conditions for external and internal model computations are expressed in the equations below. In the DYNAMO compiler all levels and some rates require initial condition equations or constants.

| | | |
|---|---|---|
| 13N | RI36=(SS36)(RFG36)(RMC36) | N-Raw Material Inventory |
| 12N | UO36=(GS36)(SD36) | N-Unfilled Orders |
| 12N | FG36=(SS36)(FGC36) | N-Finished Goods Inventory |
| 6N | SS36=S36 | N-Smoothed Sales |
| 6N | CA36=Constant | N-Cash |
| 6N | DBT36=Constant | N-Debt Level |
| 6N | PEV36=Constant | N-Plant and Equipment Value |
| 12N | RP36=(SS36)(RFG36) | N-Raw Material Purchased |
| 6N | GS36=SS36 | N-Goods Shipped |
| 12N | DE36=(DEP36)(PEV36) | N-Depreciation Payments |
| 18N | LP36=(WR36C)(DP36+IP36) | N-Labor Payments |

# MANUFACTURING SECTOR
## FINANCE SUBSECTOR

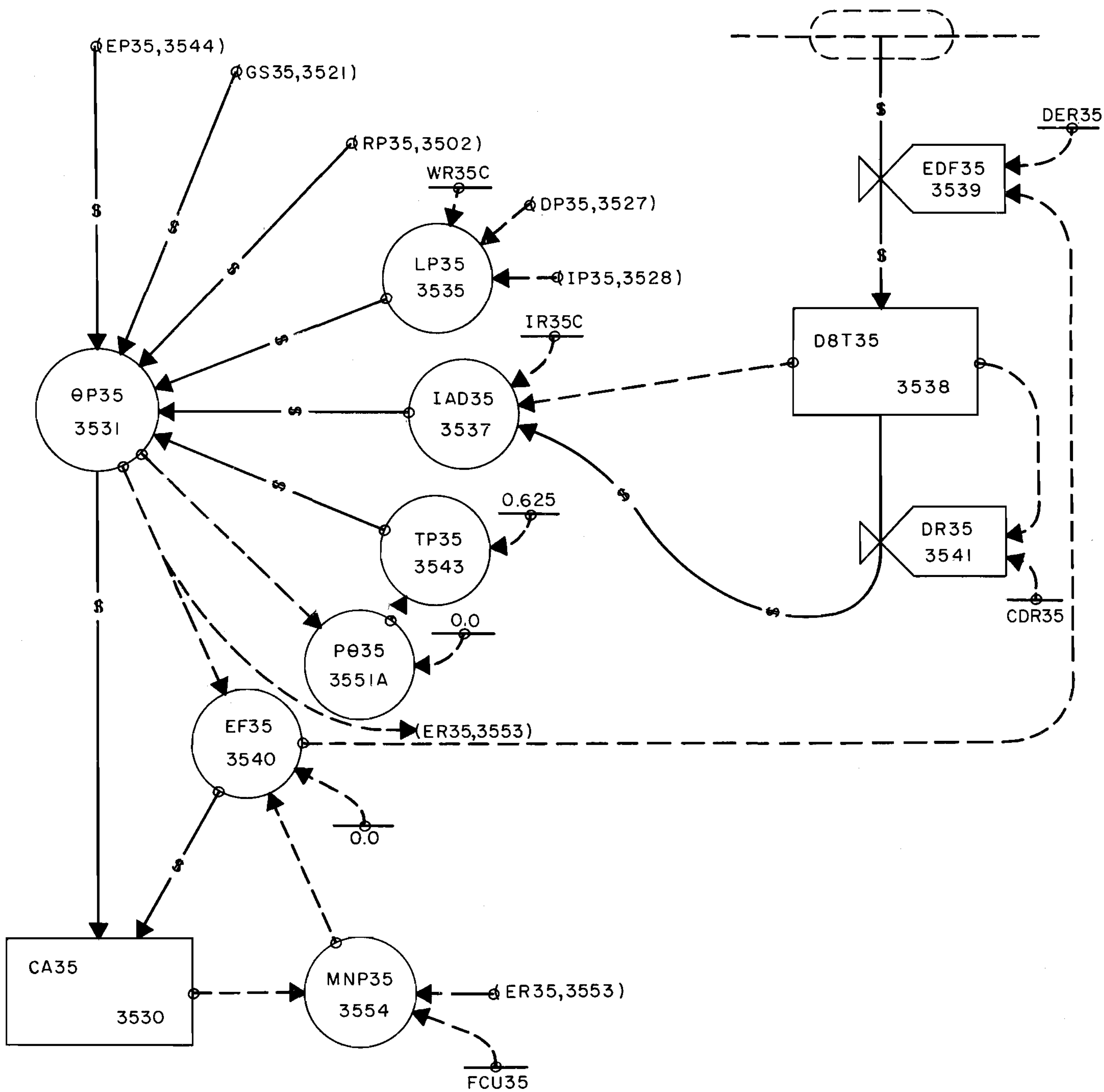


FIGURE 9

# MANUFACTURING SECTOR
# PLANT & EQUIPMENT SUBSECTOR

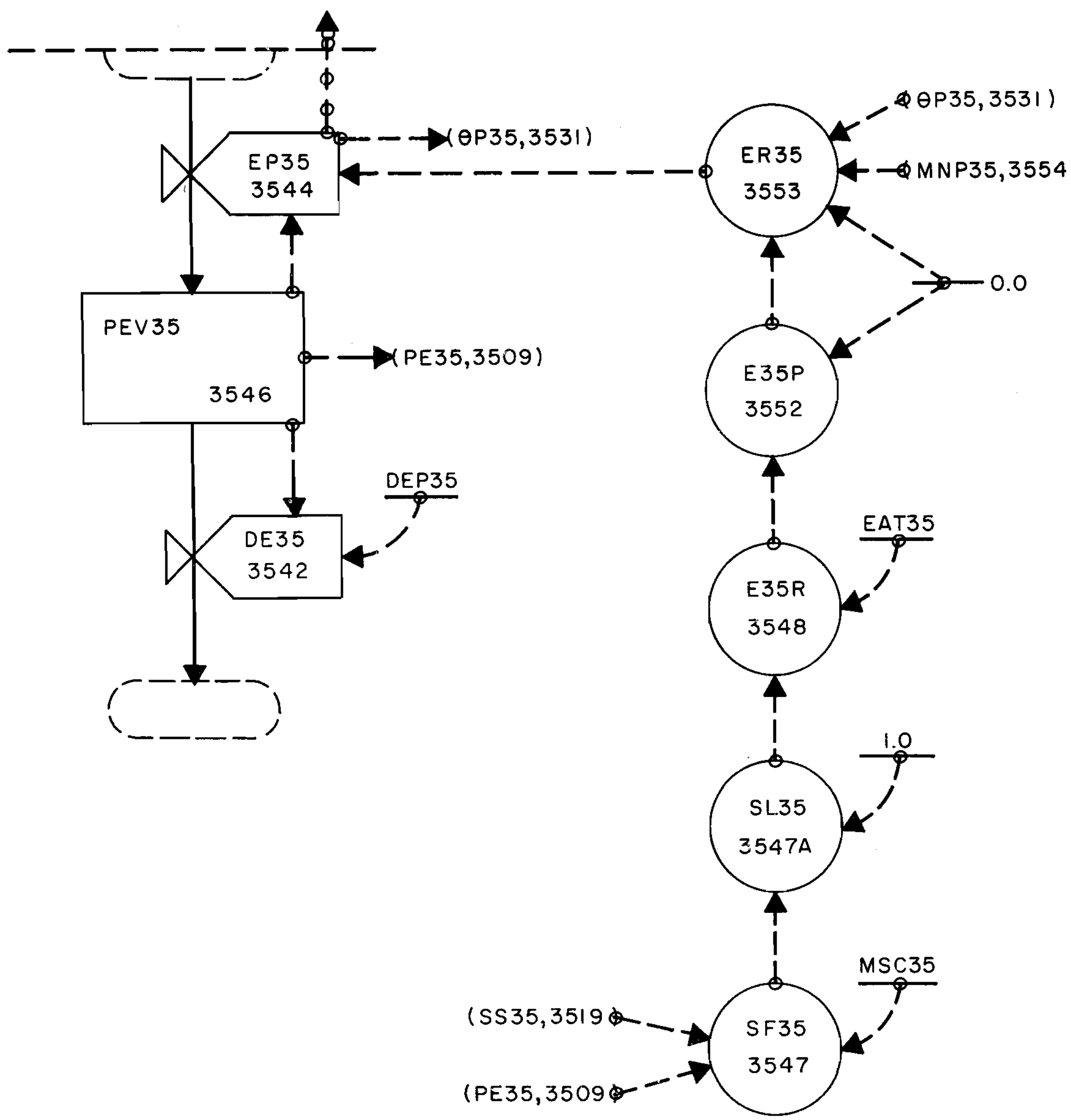


FIGURE 10

| | | |
|---|---|---|
| 14N | IAD36=DR36+(IR36C)(DBT36) | N-Interest and Debt Payment |
| 12N | TP36=(PO36)(TAXC) | N-Tax Payments |
| 6N | EP36=DE36 | N-Expansion Payments |
| 6N | PI36=SS36 | N-Production Initiated |

Note: N is used in abbreviation for initial.

5. Constants

Dynamic behavior of the model will depend jointly on the equations just described and the model constants. These constants will be determined in the data collection and processing phase of the program. The symbols for these constants are shown below:

| | | |
|---|---|---|
| C | TR36=Constant | Raw Material Inventory Adjustment Time |
| C | TI36=Constant | Finished Goods Inventory Adjustment Time |
| C | DPC36=Constant | Direct Personnel Productivity |
| 20N | PE36C=PE36/PEV36 | Plant-Equipment Production Coefficient |
| C | SD36=Constant | Production-Shipping Delay |
| C | TS36=Constant | Sales Smoothing Time |
| C | FGC36=Constant | Finished Goods Inventory Constant |
| C | RMC36=Constant | Raw Material Inventory Constant |
| C | RFG36=Constant | Raw-Finished Goods Ratio |
| 12N | IPC36=(PAR36)(DPC36) | Indirect Personnel Productivity Coefficient |
| C | PAR36=Constant | Administrative Ratio |
| C | WR36C=Constant | Wage Rate |
| C | IR36C=Constant | Interest Rate Coefficient |
| C | DER36=Constant | Debt Ratio of External Financing |
| C | CDR36=Constant | Coefficients for Debt Retirement |
| C | DEP36=Constant | Depreciation Rate |
| C | FCU36=Constant | Fraction of Cash Used |
| C | MSC36=Constant | Maximum Sales Coefficient |
| C | NER36=Constant | Non-Debt Ratio of External Financing |

6. Symbology

Symbols used in the above equations and their units are defined in the list below. Dollar equivalent units ($ - equiv.) represent the dollar value of non-money flow. R$ - equiv. designates the raw (unfinished) value. F$ - equiv. designates the finished value.

Levels (or Auxiliaries)

RI36 = Raw material inventory (R$ - equiv.)
UO36 = Unfilled sales orders (F$ - equiv.)
FG36 = Finished Goods Inventory (F$ - equiv.)
SS36 = Smoothed Sales (F$ - equiv.)
DP36 = Direct Personnel employed in production (men)
IP36 = Indirect personnel employed in sales, research, engineering and administration (men)
CA36 = Cash and liquid securities ($)
DBT36 = Debt ($)
PEV36 = Plant and equipment value ($)
DR36 = Debt Retirement ($/wk)

Rates (or Auxiliaries)

RP36 = Raw Material Purchases (R-$ equiv./wk)
PE36 = Plant and equipment production possible as a maximum limit ($ - equiv./wk)
GS36 = Goods shipped per week ($ - equiv./wk)
DE36 = Depreciation of plant and equipment ($/wk)
LP36 = Labor payments to direct personnel ($/wk)
IAD36 = Interest and debt retirement payments ($/wk)
TP36 = Tax payments (% of operation profit) ($/wk)
EP36 = Expansion payments for new plant and equipment ($/wk)
DIV36 = Dividend payments - a % of net profit ($/wk)
PI36 = Production initiated in the plant (F $ - equiv./wk)

Constants

TR36 = Raw material inventory adjustment time (wks)
TI36 = Finished goods inventory adjustment time (wks)
PE36C = Plant and equipment investment factor

$$\frac{(\text{F \$ - equiv./wk})}{(\text{\$ invested})}$$

SD36 = Shipping and production delay (wks)
TS36 = Sales Smoothing Time (wks)
FGC36 = Finished goods inventory constant (wks) - the number of wks of smoothed sales
RMC36 = Raw material inventory constant (wks)
RFG36 = Raw material to finished goods ratio (R$ - equiv/F$ - equiv)
OV36C = Overtime production constant =

$$\frac{\text{overtime production (\$ - equiv/wk)}}{\text{Production desired (\$ - equiv/wk)}}, \text{a } (\%)$$

WR36C = Wage-salary rate ($man-wk)
IR36C = Interest rate on debt (%/wk)
DIR36C = Dividend rate
DER36 = Debt Ratio of external financing (%)
CDR36 = Constant for debt retirement (%/wk)
DEP36 = Depreciation rate of plant and equipment (%/wk)
EAT36 = Expansion Adjustment Time - (wks)

$\frac{1}{\text{EAT36}}$ is that fraction of needed expansion which is authorized each week.

FCU36 = That fraction of cash and liquid securities which is allowed to be used during a period of negative net profit without external financing being present (%/wk)
CDT36 = Construction delay time - (wks) time between initiation of new plant construction and equipment purchases and the time that the same are ready for use in actual production.
MSC36 = Maximum sales coefficient (MSC 1.0)
- relates maximum plant production (PE36) to smoothed sales. (SS36)(MSC36)=PE36

## C. AGRICULTURAL SECTOR (Includes Forestry, Fisheries and Mining) - INTRA-REGIONAL

### 1. General

Agriculture is still a major though declining activity in this region. Forestry, fisheries and mining are minor activities in the region accounting for only 0.2% of total employment in 1950. These activities have a common extractive characteristic that makes this aggregative equation grouping possible.

Extractive industries such as agriculture have certain characteristics in common with the manufacturing sectors just described. Both industries produce a physically tangible product using people and equipment. Both types of industry must market and finance their products. Raw materials, however, play a different role in each industry. In agriculture, raw materials are the product while in manufacturing they are the input. Agriculture does, however, use raw materials in the form of fertilizers and feeds, some of which are purchased. For this reason, raw material equations are still included in the agriculture sector. Raw material and equipment purchases and farm product sales relate agriculture to the other sectors in the input-output framework of the model.

### 2. External Relationships

The external equations in this sector will be of an identical format as those described in the manufacturing sectors except for the code number designations.

```
7R   S01.KL=IS01.K+ES01.K
17A  IS01.K=(S0150)(I0150)(MPX50.K)+. . . .
17A  ES01.K=(S0190)(E0190)(MPX90.K)+. . . .
```

| | |
|---|---|
| S01 | Total sales, sector 01 |
| IS01 | Internal sales, sector 01 |
| ES01 | Export sales, sector 01 |
| S0150 | Ratio of sales of 01 to 50 (wholesale trade) |
| I0150 | Internal market share |
| MPX50 | Material purchases, wholesale trade |
| S0190 | Ratio of sales to 90 (external wholesale trade) |
| E0190 | External market share |
| MPX90 | Material purchases, external wholesale trade |

3. Internal Relationships

Many of the equations in this sector are identical in structure to those in manufacturing. To standardize symbology, the same equation variable abbreviations were used although they may be of less meaning than in manufacturing. Some equation forms, however, were eliminated because they were not appropriate to agriculture. The eliminated variables are:

1. Unfilled orders
2. Finished goods inventory
3. Indirect personnel
4. Dividend payments

A work in process inventory was added to provide for the long production time in some agricultural products. The sector equations are shown below. The symbology is identical to that defined in the manufacturing sector.

| | | |
|---|---|---|
| 1L | RI01.K=RI01.J+(DT)(RP01.JK-RMU01.JK) | Raw Material Inventory |
| 40R | RP01.KL=RG01.K+(1/TR01)(RD01.K-RI01.K) | Raw Material Purchased |
| 51R | PI01.KL=CLIP(SS01.K,PE01.K,PE01.K,SS01.K) | Production Initiated |
| 12A | PE01.K=(PEV01.K)(PE01C) | Production Possible |
| 12R | RMU01.KL=(RFG01)(PI01.K) | Raw Material Used |
| 1L | WP01.K=WP01.J+(DT)(PI01.JK-GS01.JK) | Work in Process |
| 20A | G01.K=WP02.K/P001 | Goods to be Shipped |
| 3L | SS01.K=SS01.J+(DT)(1/TS01)(S01.JK-SS01.J) | Smoothed Sales |
| 20A | F01.K=WP01.K/DT | Finished Goods Possible to be Shipped |
| 51R | GS01.KL=CLIP(F01.K,G01.K,G01.K,F01.K) | Goods Shipped |
| 12A | RG01.K=(SS01.K)(RFG01) | Raw Goods Purchases, Desired |
| 12A | RD01.K=(RG01.K)(RMC01) | Raw Material Inventory Desired |
| 20A | DP01.K=P101.K/DPC01 | DP Desired |
| 3L | CA01.K=CA01.J+(DT)(OP01.J+EF01.J-EP01.JK) | Cash |
| 10A | OP01.K=GS01.JK-RP01.JK-LP01.JK-IAD01.JK-TP01.JK | Cash Flow |
| 12R | LP01.KL=(WR01C)(DP01.K) | Labor Payments |
| 14R | IAD01.KL=DR01.K+(IR01C)(DBT01.K) | Interest and Debt Payments |
| 1L | DBT01.K=DBT01.J+(DT)(EDF01.JK-DR01.J) | Debt Level |
| 12R | EDF01.KL=(DER01)(EF01.K) | External Debt Financing |
| 51A | EF01.K=CLIP(-OP01.K,O,MNP01.K,OP01.K) | External Financing |
| 12A | DR01.K=(DBT01.K)(CDR01) | Debt Retirement |
| 12R | DE01.KL=(DEP01)(PEV01.K) | Depreciation Payments |
| 12R | TP01.KL=(P001.K)(TAXC) | Tax Payments |
| 13R | EP01.KL=(ER01.K)(PEV01.K)(NER01) | Expansion Payments, Non-Debt Financed |
| 1L | PEV01.K=PEV01.J+(DT)(EP01.JK-DE01.JK) | Land Buildings and Equipment Values |
| 44A | SF01.K=(SS01.K)(MSC01)/PE01.K | Sales Figure |
| 7A | SL01.K=SF01.K-1.0 | Sales Level (+ or -) |
| 20A | E01R.K=SL01.K/EAT01 | Expansion (+ or -) |
| 51A | PO01.K=CLIP(OP01.K,O,OP01.K,O) | Positive (+) Operating Profit |
| 51A | E01P.K=CLIP(E01R.K,),E01R.K,O) | Expansion (+) |
| 51A | ER01.K=CLIP(E01P.K,O,OP01.K,MNP01.K) | Expansion Rate |
| 12A | MNP01.K=(-CA01.K)(FCU01) | Minimum Net Profit |

Initial Conditions

| | | |
|---|---|---|
| 13N | RI01=(SS01)(RFG01)(RMC01) | N-Raw Material Inventory |
| 12N | U001=(GS01)(SD01) | N-Unfilled Orders |
| 12N | FG01=(SS01)(FGC01) | N-Finished Goods Inventory |
| 6N | SS01=S01 | N-Smoothed Sales |
| 6N | CA01=Constant | N-Cash |
| 6N | DBT01=Constant | N-Debt Level |
| 6N | PEV01=Constant | N-Plant and Equipment Value |
| 12N | RP01=(SS01)(RFG01) | N-Raw Material Purchased |
| 6N | GS01=SS01 | N-Goods Shipped |
| 12N | DE01=(DEP01)(PEV01) | N-Depreciation Payments |
| 12N | LP01=(WR01C)(DP01) | N-Labor Payments |
| 14N | IAD01=DR01+(IR01C)(DBT01) | N-Interest and Debt Payments |
| 12N | TP01=(PO36)(0.625) | N-Tax Payments |
| 6N | EP01=DE01 | N-Expansion Payments |
| 6N | P101=SS01 | N-Prod Initiated |

Constants

| | | |
|---|---|---|
| C | TR01=Constant | Raw Material Inventory Adjustment Time |
| C | DPC01=Constant | DP Productivity |
| 20N | PE01C=PE01/PEV01 | Pev Production Coefficients |
| C | PD01=Constant | Production Delay |
| C | TS01=Constant | Sales Smoothing Time |
| C | RMC01=Constant | Raw Material Inventory Constant |
| C | RFG01=Constant | Raw Finished Goods Ratio |
| C | WR01C=Constant | Wage Rate |
| C | IR01C=Constant | Interest Rate Coefficient |
| C | DER01=Constant | Debt Ratio of External Financing |
| C | CDR01=Constant | Coefficients for Debt Retirement |
| C | DEP01=Constant | Depreciation Rate |
| C | FCU01=Constant | Fraction of Cash Used |
| C | MSC01=Constant | Maximum Sales Coefficient |
| C | NER01=Constant | Non-Debt Ratio of External Financing |
| C | TAXC=Constant | Tax Constant |

## D. CONSTRUCTION SECTOR - INTRA-REGIONAL

### 1. General

The construction industry differs from manufacturing principally in the lesser importance of raw and finished goods inventories and the greater importance of work in process inventories. Production times in construction are sometimes quite long, and a considerable investment is always committed to supporting work in process.

Most construction is performed to a specific customer order, but there is some speculative building, and at any given time there are a number of unsold new structures on the market. These structures, however, are still grouped with work in process in the model. A raw material inventory is included in the sector even though it may be small in size because the adjustment of this inventory over time determines the dynamic characteristics of orders to construction material suppliers.

Because the format of the external relationships is identical to the sectors previously described, external and internal equations will be presented together.

### 2. External and Internal Relationships

The external and internal equations for the construction sector are listed below. Symbols, except for the change in code number to 15, indicate the same variable as in the sectors previously described.

Construction -- Sector 15

Production

| | | |
|---|---|---|
| 1L | RI15.K=RI15.J+(DT)(RP15.JK-RMU15.JK) | Raw Material Inventory |
| 40R | RP15.KL=RG15.K+(1/TR15)(RD15.K-RI15.K) | Raw Material Purchased |
| 20A | PD15.K=UO15.K/TI15 | Production Desired |
| 51A | PI15.K=CLIP(PD15.K,PE15.K,PE15.K,PD15.K) | Production Initiated |
| 12A | PE15.K=(PEV15.K)(PE15C) | Production Possible |
| 12R | RMU15.KL=(RFG15)(PI15.K) | Raw Material Used |
| 1L | WP15.K=WP15.J+(DT)(PI15.JK-PC15.JK) | Work in Process |

Marketing

| | | |
|---|---|---|
| 17A | ES15.K=(same format as in manufacturing) | |
| 17A | IS15.K=(same format as in manufacturing) | |
| 7R | S15.KL=IS15.K+ES15.K | Sales Orders |
| 1L | UO15.K=UO15.J+(DT)(S15.JK-PI15.JK) | Unfilled Orders |
| 3L | SS15.K=SS15.J+(DT)(1/TS15)(S15.JK-SS15.J) | Smoothed Sales |
| 12A | RG15.K=(SS15.K)(RFG15) | Raw Goods Purchases, Desired |
| 12A | RD15.K=(RG15.K)(RMC15) | Raw Material Inventory Desired |
| 20R | PC15.KL=WP15.K/TPD15 | |

Personnel

| | | |
|---|---|---|
| 20A | DP15.K=PI15.K/DPC15 | Direct Personnel Desired |
| 20A | IP15.K=SS15.K/IPC15 | Indirect Personnel Desired |

Finance

| | | |
|---|---|---|
| 3L | CA15.K=CA15.J+(DT)(OP15.J+EF15.J-EP15.JK) | Cash |
| 10A | OP15.K=PC15.JK-RP15.JK-LP15.JK-<br>IAD15.JK-TP15.JK-EP15.JK | Operating Profit |
| 18R | LP15.KL=(WR15C)(DP15.K+IP15.K) | Labor Payments |
| 14R | IAD15.KL=DR15.K+(IR15C)(DBT15.K) | Interest and Debt Payments |
| 1L | DBT15.K=DBT15.J+(DT)(EDF15.JK-DR15.J) | Debt Level |
| 12R | EDF15.KL=(DER15)(EF15.K) | External Debt Financing |
| 51A | EF15.K=CLIP(-OP15.K,O,MNP15.K,OP15.K) | External Financing |
| 12A | DR15.K=(DBT15.K)(CDR15) | Debt Retirement |
| 12R | DE15.KL=(DEP15)(PEV15.K) | Depreciation Payments |
| 12R | TP15.KL=(PO15.K)(0.625) | Tax Payments |
| 12R | EP15.KL=(ER15.K)(PEV15.K)(NER15) | Expansion Payments, Non-Debt |

Plant and Equipment

| | | |
|---|---|---|
| 1L | PEV15.K=PEV15.J+(DT)(EP15.JK=DE15.JK) | Plant and Equipment Value |
| 44A | SF15.K=(SS15.K)(MSC15)/PE15.K | Sales Figure |
| 7A | SL15.K=SF15.K-1.0 | Sales Level (+ or -) |
| 20A | E15R.K=SL15.K/EAT15 | Expansion (+ or -) |
| 51A | PO15.K=CLIP(OP15.K,O,OP15.K,O) | Positive (+) Operating Profit |
| 51A | E15P.K=CLIP(E15R.K,O,E15R.K,O) | Expansion (+) |
| 51A | ER15.K=CLIP(E15P.K,O,OP15.K,MNP15.K) | Expansion Rate |
| 12A | MNP15.K=(-CA15.K)(FCU15) | Minimum Net Profit |

Initial Conditions

| | | |
|---|---|---|
| 13N | RI15=(SS15)(RFG15)(RMC15) | N-Raw Material Inventory |
| 12N | UO15=(SS15)(T115) | N-Unfilled Orders |
| 6N | SS15=Constant | N-Smoothed Sales |
| 6N | DP15=Constant | N-Direct Personnel |
| 6N | IP15=Constant | N-Indirect Personnel |
| 6N | CA15=Constant | N-Cash |
| 6N | DBT15=Constant | N-Debt Level |
| 6N | PEV15=Constant | N-Plant and Equipment Value |
| 12N | DR15=(DBT15)(CDR15) | N-Debt Retirement |
| 12N | RP15=(SS15)(RFG15) | N-Raw Material Purchased |
| 6N | PE15=Constant | N-Production Possible |
| 12N | DE15=(DEP15)(PEV15) | N-Depreciation Payments |

| | | |
|---|---|---|
| 18N | LP15=(WR15C)(DP15+IP15) | N-Labor Payments |
| 14N | IAD15=DR15+(IR15C)(DBT15) | N-Interest and Debt Payments |
| 6N | TP15=Constant | N-Tax Payments |
| 6N | EP15=DE15 | N-Expansion Payments |
| 6N | P115=SS15 | N-Production Initiated |

Constants

| | | |
|---|---|---|
| C | TR15=Constant | Raw Material Inventory Adjustment Time |
| C | TI15=Constant | Finished Goods Inventory Adjustment Time |
| C | DPC15=Constant | Productivity |
| C | TPD15=Constant | Production Delay Time |
| 20N | PE15C=PE15/PEV15 | Plant Production Coefficient |
| C | TS15=Constant | Sales Smoothing Time |
| C | TMC15=Constant | Raw Material Inventory Constant |
| C | RFG15=Constant | Raw-Finished Goods Ratio |
| 12N | IPC15=(PAR15)(DPC15) | Indirect Personnel Productivity Coefficient |
| C | PAR15=Constant | Direct Personnel Administrative Ratio |
| C | WR15C=Constant | Wage Rate |
| C | IR15C=Constant | Interest Rate Coefficient |
| C | DER15=Constant | Debt Ratio of External Financing |
| C | CDR15=Constant | Coefficient for Debt Retirement |
| C | DEP15=Constant | Depreciation Rate |
| C | EAT15=Constant | Expansion Adjustment Time |
| C | FCU15=Constant | Fraction of Cash Used |
| C | MSC15=Constant | Maximum Sales Coefficient |
| C | PD15=Constant | Production Delay |
| C | NER15=Constant | Non-Debt Expansion Constant |

## E. UTILITY SECTORS

### 1. General

Utilities produce and sell energy, information (communication), transportation movement or water. Marketing, personnel, finance and plant and equipment subsectors will exist in all of the utility sectors. The production subsector is not applicable to communications and transportation.

In the energy and transportation utilities raw materials (coal, oil or gas) play a major role, but their role is minor in communication and water. In all of the utilities, plant and especially equipment play a very dominant role since these are capital intensive industries. Other minor changes have been made in each of the four utility sectors. These changes are described in the next section.

The four utility sectors are:

a. Communication Utilities (Telephone, telegraph) (49)
b. Energy Utilities (Electricity and Gas) (48)
c. Transportation (Transit, Trucking, Rail, Marine) (41)
d. Water Utilities (Water and Sewerage) (47)

### 2. Communications

#### a. General

A communications utility does not "produce" in the sense of manufacturing production or even energy utility production. A facility is provided for use by customers. For this reason, the production subsector is omitted. Only raw material usage is determined in order to tie the sector to other supplying sectors of the model. Service provided is a new equation which is a function of service desired by customers and the capability of the facility.

Order backlog, finished inventories and goods shipments do not apply to this sector and are omitted from the marketing subsector.

The financial subsector is quite similar to manufacturing except for the replacement of goods revenue by service revenue.

The plant and equipment subsector is the key to this utility and is identical in format to that subsector in previously described sectors.

b. External and Internal Relationships

The equations for the communications sector are listed below:

| | | |
|---|---|---|
| 12R | RP48.KL=(RF48C)(S48C.K) | Raw Material Used |
| 17A | ES58.K=(Same format as in manufacturing) | |
| 17A | IS48.K=(Same format as in manufacturing) | |
| 18R | S48.KL=(SUC48*1.K)(ES48.K+IS48.K) | Sales Orders |
| 35B | SUC48=BOXCYC(12,4.3) | Supply Usage Curve |
| 3L | SS48.K=SS48.J+(DT)(1/TS48)(S48.JK-SS48.J) | Smoothed Sales |
| 51R | SP48.KL=CLIP(S48.JK,PE48.K,PE48.K,S48.JK) | Service Provided |
| 12A | PE48.K=(PEV48.K)(PE48C) | Service Possible |

Personnel

| | | |
|---|---|---|
| 20A | DP48.K=SS48.K/DPC48 | Direct Personnel |
| 20A | IP48.K=SS48.K/IPC48 | Indirect Personnel |

Finance

| | | |
|---|---|---|
| 2L | CA48.K=CA48.J+(DT)(OP48.J+EF48.J-EP48.JK) | Cash |
| 11A | OP48.K=SP48.JK-RP48.JK-LP48JK-IAD48.JK-TP48.JK-DIV48.JK | |
| 18R | LP48.KL=(WR48C)(DP48.K+IP48.K) | Labor Payments |
| 14R | IAD48.KL=DR48.K+(ER48C)(DBT48.K) | Interest and Debt Payments |
| 1L | DBT48.K=DBT48.J+(DT)(EDF48.JK-DR48.J) | Debt Level |
| 12R | EDF48.KL=(DER48)(EF48.K) | External Debt Financing |
| 51A | EF48.K=(CLIP(-OP48.K,O,MNP48.K,OP48.K) | External Financing |
| 12A | DR48.K=(DBT48.K)(CDR48) | Debt Retirement |
| 12R | DIV48.KL=(DIR48C)(PO48.K) | Dividend Payments |
| 12R | DE48.KL=(DEP48)(PEV48.K) | Depreciation Payments |
| 12R | TP48.KL=(PO48.K)(0.625) | Tax Payments |
| 12R | EP48.KL=(ER48.K)(PEV48.K)(NER48) | Expansion Payments, Non-Debt Financed |

Plant and Equipment

| | | |
|---|---|---|
| 1L | PEV48.K=PEV48.J+(DT)(EP48.JK-DE48.JK) | Plant and Equipment Value |
| 44A | SF48.K=(SS48.K)(MSC48)/PE48.K | Sales Figure |
| 7A | SL48.K=SF48.K-1.0 | Sales Level (+ or -) |
| 20A | E48R.K=SL48.K/EAT48 | Expansion (+ or -) |
| 51A | PO48.K=CLIP(OP48.K,O,OP48.K,O) | Positive (+) Operating Profit |
| 51A | E48P.K=CLIP(E48R.K,O,E48R.K,O) | Expansion (+) |
| 51A | ER48.K=CLIP(E48.K,O,OP48.K,MNP48.K) | Expansion Rate |
| 12A | MNP48.K=(-CA48.K)(FCU48) | Minimum Net Profit |

Initial Conditions

| | | |
|---|---|---|
| 6N | SS48=Constant | N-Smoothed Sales |
| 6N | DP48=Constant | N-Direct Personnel |
| 6N | IP48=Constant | N-Indirect Personnel |
| 6N | CA48=Constant | N-Cash |
| 6N | DBT48=Constant | N-Debt Level |
| 6N | PEV48=Constant | N-Plant and Equipment Value |
| 12N | DR48=(DBT48)(CDR48) | N-Debt Retirement |
| 12N | RP48=(S48)(RP48C) | N-Raw Material Purchased |
| 6N | PE48=Constant | N-Pev Production Possible |
| 6N | SP48=SS48 | N-Goods Shipped |
| 12N | DE48=(DEP48)(PEV48) | N-Depreciation Payments |

| | | |
|---|---|---|
| 18N | LP48=(WR48C)(DP48+IP48) | N-Labor Payments |
| 14N | IAD48=DR48+(IR48C)(DBT48) | N-Interest and Debt Payments |
| 6N | TP48=Constant | N-Tax Payments |
| 6N | EP48=DE48 | N-Expansion Payments |

Constants for Sector 48

| | | |
|---|---|---|
| C | DP48C=Constant | Productivity |
| 20N | PE48C=PE48/PEV48 | Plant Production Coefficient |
| C | TS48=Constant | Sales Smoothing Time |
| C | RF48C=Constant | Raw Finished Goods Ratio |
| 12N | IPC48=(PAR48)(DPC48) | Indirect Personnel Productivity Coefficient |
| C | PAR48=Constant | Direct Personnel/Administrative Ratio |
| C | WR48C=Constant | Wage Rate |
| C | IR48C=Constant | Interest Rate Coefficient |
| C | DER48=Constant | Debt Ratio of External Financing |
| C | CDR48=Constant | Coefficient for Debt Retirement |
| C | DEP48=Constant | Depreciation Rate |
| C | EAT48=Constant | Expansion Adjustment Time |
| C | FCU48=Constant | Fraction of Cash Used |
| C | MSC48=Constant | Maximum Sales Coefficient |
| C | SUC48=Constant | |
| C | NER48=Constant | Non-Debt Ratio |
| C | DIR48C=Constant | Dividend Ratio |

3. Energy Utilities

a. General

Energy (electricity and gas) utilities use raw materials in the form of coal or gas to produce the energy needed in the region. This sector includes a production sector without a raw materials inventory. Raw material purchases as needed for production, however, are accounted for in the model. Production is limited by plant-equipment capacity. Otherwise, the sector is identical to communications.

b. External-Internal Relationships

The equations for the energy sector are as shown below:

Energy Utilities -- Sector 49

Production

| | | |
|---|---|---|
| 51A | PI49.K=CLIP(SS49.K,PE49.K,PE49.K,SS49.K) | Production Initiated |
| 12A | PE49.K=(PEV49.K)(PE49C) | Plant Production Possible |
| 12R | RP49.KL=(RFG49)(PI49.K) | Raw Material Used |

Marketing

| | | |
|---|---|---|
| 17A | ES49.K=(same format as in manufacturing) | |
| 17A | IS49.K=(same format as in manufacturing) | |
| 18R | SAF.KL=(SUC49*1.K)(ES49.K+IS49.K) | Sales Orders |
| 35B | SUC49=BOXCYC(12,4.3) | Supply Usage Curve |
| 3L | SS49.K=SS49.J+(DT)(1/TS49)(S49.JK-SS49.J) | Smoothed Sales |

Personnel

| | | |
|---|---|---|
| 20A | DP49.K=SS49.K/DPC49 | Direct Personnel Desired |
| 20A | IP49.K=SS49.K/IPC49 | Indirect Personnel Desired |

Finance

| | | |
|---|---|---|
| 2L | CA49.K=CA49.J+(DT)(OP49.J+EF49.J-EP49.JK) | Cash |
| 11A | OP49.K=PI49.JK-RP49.JK-LP49.JK-IAD49.JK-TP49.JK-DIV49.JK | |
| 18R | LP49.KL=(WR49C)(DP49.K+IP49.K) | Labor Payments |
| 14R | IAD49.KL=(DR49.K+(IR49C)(DBT49.K) | Interest and Debt Payments |
| 1L | DET49.K=DBT49.J+(DT)(EDF49.JK-DR49.J) | Debt Level |

| | | |
|---|---|---|
| 12R | EDF49.KL=(DER49)(EF49.K) | External Debt Financing |
| 51A | EF49.K=CLIP(-OP49.K,O,MNP49.K,OP49.K) | External Financing |
| 12A | DR49.K=(DBT49.K)(CDR49) | Debt Retirement |
| 12R | DIV49.KL=(DIR49C)(PO49.K) | Dividend Payments |
| 12R | DE49.KL=(DEP49)(PEV49.K) | Depreciation Payments |
| 12R | TP49.KL=(PO49.K)(0.625) | Tax Payments |
| 12R | EP49.KL=(ER49.K)(PEV49.K)(NER49) | Expansion Payments, Non-Debt Financed |

Plant and Equipment

| | | |
|---|---|---|
| 1L | PEV49.K=PEV49.J+(DT)(EP49.JK-DE49.JK) | Plant and Equipment Value |
| 44A | SF49.K=(SS49.K)(MSC49)/PE49.K | Sales Figure |
| 7A | SL49.K=SF49.K=1.0 | Sales Level (+ or -) |
| 20A | E49R.K=SL49.K/EAT49 | Expansion (+ or -) |
| 51A | PO49.K=CLIP(OP49.K,O,OP49.K,O) | Positive (+) Operating Profit |
| 51A | E49P.K=CLIP(E49R.K,O,E49R.K,O) | Expansion (+) |
| 51A | ER49.K=CLIP(E49P.K,O,OP49.K,MNP49.K) | Expansion Rate |
| 12A | MNP49.K=(-CA49.K)(FCU49) | Minimum Net Profit |

Initial Conditions

| | | |
|---|---|---|
| 13N | RI49=(SS49)(RFG49)(RMC49) | N-Raw Material Inventory |
| 12N | FG49=(PE49)(FGC49) | N-Finished Goods Inventory |
| 6N | SS49=Constant | N-Smoothed Sales |
| 6N | DP49=Constant | N-Direct Personnel |
| 6N | IP49=Constant | N-Indirect Personnel |
| 6N | CA49=Constant | N-Cash |
| 6N | DBT49=Constant | N-Debt Level |
| 6N | PEV49=Constant | N-Plant and Equipment Value |
| 12N | DR49=(DET49)(CDR49) | N-Debt Retirement |
| 12N | RP49=(S49)(RF49E) | N-Raw Material Purchased |
| 6N | PE49=Constant | N-Plant Production Possible |
| 12N | DE49=(DEP49)(PEV49) | N-Depreciation Payments |
| 18N | LP49=(WR49C)(DP49+IP49) | N-Labor Payments |
| 14N | IAD49=DR49+(IR49C)(DBT49) | N-Interest and Debt Payments |
| 6N | IP49=Constant | N-Tax Payments |
| 6N | EP49=DE49 | N-Expansion Payments |
| 6N | PI49=SS49 | N-Production Initiated |

Constants for Sector 49

| | | |
|---|---|---|
| | DP49E=Constant | Direct Personnel Productivity |
| 20N | PE49C=PE49/PEV49 | Pev Production Coefficients |
| C | TS49=Constant | Sales Smoothing Time |
| C | RFG49=Constant | Raw Finished Goods Ratio |
| 12N | IPC49=(PAR49)(DPC49) | Indirect Personnel Productivity |
| C | PAR49=Constant | Direct Personnel Administrative Ratio |
| C | WR49C=Constant | Wage Rate |
| C | IR49C=Constant | Interest Rate Coefficients |
| C | DER49=Constant | Debt Ratio of External Financing |
| C | CDR49=Constant | Coefficient for Debt Retirement |
| C | DEP49=Constant | Depreciation Rate |
| C | EAT49=Constant | Expansion Adjustment Time |
| C | FCU49=Constant | Fraction of Cash Used |
| C | MSC49=Constant | Maximum Sales Coefficient |
| C | SUC49*=Constant | Supply Usage |
| C | NER49=Constant | Non-Debt Ratio |
| C | DIR49=Constant | Dividend Ratio |

4. Transportation

a. General

The transportation sector includes all public and private organizations providing transportation for people or goods. Rail and bus transit, trucking, railroads or marine transportation are all included in the sector. Here transportation is considered only as a spaceless economic function. The spatial aspects of transportation are analyzed in the spatial activity and transportation models. As an activity sector, this sector is identical to communications except for the code number designation which here is 41. For this reason the equations need not be listed in this appendix.

5. Water-Sewerage Utilities
   a. General

Water-Sewerage Utilities are depicted only in their functional economic role. Spatial and detailed supply-demand characteristics of water resources are shown in the water system model. Within this spaceless framework, these utilities have equations identical in format to the energy utilities. The equations will have the code number 47.

## F. SERVICE SECTORS

1. General

A wide variety of activities are included in this sector including:

a. Business Services
b. Repair Services
c. Personal Services
d. Entertainment and Recreation Services
e. Professional Services
f. Medical Services

At a later date, it may be desirable to separate some of these services into separate sectors. Medical services, for example, are a large and growing element in the economy and might well be considered separately later. Because this sector markets services without any production in the usual sense, the communications sector format is appropriate. The equations of this sector will be identical to the communications sector except for the code number which here will be 72.

## G. WHOLESALE AND RETAIL TRADE

1. General

The wholesale and retail trade sectors differ from manufacturing principally in their lack of a production sector. Otherwise, the sector resembles manufacturing closely in the marketing, personnel, financial and plant-equipment subsectors. The plant-equipment subsector is of lesser importance and provision is made for leasing facilities.

The retail sector includes a wide variety of retail establishments from automobile dealers to grocery stores. It may be desirable to subdivide this sector at a later date.

2. External and Internal Relationships

The equations for the wholesale and retail sectors are listed below:

Wholesale Trade - Sector 50

Sales and Inventory Equations

| | | |
|---|---|---|
| 17A | ES50.K=(Same format as manufacturing) | |
| 17A | IS50.K=(Same format as manufacturing) | |
| 40A | MPX50.K=SS50.K+(1/TI50)(ID50.K-FG50.K) | Material Purchased |
| 12A | SE50.K=(SEV50.K)(SE50C) | Store and Equipment Sales Limit |
| 7R | S50.KL=ES50.K+IS50.K | Sales Orders |
| 1L | UO50.K=UO50.J+(DT)(S50.JK-GS50.JK) | Unfilled Orders |
| 20A | G50.K=UO50.K/SD50C | Goods to be Shipped |
| 1L | FG50.K=FU50.J+(DT)(MPX50.JK-GS50.JK) | Finished Goods Inventory |
| 3L | SS50.K=SS50.J+(DT)(1/TS50)(S50.JK-SS50.J) | Smoothed Sales |
| 20A | F50.K=FG40.K DT | Finished Goods Possible to be Shipped |
| 51R | GS50.KL=CLIP(F50.K,G50.K,G50.K,F50.K) | Goods Shipped |
| 12A | ID50.K=(SS50.K)(FGC50) | Finished Goods Inventory Desired |
| 48R | GP50.KL=MPX50.K/(1+MUP50) | Goods Purchased |
| 51A | SA50.K=CLIP(SS50.K,SE50.K,SE50.K,SS50.K) | Sales Available |

| | | |
|---|---|---|
| Personnel | | |
| 20A | DP50.K=SA50.K/DPC50 | Direct Personnel Desired |
| 20A | IP50.K=SS50.K/IPC50 | Indirect Personnel Desired |
| Finance | | |
| 2L | CA50.K=CA50.J+(DT)(OP50.J+EF50.J-EP50.JK) | Cash |
| 11A | OP50.K-GS50.JK-GP50.JK-LP50.JK-IAD50.JK-TP50.JK-RMT50.JK | |
| 18R | LP50.KL=(WR50C)(DP50.K+IP50.K) | Labor Payments |
| 14R | IAD50.KL=DR50.K+(IR50C)(DBT50.K) | Interest and Debt Payments |
| 1L | DBT50.K=DBT50.J+(DT)(EDF50.JK-DR50.J) | Debt Level |
| 12R | EDF50.KL=(DER50)(EF50.K) | External Debt Financing |
| 51A | EF50.K=CLIP(-OP50.K,O,MNP50.K,OP50.K) | External Financing |
| 12A | DR50.K=(DBT50.K)(CDR50) | Debt Retirement |
| 12R | DE50.KL=(DEP50)(SEV50.K) | Depreciation Payments |
| 12R | TP50.KL=(PO50.K)(TAXC) | Tax Payments |
| 12R | EP50.KL=(ER50.K)(SEV50.K) | Expansion Payments |
| 12R | RNT50.KL=(SEV50.K)(RT50C) | Rent Payments |
| Store and Equipment Values | | |
| 1L | SEV50.K=SEV50.J+(DT)(EP50.JK-DE50.JK) | Store and Equipment Value |
| 44A | SF50.K=(SS50.K)(MSC50)/SE50.K | Sales Figure |
| 7A | SL50.K=SF50.K-1.0 | Sales Level (+ or -) |
| 20A | F50R.K=SL50.K/EAT50 | Expansion (+ or -) |
| 51A | PO50.K=CLIP(OP50.K,O,OP50.K,O) | Positive (+) Operating Profit |
| 51A | E50P.K=CLIP(E50R.K,O,E50R.K,O) | Expansion (+) |
| 51A | ER50.K=CLIP(E50P.K,O,OP50.K,MNP50.K) | Expansion Rate |
| 12A | MNP50.K=(-CA50.K)(FCU50) | Minimum Net Profit |
| Initial Conditions | | |
| 12N | UO40=(GS50)(SD50) | N-Unfilled Orders |
| 12N | FG50=(SS50)(FGC50) | N-Finished Goods Inventory |
| 6N | SS50=Constant | N-Smoothed Sales |
| 6N | DP50=Constant | N-Direct Personnel |
| 6N | IP50=Constant | N-Indirect Personnel |
| 6N | CA50=Constant | N-Cash |
| 6N | DBT50=Constant | N-Debt Level |
| 6N | SEV50=Constant | N-Store and Equipment Value |
| 12N | DR50=(DBT50)(CDR50) | N-Debt Retirement |
| 48N | GP50=GS50/(1+MUP50) | N-Goods Purchased |
| 6N | SE50=Constant | N-Sales Possible |
| 6N | GS50=SS50 | N-Goods Shipped |
| 12N | DE50=(DEP50)(SEV50) | N-Depreciation Payments |
| 6N | MPA50=GP50 | N-Material Payments |
| 18N | LP50=(WR50C)(DP50+IP50) | N-Labor Payments |
| 14N | IAD50=DR50+(IR50C)(DBT50) | N-Interest and Debt Payments |
| 6N | TP50=Constant | N-Tax Payments |
| 6N | EP50=Constant | N-Expansion Payments |
| Constants for Section 50 | | |
| C | TI50=Constant | Finished Goods Adjustment Time |
| C | DPC50=Constant | Direct Personnel Productivity |
| 20N | SE50C=SE50/SEV50 | Sales Coefficient |
| C | SD50=Constant | Shipping Delay |
| C | TS50=Constant | Sales Smoothing Time |
| C | FGC50=Constant | Finished Goods Inventory Constant |
| 12N | IPC50=(PAR50)(DPC50) | Indirect Personnel Productivity Coefficient |
| C | PAR50=Constant | Direct Personnel/Administrative Ratio |
| C | WR50C=Constant | Wage Rate |

| | | |
|---|---|---|
| C | IR50C=Constant | Interest Rate Coefficient |
| C | DER50=Constant | Debt Ratio of External Financing |
| C | CDR50=Constant | Coefficient for Debt Retirement |
| C | DEP50=Constant | Depreciation Rate |
| C | EAT50=Constant | Expansion Adjustment Time |
| C | FCU50=Constant | Fraction of Cash Used |
| C | MSC50=Constant | Maximum Sales Coefficient |
| C | MUP50=Constant | Mark Up |
| C | RT50C=Constant | Rent Coefficient |

Retail Stores - Sector 52

Sales and Inventory Equations

| | | |
|---|---|---|
| 17A | ES52.K=(Same format as manufacturing) | |
| 17A | IS52.K=(Same format as manufacturing) | |
| 40A | MPX52.K=SS52.K+(1/T152)(ID52.K-FG52.K) | Material Purchased |
| 12A | SE52.K=(SEV52.K)(SE52C) | Store and Equipment Sales Limit |
| 7R | S52.KL=ES52.K+IS52.K | Sales Orders |
| 1L | UO52.K=UO52.J+(DT)(S52.JK-GS52.JK) | Unfilled Orders |
| 20A | G52.K=UO52.K/SD52 | Goods to be Shipped |
| 1L | FG52.K=FG52.J+(DT)(MPX52.JK-GS52.JK) | Finished Goods Inventory |
| 3L | SS52.K=SS52.J+(DT)(1/TS52)(S52.JK-SS52.J) | Smoothed Sales |
| 20A | F52.K=FG52.K/DT | Finished Goods Possible to be Shipped |
| 51R | GS52.KL=CLIP(F52.K,G52.K,G52.K,F52.K) | Goods Shipped |
| 12A | ID52.K=(SS52.K)(FGC52) | Finished Goods Inventory Desired |
| 48R | GP52.KL=MPX52.K/(1+MUP52) | Goods Purchased |

Personnel

| | | |
|---|---|---|
| 20A | DP52.K=SA52.K/DPC52 | Direct Personnel Desired |
| 51A | SA52.K=CLIP(SS52.K,SE52.K,SE52.K,SS52.K) | Sales Available |
| 20A | IP52.K=SS52.K/IPC52 | Indirect Personnel Desired |

Finance

| | | |
|---|---|---|
| 2L | CA52.K=CA52.J+(DT)(OP52.J+EF52.J-EP52.JK) | Cash |
| 11A | OP52.K=GS52.JK=GP52.JK-LP52.JK-IAD52.JK-TP52.JK-RNT52.JK+O | |
| 18R | LP52.KL=(WR52C)(DP52.K+IP52.K) | Labor Payments |
| 14R | IAD52=DR52.K+(IR52C)(DBT52.K) | Interest and Debt Payments |
| 1L | DBT52.K=DBT52.J+(DT)(EDF52.JK-DR52.J) | Debt Level |
| 12R | EDF52.KL=(DER52)(EF52.K) | External Debt Financing |
| 51A | EF52.K=CLIP(-OP52.K,O,MNP52.K,OP52.K) | External Financing |
| 12A | DR52.K=(DBT52.K)(CDR52) | Debt Retirement |
| 12R | DE52.KL=(DEP52)(SEV52.K) | Depreciation Payments |
| 12R | TP52.KL=(PO52.K)(0.625) | Tax Payments |
| 12R | EP52.KL=(ER52.K)(SEV52.K) | Expansion Payments |
| 12R | RNT52.KL=(SEV52.K)(RT52C) | Rent Payments |

Store and Equipment Values

| | | |
|---|---|---|
| 1L | SEV52.K=SEV52.J+(DT)(EP52.JK-DE52.JK) | Store and Equipment Value |
| 44A | SF52.K=(SS52.K)(MSC52)/SE52.K | Sales Figure |
| 7A | SL52.K=SF52.K-1.0 | Sales Level (+ or -) |
| 20A | E52R.K=SL52.K/EAT52 | Expansion (+ or -) |
| 51A | PO52.K=CLIP(OP52.K,O,OP52.K,O) | Positive (+) Operating Profit |
| 51A | E52P.K=CLIP(E52R.K,O,E52R.K,O) | Expansion (+) |
| 51A | ER52.K=CLIP(E52P.K,O,OP52.K,MNP52.K) | Expansion Rate |
| 12A | MNP52.K=(-CA52.K)(FCU52) | Minimum Net Profit |

Initial Conditions

| | | |
|---|---|---|
| 12N | UO52=(GS52)(SD52) | N-Unfilled Orders |
| 12N | FG52=(SS52)(FGC52) | N-Finished Goods Inventory |

| | | |
|---|---|---|
| 6N | SS52=Constant | N-Smoothed Sales |
| 6N | DP52=Constant | N-Direct Personnel |
| 6N | IP52=Constant | N-Indirect Personnel |
| 6N | CA52=Constant | N-Cash |
| 6N | DBT52=Constant | N-Debt Level |
| 6N | SEV52=Constant | N-Store and Equipment Value |
| 12N | DR52=(DBT52)(CDR52) | N-Debt Retirement |
| 48N | GP52=GS52/(1+MUP52) | N-Goods Purchased |
| 6N | SE52=Constant | N-Sev Sales Possible |
| 6N | GS52=SS52 | N-Goods Shipped |
| 12N | DE52=(DEP52)(SEV52) | N-Depreciation Payments |
| 6N | MPA52=GP52 | N-Material Payments |
| 18N | LP52=(WR52C)(DP52+IP52) | N-Labor Payments |
| 14N | IAD52=DR52+(IR52C)(DBT52) | N-Interest and Debt Payment |
| 6N | TP52=Constant | N-Tax Payments |
| 6N | EP52=Constant | N-Expansion Payments |

Constants for Sector 52

| | | |
|---|---|---|
| C | TI52=Constant | Finished Goods Inventory Adjustment Time |
| C | DPC52=Constant | Direct Personnel Productivity |
| 20N | SE52C=SE52/SEV52 | Sales Coefficient |
| C | SD52=Constant | Shipping Delay |
| C | TS52=Constant | Sales Smoothing Time |
| C | FGC52=Constant | Finished Goods Inventory Constant |
| 12N | IPC52=(PAR52)(DPC52) | Indirect Personnel Productivity Coefficient |
| C | PAR52=Constant | Direct Personnel/Administrative Ratio |
| C | WR52C=Constant | Wage Rate |
| C | IR52C=Constant | Interest Rate Coefficient |
| C | DER52=Constant | Debt Ratio of External Financing |
| C | CDR52=Constant | Coefficient for Debt Retirement |
| C | DEP52=Constant | Depreciation Rate |
| C | EAT52=Constant | Expansion Adjustment Time |
| C | FCU52=Constant | Fraction of Cash Used |
| C | MSC52=Constant | Maximum Sales Coefficient |
| C | MUP52=Constant | Mark Up |
| C | RT52C=Constant | Rent Coefficient |

## H. EDUCATION SECTORS

### 1. General

The new feature in these sectors is the student subsector. This subsector is interrelated with the population subsector of the household sector by the equations classifying student enrollment. Total enrollment is determined from the summation of the students enrolled in each of the 5-year age classifications.

Three different education sectors are included in the model for:

a. Elementary Education
b. Secondary Education
c. University Education

Appropriate 5-year age group classifications apply to each sector.

Student-handling capability is limited by both teaching personnel and facilities.

The financial sector accounts for both public tax and private tuition revenues. Public funds are determined in the Government Sector on the basis of school needs. The operating budget for salaries and supplies is kept separate from the capital budget for new facilities.

2. External and Internal Relationships

The equations listed below are for the secondary education sector. The equations for the other two educational sectors are identical except for the code numbers.

| | | |
|---|---|---|
| 12A | MPXS.K=(SEXS.K)(MSXSC) | Supplies Purchased |
| 15A | SXS.K=(P15XS)(P15.K)+(P20XS)(P20.K) | Secondary Students |
| 3L | SSXS.K=SSXS.J+(DT)(1/TSXS)(SXS.J-SSXS.J) | Average Students Eligible |
| 43A | SEXS.K=SAMPLE(SXS.K,26) | Students Attending |
| 51A | SHAXS.K=CLIP(SHAX1.K,SHAX2.K,SHAX2.K, SHAX1.K) | School Handling Ability |
| 20A | SHAX1.K=ESFXS.K/DISXS | Facility Limit |
| 20A | SHAX2.K=TEXS.K/DTSXS | Faculty Limit |
| 20A | TXS.K=SEXS.K/SPTXS | Teachers Desired |
| 20A | IPXS.K=SSXS.K/SIPXS | Indirect Personnel |
| 43A | TEXS.K=SAMPLE(TXS.K,52) | Teachers Employed |
| | SSCB.KL=(IN GOVERNMENT SECTOR) | Secondary School Capital Budget |
| 18R | LPXS.KL=(WRXSC)(TEXS.K+(IPXS.K) | Salaries |
| 8R | TRXS.KL=SSCB.JK+SSOB.JK+SSTU.K | Tax-Tuition Revenue |
| 10A | OPXS.K=TRXS.JK-MPXS.JK-LPXS.JK- IADXS.JK-SCIXS.JK+O | Money Flows |
| 2L | SFAXS.K=SFAXS.J+(DT)(OPXS.J+EFXS.J+ SCBXS.JK+O+O+O) | Funds |
| 12A | MNPXS.K=(-SFAXS.K)(FFUXS) | Minimum Net Balance |
| | SSOB.KL=(IN GOVERNMENT SECTOR) | Secondary School Operating Budget |
| 12R | SDEXS.KL=(DRXSC)(ESFXS.K) | School Depreciation |
| 14R | IADXS.KL=DRXS.K+(IRXSC)(DBTXS.K) | Interest and Debt |
| 1L | DBTXS.K=DBTXS.J+(DT)(EDFXS.JK-DRXS.J) | Debt Level |
| 12R | EDFXS.KL=(DERXS)(EFXS.K) | Debt Financing |
| 51A | EFXS.K=CLIP(-OPXS.K,O,MNPXS.K,OPXS.K) | External Financing |
| 12A | DRXS.K=(DBTXS.K)(CDRXS) | Debt Retirement Payments |
| 13A | SSTU.K=(SEXS.K)(PPSA)(STUC) | Secondary School Tuition |
| 1L | ESFXS.K=ESFXS.J+(DT)(SCIXS.JK-SDEXS.JK) | School Facilities |
| 51R | SCIXS.KL=CLIP(EPXS.K,O,NPXS.K,MNPXS.K) | Construction Initiated |
| 27A | FUXS.K=(SXS.K/SHAXS.K)-1.0 | Facility Utilization |
| 20A | EXSR.K=FUXS.K/EATXS | Expansion (+ or -) |
| 51A | ERXS.K=CLIP(EXSR.K,O,EXSR.K,O) | Expansion Rate |
| 13A | EPXS.K=(ERXS.K)(ESFXS.K)(NERXS) | Expansion Payments |
| 6R | SCEXS.KL=SCCXS.JK | Construction Expenditures |

Initial Conditions

| | | |
|---|---|---|
| 6N | MIXS=Constant | N-Material Inventory |
| 6N | SSXS=Constant | N-Smoothed Students Eligible |
| 6N | TXS=Constant | N-Teachers |
| 6N | IPXS=Constant | N-Indirect Personnel |
| 6N | DBTXS=Constant | N-Debt |
| 6N | ESFXS=Constant | N-School Facilities |
| 15N | SEXS=(P10XS)(P10)+(P15XS)(P15) | N-Students Attending |
| 6N | TEXS=TXS | N-Teachers Employed |
| 12N | DRXS=(DBTXS)(CDRXS) | N-Debt Retirement |
| 50N | GPXS=(SEXS)(MSXSC)/(1.0+MUPXS) | N-Goods Purchased |
| 13N | SRXS=(PMSXS)(SEXS)(MSXSC) | N-Sales Revenue |
| 18N | LPXS=(WRXSC)(TEXS+IPXS) | N-Labor Payments |
| 14N | IADXS=DRXS+(IRXSC)(DBTXS) | N-Interest and Debt Payment |
| 12N | SDEXS=(DRXSC)(ESFXS) | N-Depreciation |
| 6N | SCIXS=DEXS | N-Construction Initiated |

Constants

| | | |
|---|---|---|
| C | TMXS=Constant | Material Adjustment Time |
| C | MITXS=Constant | Material Inventory Time |
| C | MSXSC=Constant | Material Used Per Student |

| | | |
|---|---|---|
| C | TSXS=Constant | Sales Smoothing Time |
| C | DISXS=Constant | Dollars/Student |
| C | MUPXS=Constant | Mark Up |
| C | PMSXS=Constant | Percent Material Sold |
| C | SFTXS=Constant | Students/Teacher |
| C | SIPXS=Constant | Students/Indirect |
| C | WRXSC=Constant | Wage Rate |
| C | DRXSC=Constant | School Depreciation Coefficient |
| C | FFUXS=Constant | Fraction Funds Used |
| C | IRXSC=Constant | Interest Rate |
| C | DERXS=Constant | Debt Ratio of External Funds |
| C | CDRXS=Constant | Coefficient for Debt Retirement |
| C | EATXS=Constant | Expansion Adjustment Time |
| C | P15XS=Constant | Population 10-15 years |
| C | P20XS=Constant | Population 15-20 years |
| C | DTSXS=Constant | Students/Teacher |
| C | PPSA=Constant | Secondary Private Percentage Students Attending |
| C | STUC=Constant | Secondary Tuition Rate, Private |
| C | NERXS=Constant | Non-Debt Expansion |

## I. FINANCIAL INSTITUTIONS SECTOR

### 1. General

Financial institutions play a key role in the flow of funds from savings into investment. Money not spent for current consumption in households, industry and government is usually deposited with savings institutions that in turn channel these funds back to households, industry and government for investment purposes.

A number of financial institutions play important roles in fund flows in the region:

1. Commercial Banks (60)
2. Savings Banks (61)
3. Savings and Loan Associations (62)
4. Insurance Companies (63)
5. Stock, Bond and Commodity Exchanges (64)
6. Credit Unions and Miscellaneous (65)

Each of these subsectors receives savings from other sectors and after maintaining a minimum legal reserve channels the remaining funds to various other sectors. Some institutions such as savings and loan associations are severely restricted in their investments to particular applications such as home mortgages. Others such as commercial banks loan money to a variety of investments.

The other sectors are linked to financial institutions through their finance subsectors. External financing in the form of debt or equity is described in each of the finance subsectors.

To date model development in this sector has emphasized external relationships, i. e., fund inflows and outflows. Internal operational relationships have been limited to gross profitability and personnel employment. Further development is planned for these internal variables after the completion of a study of the financial structure of the region.

### 2. External and Internal Relationships

The equation format for one of the subsectors will be presented. The formats of the other subsectors are identical.

Fund inflows to a financial institution, in this case savings and loan associations, are formulated in the same manner as sales orders in the manufacturing sectors. External (extra-regional) funds (EF62) and internal (inter-regional) funds (IF62) are transmitted from the household sectors.

11A EF52.KL=FSL98.JK+ . . . . (Other sector Inputs)

11A IF52.KL=FSL88.JK+ . . . . (Other sector Inputs)
FSL98 - Funds from external households
FSL88 - Funds from internal households

These funds accumulate in a reserve assets level equation from which they are withdrawn for loans.

2L RA62.K=RA62.J+(DT)(EF62.JK+IF62.JK-LW62.JK+O+O+O)
RA62 - Reserve Assets
LW62 - Loan Withdrawals

Loan withdrawals (E6288, E6298) are then divided according to their sector of destination.

12R E6288.KL=(LW88C)(LW62.JK)
12R E6298.KL=(LW98C)(LW62.JK)
LW88C - Loan withdrawals to internal households, coefficient
LW98C - Loan withdrawals to external households, coefficient

Other financial institutions sectors will have a larger number of sector destinations, but the principle is the same.

Loans liabilities for each sector are posted in a level equation.

L6288.K=L6288.J+(DT)(E6288.JK-D6288.JK)
L6288 - Loans from 62 to 88
D6288 - Debt retirement 88 to 62

It will be noted that short term fluctuations due to depositor's withdrawals are not accounted for, since only longer term flows are emphasized. At a later time these variables may easily be inserted.

Personnel are employed as a function of total assets.

20A DP62.K=(TA88.K)/(DPC62)
DP - Personnel
TA - Total Assets
DCP62 - Personnel coefficient

Profit and loss for the sector are determined in an equation similar to earlier sectors.

10A OP62.K=IC62.JK-RP62.JK-LP62.JK-IAD62.JK-TP62.JK-EP62.JK
IC62 - Interest and other income received

The other variables have the same meaning as in the other sectors.

This sector is still in the initial formulation stage. More information on the structure of local financial institutions is necessary to bring this sector up to the level of development of the other sectors.

## J. GOVERNMENT SECTORS

### 1. General

Governments receive funds through taxes and debt financing. These funds are budgeted for various public services. Some of these services such as education and utilities are provided for in other sectors, and the government sector performs only a budgeting function in these areas. Other governmental functions such as administration and fire-police protection are entirely accounted for within this sector.

This sector like the financial institutions sector is still in the initial stages of formulation since, like that sector, its final format is critically dependent on the form of the other sectors.

2. External and Internal Relationships

a. Taxes

Tax revenues from the other sectors are summed to obtain total tax revenue:

11A TT91.K=TP01.K+TP15.K+ . . . . . . .
TT91 - Total Tax Revenue
TP01 - Tax payments, sector 01

Operating and capital budgets are determined as percentages of tax revenue. As an example, the operating budget for education would be expressed as:

12R SSOB.KL=(TT91.K)(SSOBC)
SOBC - Secondary school operating budget

Budgets for other operating functions such as health, welfare and police-fire will be formulated in a similar manner.

Capital budgets will be established with equations similar to the above if such budgets use current tax funds. Budgets involving external debt financing or withdrawals from past funds will use - financial equations similar to those in previous finance subsectors.

The personnel equations derive from the number of personnel assigned to each function which in turn is proportional to the tax revenue and the coefficient assigned to the function.

Further development of this sector is planned after the external relationships of the other sectors have been tested.

## K. HOUSEHOLD SECTOR

1. General

Two primary socio-economic functions are included in this sector:

a. The household in its economic functions of selling labor and property services, purchasing consumer goods and services and saving money for investment.

b. The household in its social function of population growth.

In the first of the above functions, the household sector is much like other sectors in that it purchases inputs from other sectors and sells outputs to these same sectors.

The social function of population growth relates to the other sectors in a somewhat different way. All of the personnel subsectors in each of the other sectors are dependent on the population existing in the household sector. In other words, the human resource in the region is accounted for in this sector.

Because this sector differs so significantly from the other sectors, the equations will be described in some detail.

2. External and Internal Relationships

a. Household Income

Household income is the sum of all of the wage-salary, dividend, interest and rent payments received from the other sectors. Payments are determined from adding all of the payment variables previously listed in the other sectors. A special class of payments from the government sector is that of transfer payments. Insurance payments are also a special class of income received from the financial institutions.

11A TSP88.K=LP01.JK+LP15.JK+LP20.JK+LP27.JK+ LP33.JK+LP34.JK+LP35.JK+AUX8.K — Total Wage-Salary Payments
11A AUX8.K=LP36.JK+LP37.JK+LP38.JK+LP41.JK+ LP48.JK+LP49.JK+LP47.JK+AUX9.K
11A AUX9.K=LP50.JK+LP52.JK+LP72.JK+LPXE.JK+ LPXS.JK+LPXU.JK+LP60.JK+LP91.JK
11A TDP88.K=(same format as above) — Total Dividends Received
12A TRP88.K+(same format as above) — Rent Payments
12A TIP88.K=(same format as above) — Interest Paid to Householders
7A TTIP.K=INP60.JK+TRP91.JK+TRP87.JK — Insurance and Transfer Payments
9A NHI88.K=TLP88.K+TDP88.K+TRP88.K+TIP88.K+TTIP.K — Total Household Income

b. Purchases

Income usage is divided between consumption (purchases) and savings. Purchases from each of the other sectors are expressed in the model as percentages of total household income. Purchases are made from both intra-and extra-regional sectors. Typical sectoral purchases are listed in the equations below. Similar relations will exist with other sectors although a large percentage of consumer purchases pass through the retail trade sector. This sector along with the utility and service sectors account for a large preponderance of consumer purchases. At a later date further subdivision of trade purchases such as durables and non-durables and service purchases such as medical and personnel may be made as desired. Capital purchases of consumers such as new housing expenditures are described later in this section.

| | | |
|---|---|---|
| 12A | HP52.K=(HP52C)(NHI88.K) | Purchases-Retail |
| 12A | HP41.K=(HP41C)(NHI88.K) | Purchases-Transportation |
| 12A | HP48.K=(HP48C)(NHI88.K) | Purchases-Energy |
| 12A | HP49.K=(HP49C)(NHI88.K) | Purchases-Communications |
| 12A | HP47.K=(HP47C)(NHI88.K) | Purchases-Water |
| 12A | HP72.K=(HP72C)(NHI88.K) | Purchases-Services |
| 10A | THP88.K=HP52.K+HP49.K+HP48.K+HP41.K+ HP47.K+HP72.K | Total household purchases |

c. Savings and Investment

The difference between income and consumption, interest and debt retirement, tax and capital payments is savings. In this subsector savings are determined and directed to appropriate destinations in the financial institutions sector. A cash - or liquidity - balance is maintained along with consumer debt variable relationships.

| | | |
|---|---|---|
| 10A | NHS88.K=NHI88.K-THP88.K-IAD88.JK- TP88.JK+O | Net Savings |
| 3L | NSS88.K=NSS88.J+(DT)(1/TSS88)(NHSS88.J) | Net Savings Smoothed |
| 3L | CA88.K=CA88.J+(DT)(NHS88.J+EDF88.JK- EP88.JK) | Cash |
| 14R | IAD88.KL=DR88.K+(IR88C)(DBT88.JK) | Interest and Debt Payments |
| 1L | DBT88.K=DBT88.J+(DT)(EDF88.JK-DR88.JK) | Debt |
| 51R | EDF88.KL=CLIP(-NHS88.K,O,MNS88.K,NHS88.K) | External Debt Financing |
| 12A | DR88.K=(DBT88.K)(CDR88) | Debt Retirement |
| 12R | DE88.KL=(DEP88)(HFV88.K) | Depreciation |
| 12R | TP88.KL=(NHI88.K)(TAXR) | Tax Payments |
| 13R | EPX88.KL=(ER88.K)(HFV88.K)(NER88) | Non-Debt Expansion Payments |
| 12R | MNS88.K=(FCU88)(-CA88.K) | Minimum Net Savings |
| 12R | FCB88.KL=(FFCBC)(NHS88.K) | Commercial Banks |
| 12R | FSB88.KL=(FFSBC)(NHS88.K) | Savings Banks |
| 12R | FSL88.KL=(FFSLC)(NHS88.K) | Savings and Loan Associations |
| 12R | FIN88.KL=(FFINC)(NHS88.K) | Insurance |
| 12R | FEQ88.KL=(FFEQC)(NHS88.K) | Equities, Stocks |
| 12R | FCU88.KL=(FFCUC)(NHS88.K) | Credit Unions and Miscellaneous |

d. Household Property

A household property subsector is included to continuously account for the housing and other asset values of this sector. Some initial attempt has been made to relate housing expansion to population growth in certain age groups.

| | | |
|---|---|---|
| 1L | HFV88.K=FGV88.J+(DT)(EP88.JK-DE88.JK) | Home and Other Property Values |
| 27A | PX1.K=(P25.K/POP25.JK)-1.0 | |
| 6R | POP25.KL=P25.K | |
| 27A | PX2.K=(P30.K/POP30.JK)-1.0 | |
| 6R | POP30.KL=P30.K | |
| 27A | PX3.K=(P35.K/POP35.JK)-1.0 | |
| 6R | POP35.KL=P35.K | |
| 16A | ERY88.K=(PXIC)(PX1.K)+(PX2C)(PX2.K)+ (PX3C)(PX3.K)+(O)(O) | |

# HOUSEHOLD SECTOR
# INCOME - CONSUMPTION SUBSECTOR

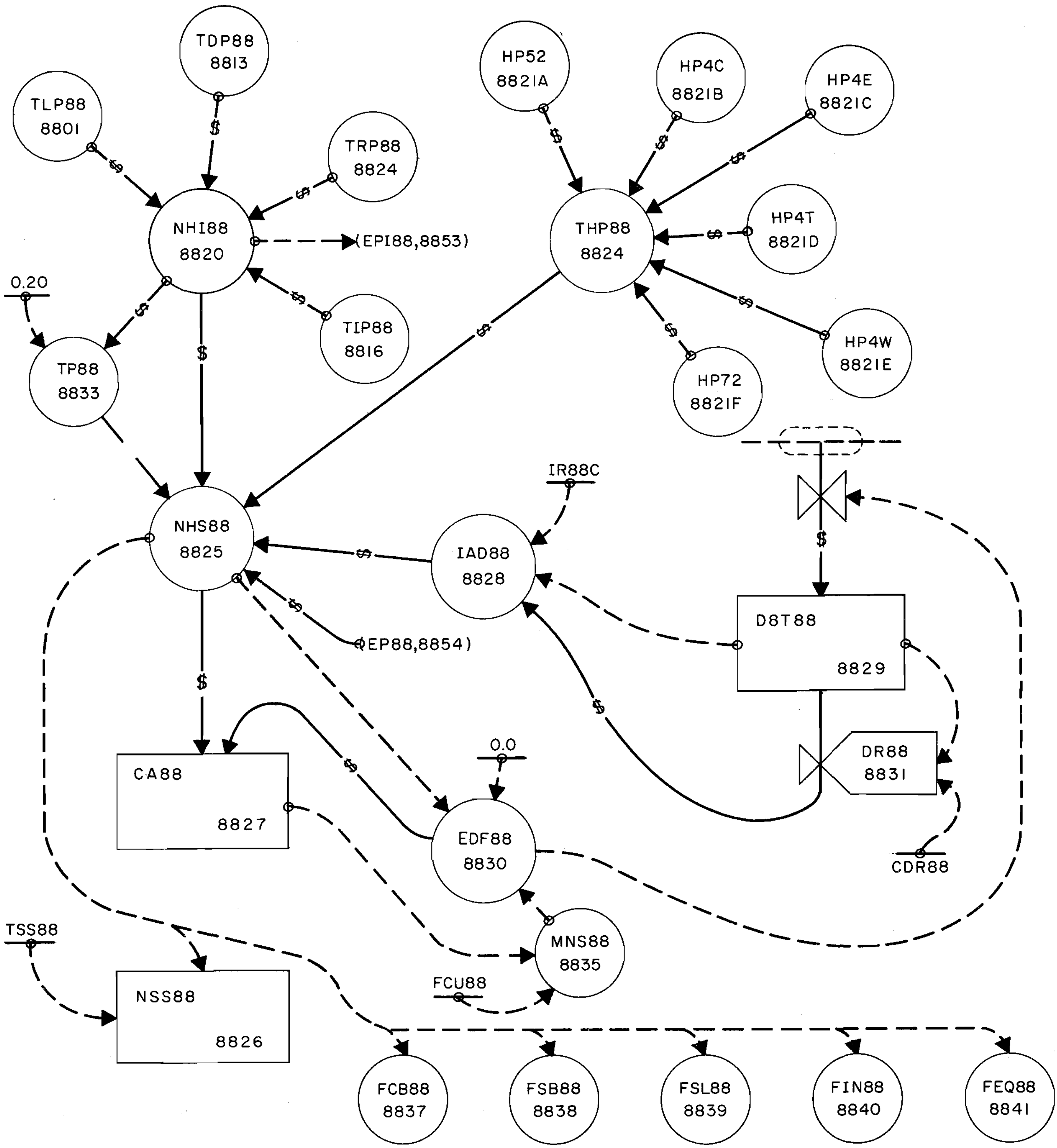


FIGURE II

| | | |
|---|---|---|
| 20A | ERX88.K=ERY88.K/DT | Expansion Rate (+ or -) |
| 51A | ER88.K=CLIP(ERX88.K,O,ERX88.K,O) | Expansion Rate (+) |
| 12A | EPI88.K=(FUE88)(NHI88.K) | Expansion Through Income |
| 51R | EP88.KL=CLIP(EPX88.K,EPX88.K,EPI88.K) | Expansion Payments |

Initial Conditions

| | | |
|---|---|---|
| 6N | CA88=Constant | N-Cash |
| 6N | DBT88=Constant | N-Debt Level |
| 6N | HEV88=Constant | N-Property Value |
| 12N | DR88=(DBT88)(CDR88) | N-Debt Retirement |
| 6N | NSS88=Constant | N-Savings Smoothed |
| 12N | DE88=(DEP88)(HEV88) | N-Depreciation |
| 14N | IAD88=DR88+(IR88C)(DBT88) | N-Interest and Debt Payments |
| 6N | TP88=Constant | N-Tax Payments |
| 6N | EP88=DE88 | N-Expansion Payments |
| 6N | POP25=P25 | N-Population 25 |
| 6N | POP30=P30 | N-Population 30 |
| 6N | POP35=P35 | N-Population 35 |

Constants

| | | |
|---|---|---|
| C | IR88C=Constant | Interest Rate Coefficient |
| C | CDR88=Constant | Coefficient for Debt Retirement |
| C | DEP88=Constant | Depreciation Rate |
| C | FCU88=Constant | Fraction of Cash Used |
| C | PX1C=Constant | Coefficient |
| C | PX2C=Constant | Coefficient |
| C | PX3C=Constant | Coefficient |
| C | FUE88=Constant | Funds used in Expansion Coefficient |
| C | DVR88=Constant | Coefficient of Dividends Paid |
| C | RT88C=Constant | Rent Coefficient |
| C | HP52C=Constant | Retail Purchase Coefficient |
| C | HP4CC=Constant | Communication Coefficient |
| C | HP4EC=Constant | Electric Coefficient |
| C | HP4TC=Constant | Transportation Coefficient |
| C | HP4WC=Constant | Water Coefficient |
| C | HP72C=Constant | Services Coefficient |
| C | TSS88=Constant | Savings Smoothing Time |
| C | FFCBC=Constant | Commercial Bank Coefficient |
| C | FFSBC=Constant | Savings Bank Coefficient |
| C | FFSLC=Constant | Savings and Loan Coefficient |
| C | FFINC=Constant | Insurance Coefficient |
| C | FFEQC=Constant | Stocks, Etc. Coefficient |
| C | ID88C=Constant | Interest and Debt Payment Coefficient |
| C | TAXR=Constant | Tax Rate |
| C | FFCUC=Constant | Credit Union Coefficient |

e. Population

1) General

The population subsector is still in the formulation stage, and it will very likely be modified in detail as a result of the regional P-6 population study. A consistent set of equations has been formulated, however, that contain some features that will probably be retained even after these modifications. These features include:

a.) Classification and computation of population growth by age, sex and race groups to facilitate the use of group-specific birth, death and migration rates.

b.) Maintenance of a continual running inventory of population in each age group for transfer to the succeeding age group in a sequential fashion.

c.) Use of statistical distributions in the simulation of birth, death and migration rates.

Use of group-specific birth, death and migration rates is generally regarded as a more accurate method of population projection than overall aggregative population change rates.

# HOUSEHOLD SECTOR
# PROPERTY SUBSECTOR

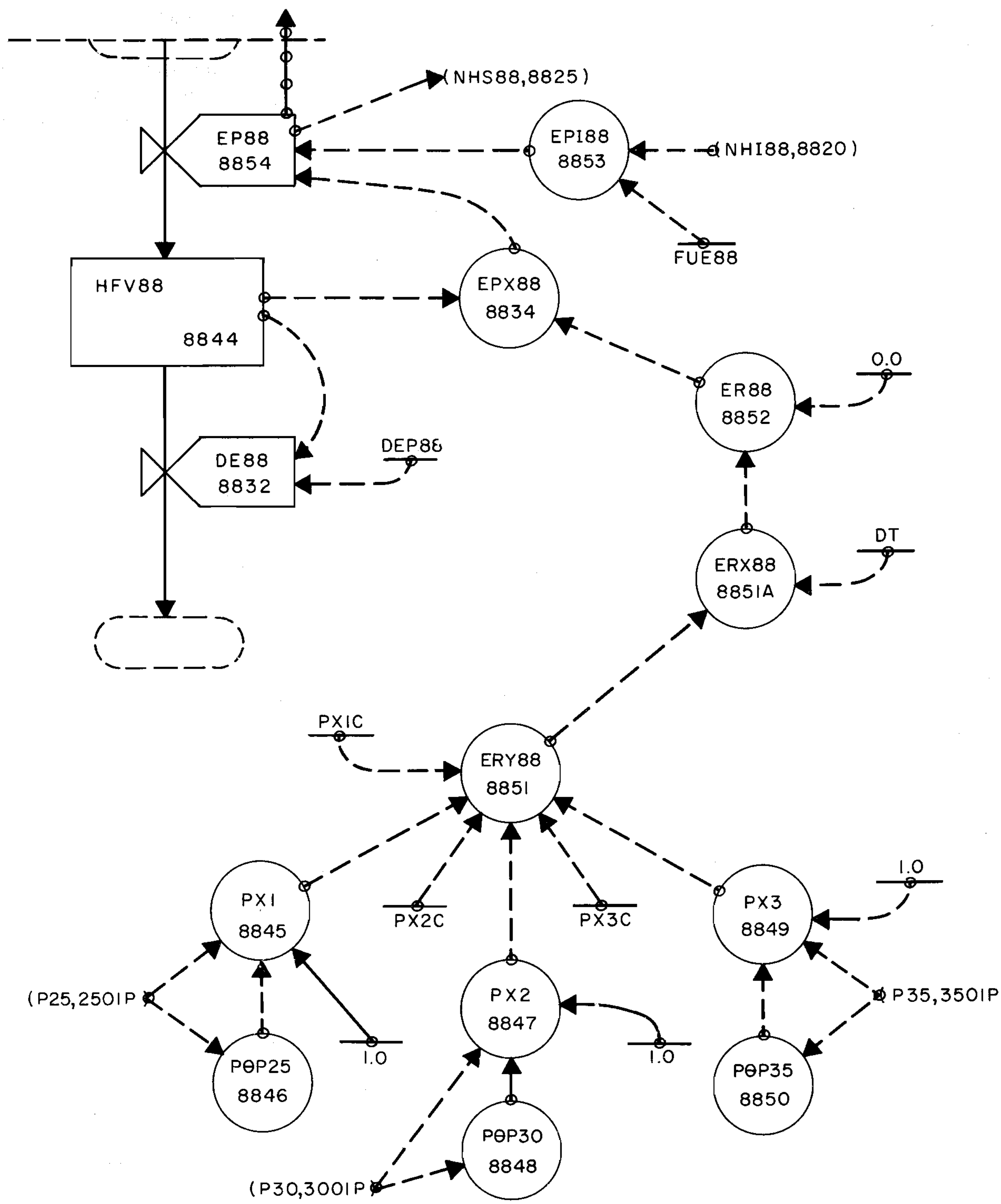


FIGURE 12

Allowing for random variance of these rates adds additional realism since the element of random uncertainty is strong in population changes.

Specific identification of population groups and the inter-relationship of one age group with another is provided for in the running inventories. As an example, the number of persons born in a certain month can be stored in the computer memory and moved along in time until they are transferred to the next age group after proper allowance for deaths and migrations.

A number of additional extensions to the model which would increase its capability will be added in the near future.

a.) Family formation and dissolution should be simulated in the manner as outlined by Orcutt in his recent book on a demographic simulation model[19]. The method of formulation would differ from the Orcutt model in that it would simulate these activities for groups of individuals and families rather than for single individuals and families.

b.) Birth rates and especially migration rates in the model should be related to the general level of employment and economic activity in the region. It is a well known fact that migration is greatly affected by employment opportunities.

c.) Consumption purchases in the household subsector should be directly tied into the quantity and structure of population growth.

2) Internal Relationships

Equations for two age group sectors are listed below. Other age group sectors are similar in format to the 5-10 year group.

| | | |
|---|---|---|
| 11A | TWP.K=WP05.K+WP10.K+WP15.K+WP20.K+ WP25.K+WP30.K+WP35.K+AUX1.K | |
| 11A | AUX1.K=WP40.K+WP45.K+WP50.K+WP55.K+ WP60.K+WP65.K+WP70.K+AUX2.K | |
| 7A | AUX2.K=WP75.K+WP80.K | White Population |
| 11A | TNWP.K=NWP05.K+NWP10.K+NWP15.K+ NWP20.K+NWP25.K+NWP30.K+NWP35.K+AUX3.K | |
| 11A | AUX3.K=NWP40.K+NWP45.K+NWP50.K+ NWP55.K+NWP60.K+NWP65.K+NWP70.K+AUX4.K | |
| 7A | AUX4.K=NWP75.K+NWP80.K | Non-White Population |
| 7A | TPOP.K=TWP.K+TNWP.K | Total Population |
| 11A | TMP.K=MP05.K+MP10.K+MP15.K+MP20.K+ MP25.K+MP30.K+MP35.K+AUX5.K | |
| 11A | AUX5.K=MP40.K+MP45.K+MP50.K+MP55.K+ MP60.K+MP65.K+MP70.K+AUX6.K | |
| 7A | AUX6.K=MP75.K+MP80.K | Male Population |
| 11A | TFP.K=FP05.K+FP10.K+FP15.K+FPCB.K+ FP55.K+FP60.K+FP65.K+AUX7.K | |
| 8A | AUX7.K=FP70.K+FP75.K+FP80.K | Female Population |

Population 0-5 Year Bracket

| | | |
|---|---|---|
| 2L | PO5.K=PO5.J+(DT)(BRR.JK+I05.JK-DO5.JK- E05.JK-ATR05.JK+O) | |
| 37B | AT05=BOXLIN(30,T) | Age Transition Data |
| 9A | AT05*1.K=BRR.JK+IO5.JK-DO5.JK-EO5.JK | Present Birth Rate |
| 6A | ATR05.KL=ATO5*30.K | Present Transition Rate |
| 12R | DO5.KL=(DRC05.K)(PO5.K) | Death Rate |
| 34R | IO5.KL=(1)NORMRN(IO5A,IO5S) | Immigration Distribution |
| 34R | E05.KL=(1)NORMRN(E05A,E05S) | Emigration Distribution |
| 12R | BRR.KL=(BRC.K)(FPCB.K) | Present Birth Rate |
| 11A | FPCB.K=FP20.K+FP25.K+FP30.K+FP35.K+ FP40.K+FP45.K+FP50.K+O | Females, Childbearing Age |
| 12A | WP05.K=(WP05)(PO5.K) | White Population |
| 7A | NWP05.K=P05.K-WP05.K | Non-White Population |

19 Guy H. Orcutt et al., Microanalysis of Socioeconomic Systems, Harper, New York; 1961.

| | | |
|---|---|---|
| 12A | MP05.K=(MP05)(P05.K) | Male Population |
| 7A | FP05.K=P05.K-MP05.K | Female Population |
| 34A | BRC.K=(1)NORMRN(BRCA,BRCS) | Birth Rate Distribution |
| 34A | DRC05.K=(1)NORMRN(DR05A,DR05S) | Death Rate Distribution |

Initial Conditions and Constants

| | | |
|---|---|---|
| 6N | D05=Constant | N-Death Rate |
| 6N | P05=Constant | N-Population, 0-5 Years |
| 6N | I05=Constant | N-Immigration Rate |
| 6N | ATR05=Constant | N-Age Transition Rate |
| 6N | E05=Constant | N-Emigration Rate |
| 6N | BRR=Constant | N-Birth Rate |
| C | T=8.6 Constant | Boxcar Shifting Time |
| C | AT05*=Constants | Age Transition |
| C | WP05=Constant | White Population Ratio |
| C | MP05=Constant | Male Population Ratio |
| C | IO5A=Constant | Immigration, Average |
| C | IO5S=Constant | Immigration, Standard Deviation |
| C | BRCA=Constant | Birth Rate, Average |
| C | BRCS=Constant | Birth Rate, Standard Deviations |
| C | DR05A=Constant | Death Rate, Average |
| C | DR05S=Constant | Death Rate, Standard Deviations |

Population 5-10 Year Bracket

| | | |
|---|---|---|
| 2L | P10.K=P10.J+(DT)(ATR05.JK+I10.JK-D10.JK-E10.JK-ATR10.JK+O) | |
| 9R | AT10*1.KL=AT05*30.K-D10.JK+I10.JK-E10.JK | Age Transition Rate |
| 37B | AT10=BOXLIN(30,T) | Age Transition Data |
| 6A | ATR10.KL=AT10*30.K | Present Transition Rate |
| 12R | D10.KL=(DRC10)(P10.K) | Present Death Rate |
| 34R | I10.KL=(1)NORMRN(I10A,I10S) | Immigration Distribution |
| 34R | E10.KL=(1)NORMRN(E10A,E10S) | Emigration Distribution |
| 12A | WP10.K=(WP10)(P10.K) | White Population |
| 7A | NWP10.K=P10.K-WP10.K | Non-White Population |
| 12A | MP10.K=(MP10)(P10.K) | Male Population |
| 7A | FP10.K=P10.K-MP10.K | Female Population |
| 34A | DRC10.K=(1)NORMRN(DR10A,DR10S) | Death Rate |

Initial Conditions

| | | |
|---|---|---|
| 6N | P10=Constant | N-Population, 5-10 Years |
| 6N | ATR10=Constant | N-Age Transition Rate |
| 6N | D10=Constant | N-Death Rate |
| 6N | I10=Constant | N-Immigration Rate |
| 6N | E10=Constant | N-Emigration Rate |

Constants

| | | |
|---|---|---|
| C | I10A=Constant | Immigration average |
| C | I10S=Constant | Immigration standard deviation |
| C | E10A=Constant | Emigration, average |
| C | E10S=Constant | Emigration, standard deviation |
| C | DR10A=Constant | Death rate, average |
| C | DR10S=Constant | Death rate, standard deviation |
| C | AT10*=Constants | |
| C | DRC10=Constant | Death Rate Coefficient |
| C | MP10=Constant | Male Population Ratio |
| C | WP10=Constant | White Population Ratio |

## L. EXTRA-REGIONAL SECTORS

### A. General

The extra-regional sectors follow equation formats identical to their inter-regional equivalents. The code number for each external sector and its inter-regional equivalent sector are listed below:

| Sector | Code Number | Equivalent |
|---|---|---|
| 1. Agriculture | 91 | Agriculture (01) |
| 2. Mining | 93 | Agriculture (01) |
| 3. Construction | 95 | Construction (15) |
| 4. Manufacturing | 96 | Manufacturing (20-38) |
| 5. Electric Utilities | 94 | Energy Utilities (48) |
| 6. Other Utilities | 92 | Communications (49) |
| 7. Wholesale-Retail Trade | 90 | Retail Trade (50) |
| 8. Financial Institutions | 97 | Financial Institutions (60) |
| 9. Service | 99 | Services (72) |
| 10. Government | 87 | Government (91) |
| 11. Households | 98 | Households (88) |

## APPENDIX II

# SPATIAL ACTIVITY MODEL DESCRIPTION

A. General

The spatial activity model is the least developed of all of the models of the regional planning system. Although there is little question that additional model development as well as data collection is necessary before the regional activity model will be useful as a planning tool, this first model is at a higher state of development than the spatial activity model.

A number of reasons account for this disparity. Most important, the regional activity model is a fortunate combination of two model building techniques that have been proven in the past: input-output and dynamic simulation. Although to the best knowledge available no such regional model of this kind has been used before, its development has been enhanced by previous development in interindustry (input-output) and dynamic simulation models. Other advantages in the formulation of the regional activity have resulted from the extensive development of economic income accounting terminology by the federal government in the last thirty years.

None of these advantages exist in the spatial activity model. Previous model development has been limited to special aspects such as residential land use. The first comprehensive spatial models are under development by the Penn-Jersey Transportation Study and the Rand Corporation, a more general approach being pursued by the Rand Corporation.

Neither of these efforts, however, was at a state of development sufficient to be of great aid in the development of the required spatial activity model. It is intended, however, that extensive study will be made of these other model efforts in order to benefit as much as possible from the concepts and techniques evolved in these other studies. It is important to emphasize, however, that the regional activity model for Southeastern Wisconsin will probably be somewhat unique because of conditions peculiar to this region. It would be a serious error to try to "pour this region into the mold" of some previously developed model. One of the few statements with which all model builders agree is that all models must be custom-built to fit the application.

Finally, it is important to point out that the spatial activity model is an area of research as well as planning operations. There are no standard "answers", and the benefits of the model will be greatly dependent on future developments now only in the early stages.

B. MODEL FORMULATION

The equations below describe a complete and consistent set of spatial activity equations. In fact, these equations as they are listed were tested on an IBM 704 using the DYNAMO compiler. These equations follow the conceptual principles for zonal growth rate determination discussed in the text of the report. Because the equations below are for only one zone, dummy constants to represent regional function variables were inserted. In the actual model, these variables would be determined from computations involving variables from all of the other zones.

Annotations after each equation and constant explain the purpose of each:

| | | |
|---|---|---|
| 1L | R111.K=R111.J+(DT)(RI111.JK-RD111.JK) | Residents, Zone 111 |
| 46R | RI111.KL=(POP5.K)(CA111.K)(ZG111.K)/ (RG.K)(1)(1) | Residential Increase Rate |
| 7A | CA111.K=RM111-R111.K | Zonal Capacity |
| 16A | ZG111.K=(AW)(A111.K)+(SW)(S111)+(X111) (1)+(TR111)(1) | Zonal Growth Factor |
| 6A | RG.K=RGC | Regional Growth Factor (Sum of Zonal Growths) |
| 47A | POP5.K=RAMP(POP5R,1) | Population, Class 5 |
| 6R | RD111.KL=DC111 | Residential Decrease Rate |
| 8A | A111.K=AE111.K+AK111.K+AS111.K | Accessibility, Total |
| 6A | AE111.K=EA001.K | Accessibility, Employment |

# SPATIAL ACTIVITY MODEL
## RESIDENTIAL SECTOR

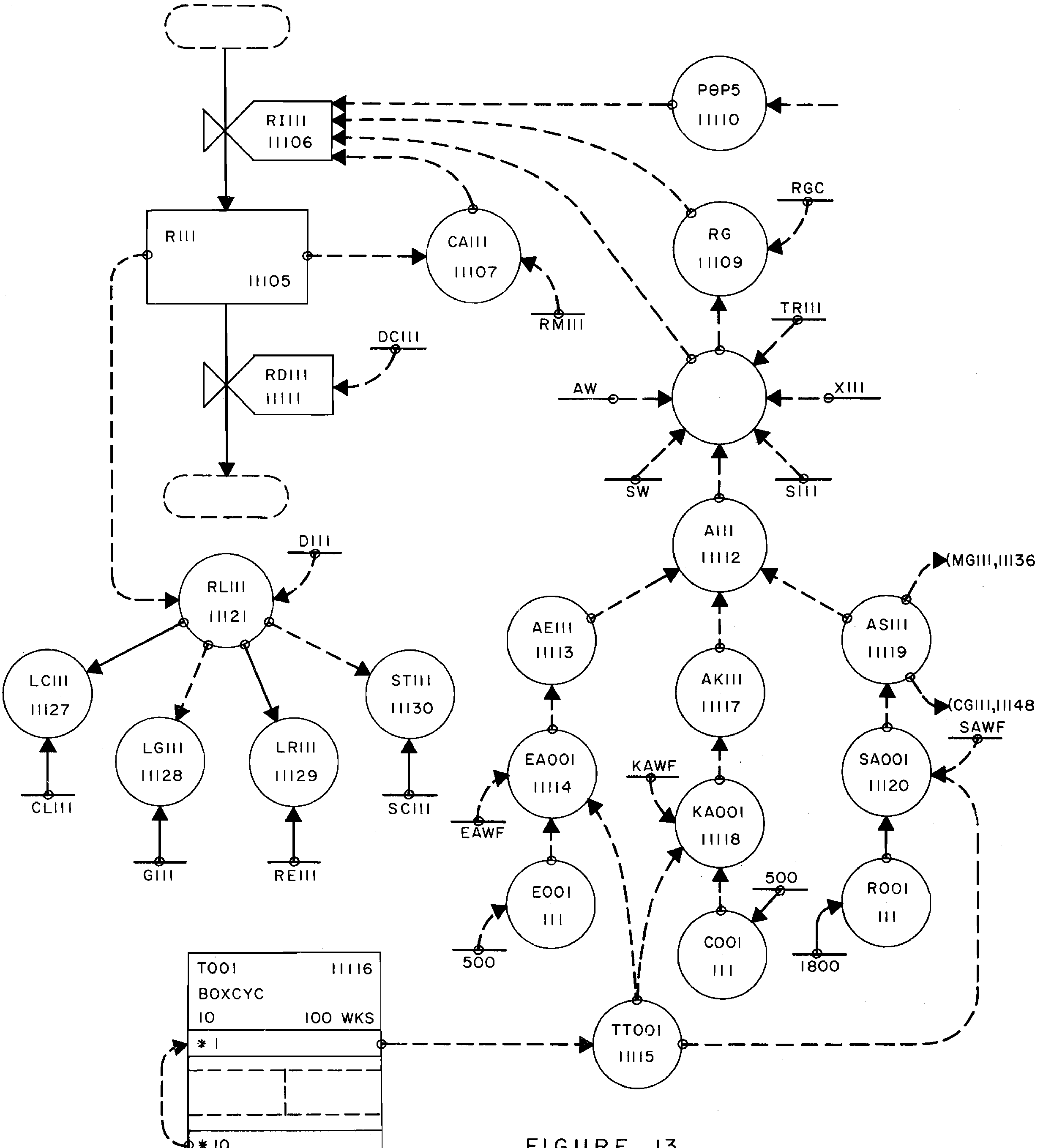


FIGURE 13

| | | |
|---|---|---|
| 44A | EA001.K=(EAWF)(E001.K)/(TT001.K) | Employment Accessibility Factor |
| 12A | TT001.K=(T001*1.K)(T001*1.K) | Travel Time Squared |
| 35B | T001=BOXCYC(10,100) | Travel Time Boxcar |
| 6A | AK111.K=KA001.K | Accessibility, Commercial |
| 44A | KA001.K=(KAWF)(C001.K)/TT001.K | Commercial Accessibility Factor |
| 6A | AS111.K=SA001.K | Accessibility, Social |
| 44A | SA001.K=(SAWF)(R001.K)/TT001.K | Social Accessibility Factor |
| 20A | RL111.K=R111.K/D111 | Residential Land Use |
| 1L | BV111.K=BV111.J+(DT)(VI111.JK-VD111.JK) | Building-Land Value |
| 6R | VI111.KL=VC111 | Building-Land Value Increase |
| 6R | VD111.KL=CV111 | Building-Land Value Decrease |
| 12A | LC111.K=(CL111)(RL111.K) | Local Commercial Land Use |
| 12A | LG111.K=(G111)(RL111.K) | Local Governmental Land Use |
| 12A | LR111.K=(RE111)(RL111.K) | Local Recreational Land Use |
| 12A | TF111.K=(TF111)(RL111.K) | Local Transportation-Utility Facilities Land Use |
| 1L | ME111.K=ME111.J+(DT)(MI111.JK-MD111.JK) | Manufacturing-Trade Employment |
| 46R | MI111.KL=(MAN5.K)(MC111.K)(MG111.K)/((MRG.K)(1)(1)) | Employment Increase |
| 7A | MC111.K=MM111-ME111.K | Employment Capacity |
| 16A | MG111.K=(MAW)(AS111.K)+(MSW)(S111)+(TR111)(1)+(RS111)(1) | Zonal Growth Factor Manufacturing |
| 6A | MRG.K=MRGC | Regional Growth Factor, Manufacturing |
| 47A | MAN5.K=RAMP(MAN5R,1) | Manufacturing Growth, Class 5 |
| 6R | MD111.KL=DM111 | Employment Decrease |
| 1L | FV111.K=FV111.J+(DT)(FI111.JK-FD111.JK) | Plant Facilities, Values |
| 6R | FI111.KL=FC111 | Facility Value Increase |
| 6R | FD111.KL=FE111 | Facility Value, Decrease |

Regional Office Activities (Commercial, Governmental, Institutional)

| | | |
|---|---|---|
| 1L | CE111.K=CE111.J+(DT)(CI111.JK-CD111.JK) | Office Employment |
| 46R | CI111.KL=(COM5.K)(CC111.K)(CG111.K)/((CRG.K)(1)(1)) | Employment Increase |
| 7A | CC111.K=CM111-CE111.K | Employment Capacity |
| 16A | CG111.K=(CAW)(AS111.K)+(MSW)(S111)+(TR111)(1)+(RS111)(1) | Zonal Growth Factor, Regional Office |
| 6A | CRG.K=CRGC | Regional Growth Factor |
| 47A | COM5.K=RAMP(COM5R,1) | Office Employment Growth, Class 5 |
| 6R | CD111.KL=DD111 | Employment Decrease |
| 1L | CF111.K=CF111.J+(DT)(UI111.JK-UD111.JK) | Office Facilities Value |
| 6R | UI111.KL=UC111 | Office Facilities Values Increase |
| 6R | UD111.KL=CU111 | Office Facilities Value Decrease |

Initial Conditions

| | | |
|---|---|---|
| 6N | R111=2000 | Residents, Initial |
| 6N | BV111=20E6 | Building-Land Value, Initial |
| 6N | ME111=2000 | Manufacturing Employment, Initial |
| 6N | FV111=50E6 | Manufacturing Facilities, Initial |
| 6N | CE111=150 | Office Employment, Initial |
| 6N | CF111=10E6 | Office Facilities, Initial |

Constants

| | | |
|---|---|---|
| C | RM111=3000 | Residents, Maximum |
| C | AW=0.4 | Accessibility Weighting |
| C | SW=0.3 | Sewer Water Weighting |
| C | S111=0.5 | Sewer=Water |
| C | X111=0.2 | Auxiliary |
| C | TR111=0.1 | Tax Rate Weighting |
| C | TGC=150 | Regional Growth Constant |
| C | DC111=2 | Residential Decrease Constant |

# SPATIAL ACTIVITY MODEL
## INDUSTRIAL SECTOR

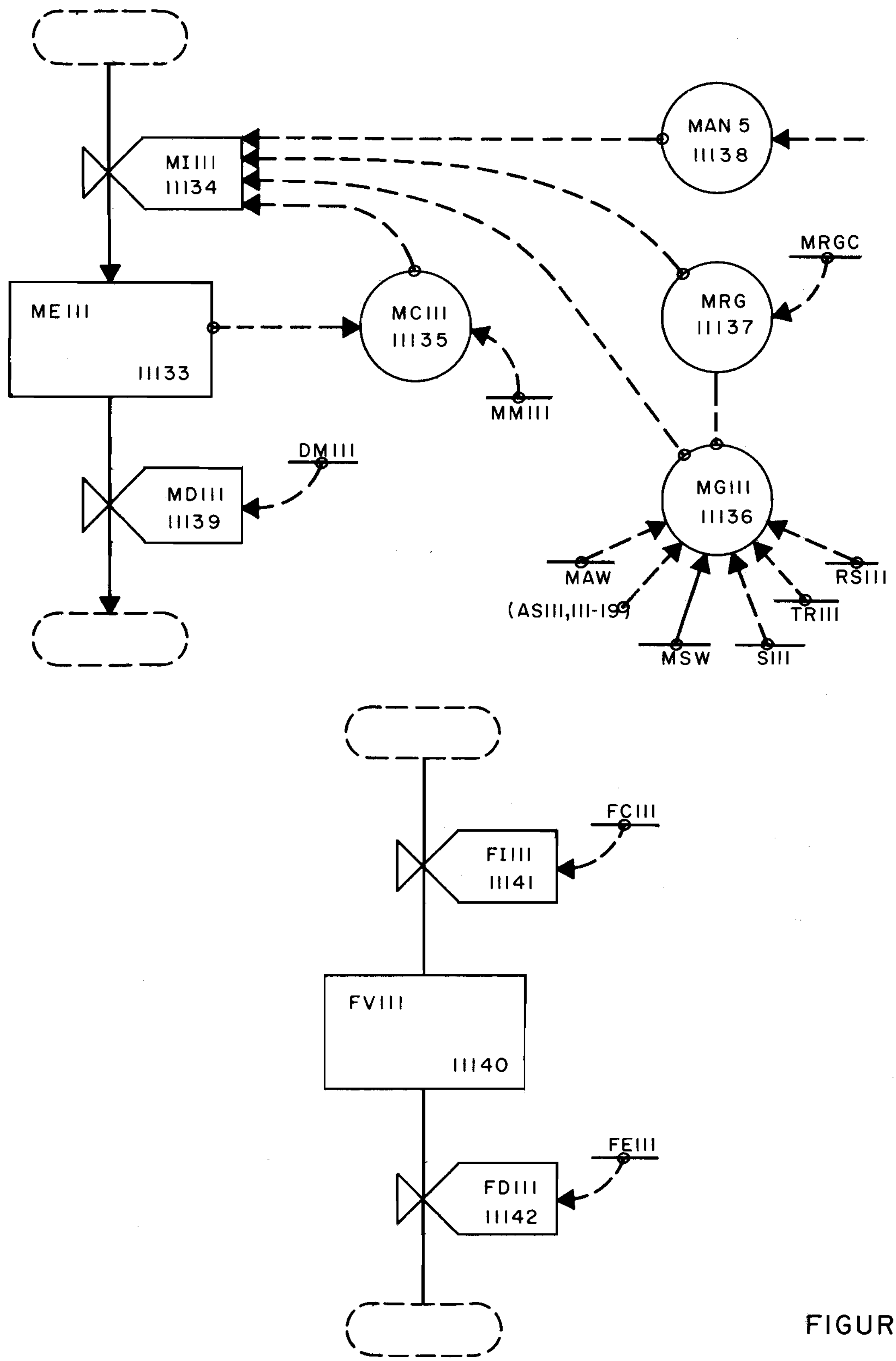


FIGURE 14

# SPATIAL ACTIVITY MODEL
# REGIONAL OFFICE SECTOR

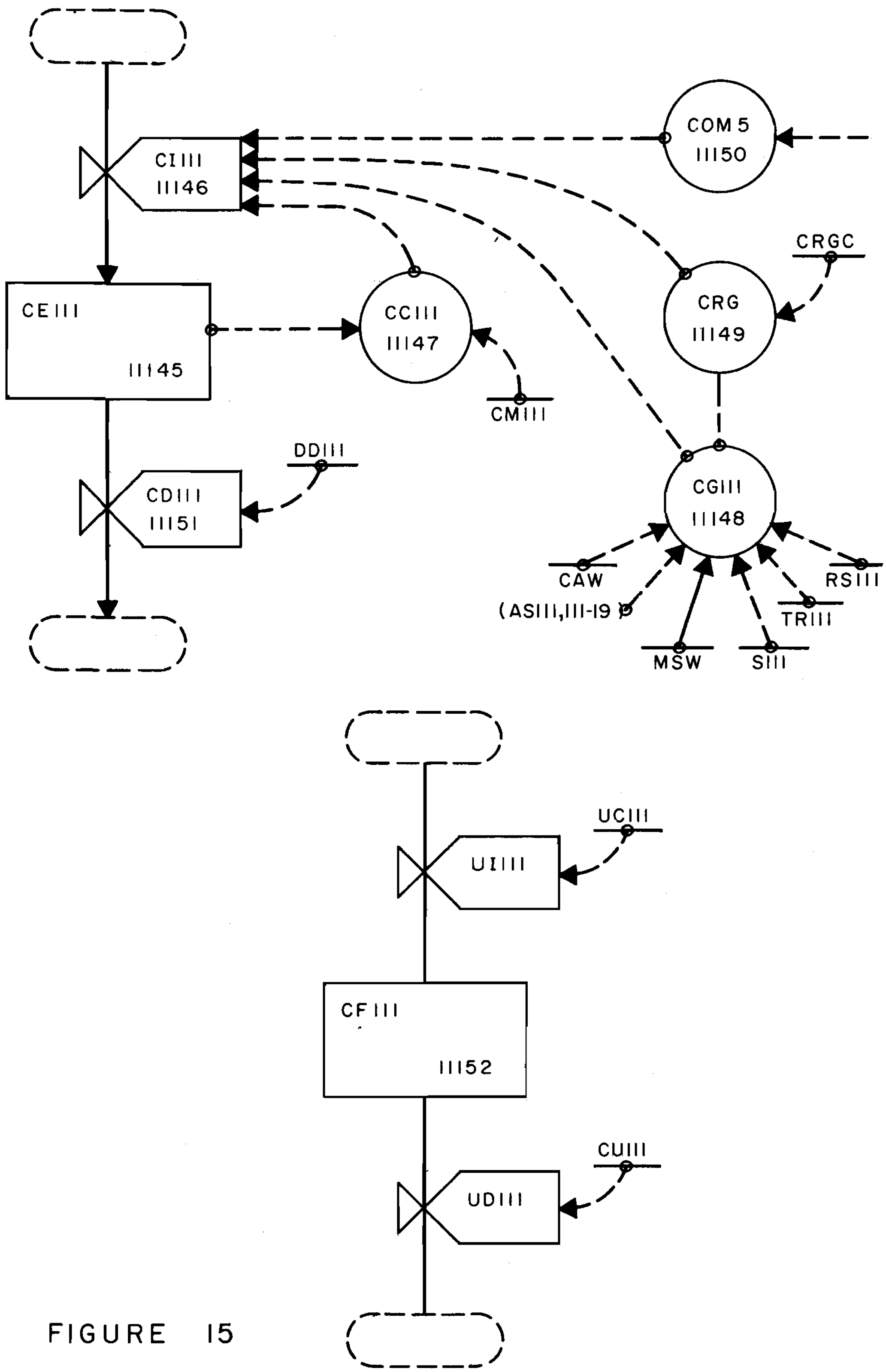


FIGURE 15

```
C    POP5R=100                                  Population, Class 5
C    T001*=27/12/15/17/19/43/22/29/30/37        Travel Times
C    D111=1000                                  Land Resident Constant
C    VC11=100                                   Land Building Value, Increase
C    CV111=70                                   Land Building Value, Decrease
C    C1111=50                                   Commercial Land Constant
C    G111=0.01                                  Government Land Constant
C    RE111=0.05                                 Recreational Land Constant
C    TF111=0.4                                  Transportation-Utility Facility
                                                  Land Constant
C    MM111=4000                                 Employment Maximum
C    MAW=0.4                                    Accessibility Weighting
C    MSW=0.2                                    Sewer-Water Weighting
C    RS111=0.2                                  Rail Service
C    MRGC=100                                   Manufacturing Regional Growth Constant
C    MAN5R=50                                   Manufacturing, Group 5
C    DM111=5                                    Employment Decrease Constant
C    FC111=150                                  Facility Increase
C    FE111=80                                   Facility Decrease
C    CM111=180                                  Office Employment, Maximum
C    CAW=0.4                                    Accessibility Weighting
C    CRGC=200                                   Office, Regional Growth
C    COM5R=95                                   Office, Group 5
C    DD111=2                                    Employment Decrease
C    UC111=66                                   Office Value Increase
C    CU111=40                                   Office Value, Decrease
C    EAWF=1                                     Employment Accessibility Factor
C    KAWF=1                                     Office Accessibility Factor
C    SAWF=1                                     Social Accessibility Factor
6A   E001.K=500                                 Employment, Zone 001
6A   C001.K=500                                 Office Employment, Zone 001
6A   R001.K=1800                                Residents, Zone 001

PRINT 1)R111,R1111,RD111,CA111,POP5/2)ZG111,RG,*,A111,T001*1
PRINT 3)AE111,AK111,AS111,*,TT001/4)BV111,V1111,VD111,*,RM111
PRINT 5)RL111,LC111,LG111,LR111,ST111/6)ME111,MI111,MD111,MC111,MAN5
PRINT 7)MG111,MRG/8)FV111,FI111,FD111,*,MM111
PRINT 9)CE111,CI111,CD111,CC111,COM5/10)CG111,CRG
PRINT 11)CF111,UI111,UD111,*,CM111
PLOT RL111=R,LC111=C,LG111=G,LR111=L,ST111=S
PLOT R111=R,ME111=M,CE111=C/RI111=S,RD111=T,MI111=N,MD111=O,CI111=D,CD1
X1 11=E
PLOT BV111=B,FV111=F,CF111=C/VI111=V,VD111=W,FI111=I,FD111=D,UI111=U,UD
X1 111=X
PLOT CA111=R,MC111=N,CC111=K/POP5=P,MAN5=M,COM5=C
PLOT ZG111=Z,A111=A,MG111=M,CG111=C/RG-R,MRG=N,CRG=D
```

NOTE: The print and plot designations indicate those variables printed in the trial test run.

## APPENDIX III

# TRANSPORTATION NETWORK MODEL

Further development of the network approach to a transportation model will continue during the regional land use-transportation study. A pilot study to being made, utilizing the city of Waukesha, to test the general validity and practicality of the approach. This city was selected because recent data on trip origins and destinations and land use were available. Analyses using a conventional gravity models and other traffic model techniques have been completed in this area and will serve as a basis for comparison with the network approach.

An electrical network analog of the Waukesha city street system is being constructed and tested. The initial system simulation will encompass a four-zone, ten-thoroughfare system. In the electrical network current sources are used to represent the trips generated in each zone and the branches contain combinations of electrical elements to represent the thoroughfares. In each branch are three electrical elements in series (1) a voltage source in series with a diode[20] (2) a current source in parallel with a diode,[20] and (3) a resistance. The first of these elements enables us to assign to each thoroughfare a cost per unit flow equal to the value of the source with an unlimited capacity for flow; the second establishes an upper limit on the amount of flow equal to the value of the source and at a zero cost per unit flow. The resistive element permits us to incorporate the aspects of time required for travel on the thoroughfare.[21] With these elements in series, cost considerations, capacity limitations and route desirability features are built into the model. The currents in the branches obtained as the solutions of the electrical network problem represent the traffic flow on the thoroughfares resulting from the trip pressures in the zones under the existing thoroughfare conditions.

Some important capabilities of this model are worth noting. Alternate routes are easily explored by the expedient of changing the parameters of the branches. This effectively answers questions such as choice of arterials. Effects of projected additions to an existing traffic system can also be examined by adding branches to the model of the existing system. By varying the magnitude of the resistive element, such problems as the effect of posted speed limits and of traffic volume can be studied. Although the resistive elements presently used are assumed to be linear, implying a straight-line relationship between travel time and choice of route, non-linear resistors can be incorporated. The cost per unit flow element can obviously incorporate both construction and operating cost features.

[20] Dennis, Jack B., op cit

[21] Grecco, W. L. and Bruening, op cit

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## APPENDIX IV

# WATER RESOURCE SYSTEM MODEL DESCRIPTION

## A. GENERAL

The zonal equations in the water resource system model are formulated in three categories:

1. External inputs from other zones
2. Internal inputs
3. Internal transformations

External inputs include both surface water and municipal water-sewerage inputs. These inputs are expressed as percentages of the outputs of adjoining zones.

Internal inputs refer to precipitation and ground water supply. Precipitation is expressed as a normal statistical distribution based upon historical data. Ground water is not strictly internal since its supply rate depends on the ground water table which is affected by withdrawals in other zones.

Most of the zonal equations are concerned with internal transformations of zonal inputs. Water inputs are accumulated in zonal level equations. Withdrawal uses will be subtracted from the zonal water level. Non-withdrawal uses will either modify the quality (waste-water carriage) or change the time-place location pattern (as in flood control). Outputs to other zones will also subtract from the quantity of zonal water levels.

The equations listed here are preliminary and general. Adaptations and modifications to emphasize specific objectives - such as flood control - or system characteristics will undoubtedly be necessary.

## B. EXTERNAL INPUTS

The external municipal, sewage and surface water inputs for a typical zone, designated by the number 11, would be as follows:

```
11R  MI11.KL=(M1011)(M010.JK)+. . .
11R  SI11.KL=(S1011)(S010.JK)+. . .
11R  RI11.KL=(R1011)(R010.JK)+. . .
     MI11 -    Municipal water input, zone 11
     M1011 -   Zone 10 to zone 11 municipal water constant
     M010 -    Municipal water output, zone 10
     SI11 -    Sewage input, zone 11
     S1011 -   Zone 10 to zone 11, sewage constant
     S010 -    Sewage output, zone 10
     RI11 -    Surface water input, zone 11
     R1011 -   Zone 10 to zone 11, surface water constant
     R010 -    Surface water output, zone 10
```

## C. INTERNAL INPUTS

Precipitation water input is expressed as a normal statistical distribution which varies seasonally.

```
12R  P11.KL=(PA11.K)(PS11*1.K)
34A  PA11.K=(1)NORMRN(PAA11,PAD11)
35B  PS11=BOXCYC(12,4.3)
C    PS11*=(0.9,1.0,1.1,1.2,1.1,1.1,1.0,0.8,0.8,0.9,1.0,1.1)
     P11 -     Precipitation, zone 11
     PA11 -    Precipitation, annual rate
     PS11 -    Precipitation, seasonal variation
```

PAA11 - Precipitation, annual average
PAD11 - Precipitation, annual deviation

Precipitation (P11) is expressed as the product of an annual normal distribution (PA11) and a seasonal variation factor (PS11). The annual precipitation has an average value (PAA11) and a standard deviation (PAD11). Seasonal variative in rainfall results from a series of monthly coefficients (PS11*) which are stored in a boxcar[22].

Ground water supply inputs are based on zonal usage and the available ground water supply. The effect of zonal ground water usage on the regional water table is accounted for by subtracting water usage in all of the zones in the ground water table level equation. This ground water level equation is replenished by natural recharge from precipitation inputs as part of the hydrologic cycle.

51R GI11.KL=CLIP(GD11,K,GM11,GM11,GD11.K)
13A GD11.K=(POP11.K)(WU11)(WC11)
GI11 - Ground water input
GD11 - Ground water demand
GM11 - Ground water input maximum (based up water table level and well capability)
POP11 - Population
WUR11 - Well usage ratio
WC11 - Water consumption rate

The ground water input (I11) will be the minimum of the demand (GD11) and the maximum water withdrawal rate (GM11). Demand in turn depends on the population (POP11), well usage (WU11) and the per capita water consumption.

D. INTERNAL TRANSFORMATIONS

1. Municipal water
Water inputs are accumulated in zonal water level equations. Local withdrawals and quality modifications are made to this water level and most of it is transmitted after an appropriate time delay to adjacent zones.

2L ML11.K=ML11.J+(DT)(MI11.JK-MU11.JK-MO11.JK)
13R MU11.KL=(POP11.K)(WC11)(MUR11)
39R MO11.KL=DELAY3(MR11.JK,MD11)
7R MR11.KL=MI11.JK-MU11.JK
ML11 - Municipal water level
MU11 - Municipal water usage
MUR11 - Municipal water usage ratio
MR11 - Municipal remaining water for transmission after zonal usage withdrawal
MD11 - Municipal water time delay (transport time)

Municipal water level (ML11) accumulates the municipal water input (MI11) which is diminished by water usage (MU11) and water output to other zones (MO11). Water usage depends on population, consumption rate and use of municipal water in the zone. The water output to other zones is delayed by the transport time through the pipe network.

2. Sewage
The general equation format is the same except that quality modification and water addition rather than withdrawal is the primary transformation involved.

2L SL11.K=SL11.J+(DT)(SI11.JK+SA11.JK-SO11.JK)
13R SA11.KL=(POP11.K)(SU11)(SUR11)
39R SO11.KL=DELAY3(ST11.JK,SD11)
7R ST11.KL=SI11.JK+SA11.JK
SL11 - Sewage level

[22] A boxcar is a DYNAMO compiler term for a computer storage register which stores numerical information.

SA11 - Sewage addition
SU11 - Sewage usage rate
SUR11 - Sewerage facilities usage ratio
ST11 - Sewage total
SD11 - Sewerage time delay
SQO11 - Sewage quality output
SQI11 - Sewage quality input
QM11 - Quality modification
N - Number of quality inputs

Sewage level (SL11) accumates sewage inputs (SI11) and zonal water additions (SA11). This level is depleted by sewage output (SO11) which is transmitted to adjacent zones after a time delay (SD11). The quality of the sewage input (SQI11) is modified in the (QM11) equation which degrades water quality except in zones having treatment plant facilities.

3. Surface Water

Surface water flows are based on the natural watershed network. For this application, the zonal layout may be modified so as to provide inclusion of important stream junctions, flood places or dams in separate zones. Otherwise the equation pattern resembles the other water flow network.

2L RL11.K=RL11.J+(DT)(RI11.JK+PI11.JK-RU11.JK-RC11.JK-RE11.JK-RO11.JK)
18R RC11.KL=(RCC11)(RI11.JK+PI11.JK)
18R RE11.KL=(REC11)(RI11.JK+PI11.JK)
18R RR11.KL=(RRC11)(RI11.JK+PI11.JK)
18R RU11.KL=(RUC11)(RI11.JK+PI11.JK)
39R RO11.KL=DELAY3(RR11.JK,RD11)
51A RF11.K=CLIP(RX11.K,O,RX11.K,O)
7A RX11.K=RL11.K-RM11

RL11 - Surface water level
RC11 - Surface water ground recharge
RF11 - Surface water evaporation
RU11 - Surface water usage
RCC11 - Recharge constant
REC11 - Evaporation constant
RRC11 - Outflow constant
RUC11 - Usage constant
RD11 - Surface water time delay
RF11 - Surface water flooding
RX11 - Surface water excess
RM11 - Surface water maximum

Surface water level in a zone is augmented by surface inflows from adjacent zones and local precipitation. This level is reduced by ground water recharge, evaporation and outflows to adjacent zones.

Flow rates are determined from the zonal delay time. Facilities such as dams and reservoirs would be represented by a separate level with a larger capacity and a slow outflow rate (long time delay).

Water quality equations of the type used in the sewage water set can be added if water quality is of interest.

4. Ground Water

The ground water level equation is an expression of the hydrologic cycle. The ground water table is augmented by ground recharge inputs-natural and artificial - and water inflows from adjacent zones. This level is depleted by local usage and outflows to adjacent zones. The equation format would be similar to that in surface water except that flow rates between zones would be much slower. Quality equations, similar to those in sewerage water, may be added as required.

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## STAFF MEMBERS

Kurt W. Bauer . . . . . . . . . . . . . . . . . . . . . . . . . Executive Director

Louis E. Keefer . . . . . . . . . . . . . . . . . . . . . . . . Transportation Study Director

Kenneth J. Schlager . . . . . . . . . . . . . . . . . . . . . . Chief Systems Engineer

Harlan E. Clinkenbeard . . . . . . . . . . . . . . . . . . . . Chief, Community Planning Assistance

David Fonseca, Jr. . . . . . . . . . . . . . . . . . . . . . . Chief Resources Planner

Ronald S. Humphrey . . . . . . . . . . . . . . . . . . . . . . Acting Planning Illustrator

Dallas R. Behnke . . . . . . . . . . . . . . . . . . . . . . . Planning Draftsman

Leroy H. Zocher . . . . . . . . . . . . . . . . . . . . . . . . Planning Draftsman

Jean C. Brady . . . . . . . . . . . . . . . . . . . . . . . . . Research Assistant

Elnora Rates . . . . . . . . . . . . . . . . . . . . . . . . . . Clerk-Stenographer

Peg Van Altena . . . . . . . . . . . . . . . . . . . . . . . . . Clerk-Stenographer

Mary Lockerman . . . . . . . . . . . . . . . . . . . . . . . . . Clerk-Typist