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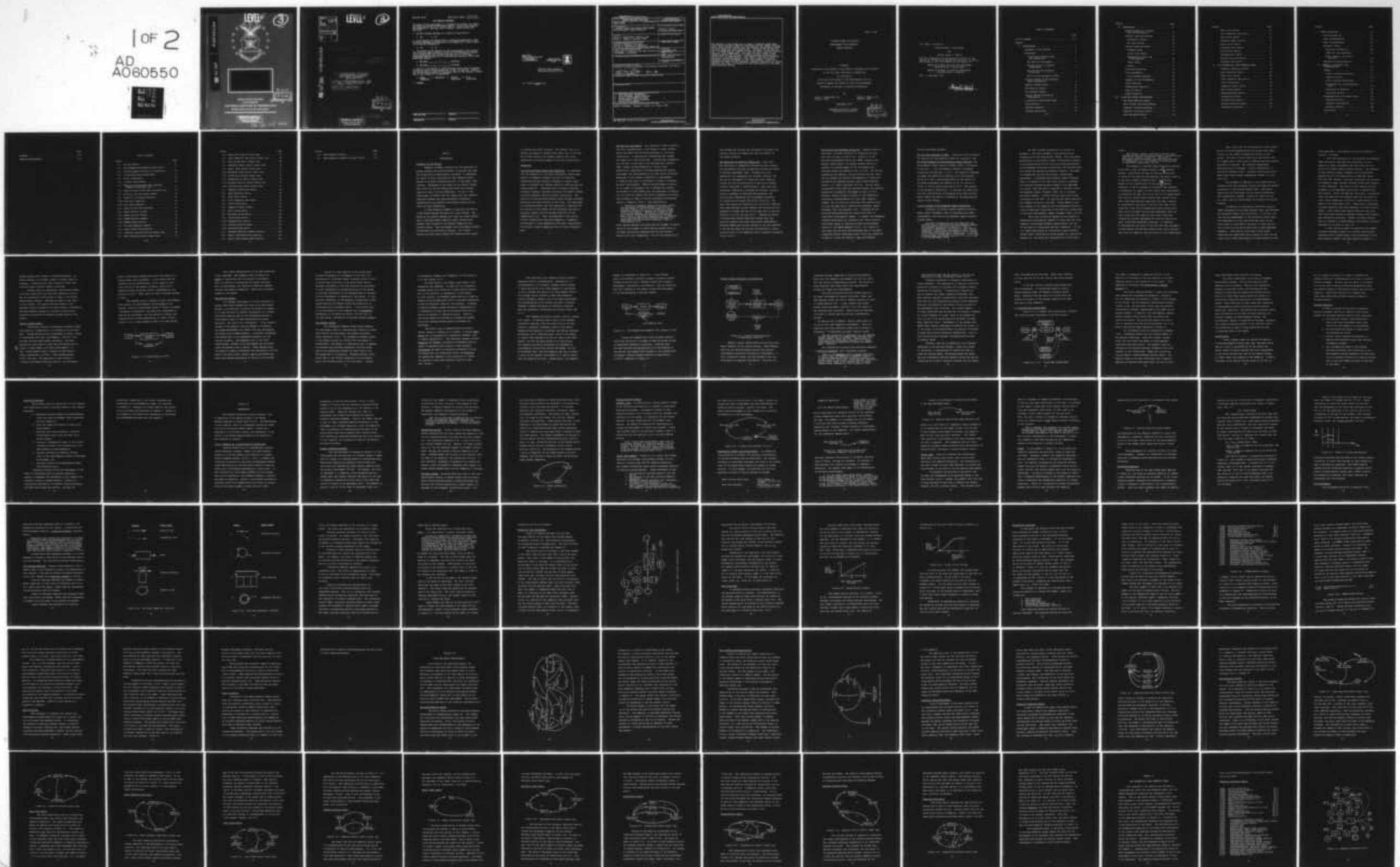

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6 A DYNAMIC MODEL FOR MISSION REALIGNMENT SOCIO-ECONOMIC IMPACT ANALYSIS.

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The purpose of this study was to create a computer based model using System Dynamics modeling techniques and the DYNAMO language which would provide insight into the economic relationships among military bases and local communities. The model can be used to aid in forecasting the impacts of base closures or mission changes upon the local communities. The need for such a model arises because previous DOD efforts to predict economic effects have fallen short of expectations. The research strives to determine pertinent interrelationships, trace their causes and effects, formulate control processes for the relationships, construct a mathematical model of the processes, generate simulation of system behavior over time, and finally to test the validity of the model with historical data.

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A DYNAMIC MODEL FOR MISSION REALIGNMENT SOCIO-ECONOMIC IMPACT ANALYSIS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Facilities Management

and Master of Science in Logistics Management

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September 1978

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This thesis, written by

Captain Brian J. McCollough

and

Captain Ralph J. Templin

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degrees of

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(Captain Brian J. McCollough)

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(Captain Ralph J. Templin)

Date: 8 September 1978

Thomas D. Clark Jr.

COMMITTEE CHAIRMAN

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INTRODUCTION

Statement of the Problem

Emphasis on budget austerity has led Department of Defense planners and decision-makers to conclude that some activities must be consolidated, realigned, or terminated. One result of this conclusion has been numerous mission changes at military installations and, in some cases, base closures. Regardless of the extent of the mission change, each action has had far-ranging and long-lived economic impacts on local civilian communities. As part of DOD requirements to predict what the impacts will be, computer-based data systems have been developed to determine mathematically the economic relationships among military bases and local communities.

To date modeling attempts to replicate the effects of DOD consolidations have been of a static design. The models do not predict changes over time, but rather present static long-term effects based on stable current data. However, base closures or any mission changes are not distinct events. They are dynamic activities whose variable interactions are continually changing. As a result, predictions using static models have generally been remiss in forecasting actual outcomes. The problem, then is to develop and operate a dynamic model which will effectively and reliably predict the economic impacts upon local communities of mission changes at military installations.

Background

Interactions between bases and communities. An awareness that the presence of a military installation affects many aspects of community economic activity has been well established through literally hundreds of studies undertaken to determine the economic effects of DOD policies and expenditures (32). Investigations of economic interrelationships regularly indicate a mutuality of benefit between the local community and the military installation. The benefits are derived from economic growth through increased population and ready sources of work force. The magnitudes of interrelationships vary from community to community and are relative to the length of time the bases have been in existance coupled with the economic diversity of the communities (1:7-8). Thus, the magnitude of the effects of base closures also vary from community to community: from minimal in large communities with small installations, to profound in small communities with no other industrial base.

The need for realignment. New technology, budget austerity, political considerations, or any number of other considerations may affect the continued existence of a military installation. A technological breakthrough may outmode the mission of a particular base. International agreements can, and have in the case of the Anti-Ballistic Missile (ABM), negate the requirements for certain sites. Additionally, reductions in defense spending may require realignment and consolidation of military force structures. Regardless of the reasons, reductions in requirements or capabilities result in decisions to reduce or eliminate military installations. Despite decision-maker's desires at all levels of government not to degrade the economic environment of local communities, the Department of Defense can "ill afford to depart from strict standards of military effectiveness in order to aid any economically distressed region or community (14:9)." More specifically:

> Failure to eliminate obsolete facilities dilutes the efficiency and effectiveness of the nation's military forces. Like it or not there are limited resources available to satisfy the unlimited needs of the total society. Therefore, in peace or war, only limited resources are available for defense. Every dollar or any other resource which is committed to one activity means less resources available for some other activity and thus a potential loss in effectiveness [6:3].

Thus, Defense agencies are faced with the dilemma of being forced to close bases to effect mission changes while at the same time sharing responsibility for the economic stability of local communities. Part of the resolution to that dilemma has involved DOD assistance in planning the economic recovery of communities from the effects of realignment actions.

DOD assistance to affected communities. Since 1961, DOD assistance to communities affected by base closures and realignments has been accomplished through the Office of Economic Adjustment (OEA). Although the local communities are responsible for economic recovery, the OEA can be instrumental in aiding the local community through the four-fold objectives of mobilizing federal financial resources to provide grants, loans, and loan guarantees; developing a strategy for recovery; allowing priority placement of displaced DOD employees; and familiarizing communities with government procedures for acquisition of excess facilities (23:15-19). The basic idea behind the objectives is to allow the community early opportunities to plan recovery and initiate actions necessary to offset the loss of the base such as inviting industry in to fill the gap (14:5). Inasmuch as efforts to reverse base closure decisions through legal and political pressure have been historically unsuccessful, affected communities are well-advised to use the resources of the OEA and other DOD sources of assistance to center attention early on the demanding task of economic conversion (14:xii and 17).

The National Environmental Policy Act. Another source of assistance, although initially not recognized as such, came from the area of public law. Section 2 of the National Environmental Policy Act (NEPA) stated as one purpose, among others, "to promote efforts which will prevent or eliminate damage to the environment and... stimulate health and welfare of man...[2:23]. The initial response by DOD agencies, and particularly the Air Force, did not address the economic environment but rather only considered how proposed projects would impact physical nature, i.e., water, and noise (21:7-8). The Air Force interpretation that NEPA was concerned solely with physical impacts was successfully challenged in April of 1975. Through a lawsuit brought on behalf of the communities surrounding Richards-Gebaur Air Force Base, Missouri (RGAFB), the Air Force was restrained from taking action to close the base until a detailed Environmental Impact Statement (EIS) was prepared (15:3). Although the Air Force had determined that the closure would have no significant environmental impact, the lawsuit and subsequent research established the contention that there would be significant impact on housing and other socio-economic factors in the RGAFB community (15:4). As a result of this case, the Air Force has determined that all projects concerning mission realignment shall follow the guidelines of NEPA to include the effects of all environmental factors--including economic.

The Air Force approach to NEPA. Current Air Force direction for meeting the requirements of NEPA are outlined in the Air Force Handbook for Environmental Impact Analysis. The Environmental Impact Analysis Process (EIAP) is conducted to quantify "...the environmental effects of proposed actions and alternatives...[9:9]." The process is designed to answer the questions of whether or not the proposed action will have a significant effect on the quality of the human environment and whether or not the action is likely to involve public controversy (9:9). The essence of the process is prediction. It requires the identification and quantification of variables which cause environmental impact followed by a forecast of the magnitude and impact of the effects.

Current Methods of Environmental Impact Formulation

Currently, Air Force planners formulate Environmental Impact Statements (EIS) in accordance with NEPA requirements, utilizing an environmental impact analysis process (EIAP).

> The EIAP, conducted by the unit sponsoring the proposed action, quantifies the environmental effects of a proposed action and alternatives. EIAP is conducted to determine if an action (1) will have or could have a significant environmental impact through comparative quantification of change and (2) involves or is likely to create public controversy. It is also conducted when the proposed action is (3) a line item in the annual budget [9:9].

The EIAP includes preparation of a series of documents. The first document is the Description of Proposed Action and Alternatives (DOPAA), which delineates descriptions of the project itself, alternatives, existing site characteristics for all sites and locations affected by the proposed action and alternatives, and considerations that offset the adverse environmental effects. The DOPAA is incorporated into the EIS through a three-stage development. A Candidate Environmental Impact Statement (CEIS) is created at the level where action is proposed and forwarded through the Major Command to HQ USAF/PREV for review. When the CEIS is approved it becomes a draft environmental impact statement (DEIS) and is released for public comment. A public hearing takes place during circulation of the DEIS. All parties may submit questions and comments relative to the DEIS. These comments along with answers to the questions and any subsequent modifications or additions to the text of the DEIS are incorporated in the final environmental impact statement (FEIS) (9:9-10).

While data collection systems for the purpose of determining environmental impacts of a base upon the local community have become extremely sophisticated, the use of this data for forecasting has been inadequate. In the U.S. Army's description of its Economic Impact Forecast System (EIFS), which the Air Force perused as a predictive measure (8), the guide for interpretation of EIFS output states:

> EIFS output is meant to be only a planning and information tool for the decision-maker; its predictions must not be treated as absolute. The system's advantages (speed of access, cost-effective retrieval of information, etc.) far outweigh the disadvantages of prediction inaccuracies [14:10].

One drawback of existing impact forecasting systems within DOD is that the models present a worst possible outcome. Predictions are made by applying multipliers to events at the base and then applying the result directly to the local community baseline data. An excellent example of the insufficiency of this worst-possible technique is the EIS prepared on Kincheloe AFB, Michigan. In addressing the impact of base closure upon unemployment, an assumption was made that 62 per cent of the Appropriated Fund civilian workers would relocate upon closure of the base, based upon previous experience with base closures. No consideration was given to the fact that some of the remaining 38 per cent of Appropriated Fund workers would elect early retirement and not seek employment after the base closure nor that some civilian sector jobs were occupied by military dependents who would be leaving the area, as previous experience indicated. In addition, no consideration was given to the fact that some non-appropriated workers and off-base workers would likely relocate away from the community with the threat of high unemployment.

Thus, 38 per cent of the Appropriated Fund workers and all of the Non-Appropriated Fund workers were added directly to the number of unemployed workers in the region. The total civilian labor force was reduced only by a number equal to the total of Appropriated Fund workers predicted to relocate. The resultant unemployment prediction was 31.9 percent, a likely exaggeration of what would logically occur. Certainly some workers would depart this region before unemployment reached 31.9 per cent (22).

The treatment of impacts on local communities by presenting the worst possible outcome overcomes the problem encountered in the Richards-Gebaur case. Significant impacts are not overlooked, but are usually exaggerated. This exaggeration, however, counters the desire on the Air Force's part to reduce public controversy over mission changes.

In addition to inaccuracies induced by treating impact statements as the worst possible case, the forecasts are presented without time orientation. In reality, the only way the unemployment in the Kincheloe closure would have approached 31.9 per cent would have been for the entire base to close down at one point in time, and for none of the civilian sector work force to seek employment elsewhere. This does not occur when a base closes. Operations are phased down over a period of time, and the public has at least some warning, allowing workers to seek other employment. This warning also allows changes in industry, if needed.

Since the formulation of the Kincheloe Environmental Impact Statement, some agencies responsible for the drafting of impact statements have been more realistic during the economic impact analysis process. Two examples of more realistic impact statements are the documents prepared prior to the deactivation of Webb AFB, Texas and Craig AFB, Alabama. Two major departures from previous environmental impact analysis process efforts were apparent in these endeavors. The first of these changes involved treatment of the employment termination of Appropriated Fund workers. Within the Webb and Craig EIS's, a multiplier effect was applied to the Appropriated Fund job cancellations, which caused only a portion of these workers to be added to the unemployment rules. Additionally, dependents occupying community jobs were addressed in a more realistic manner. These workers were deleted from both the total labor force and category of employed workers before employment projections were made. However, the base closures were not treated in a phased manner, but assumed to totally terminate at one point in time (17).

A more realistic method of predicting the impacts of mission changes at bases is to present time-oriented forecasts after thorough study of the interactions of the base-community system. The base community system is a dynamic system with a number of interrelationships. To predict behavior of a dynamic system, a dynamic model is necessary. Predictions can then be made for given time intervals after a mission change is directed.

Because there are significant interactions between a military installation and the local community, the two must be considered as one process in order to accurately assess mission changes. The mission change is the input to this process. The output from the process is the aggregate results of making the mission change. Considering the base-community system as a process of interactions suggests an application of general systems theory to the system.

General Systems Theory

Traditional theories of systematic processes viewed the system as a closed entity not affected by its environment. "Closed systems have no interchange of matter, energy or information with their environments...[16:160]," and are thus isolated from outside influences. One major problem with this theory is that very few systems fail to relate, to some extent, with their environments. In fact, closed systems "have a tendency to move toward a static equilibrium...[11:109]." When systems become static, they die. The importance of this concept to a dynamic environment should be obvious: an environment which is continually changing must have some effect on a system within that environment. If the system does not interact with its surroundings, it will cease to exist. "The survival of the system, in effect, would not be possible without continuous inflow, transformation, and outflow [11:110]." Thus, there is need to consider systems as open.

Open systems react to changes in their environments. Additionally, the environments are acted upon by the systems. There is a continuous inflow or output, of energy, information, and material; the inputs are transformed in some way by the system: and the outflow or outputs, are representative of some modifications of inputs (16:160). Figure 1-1 is a simple schematic model of an open system.

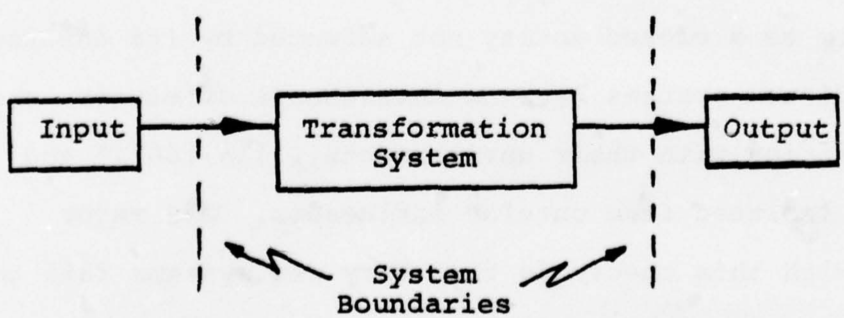


Figure 1-1. An Open System (11:110)

This simple representation of the open system has a major drawback. The schematic does not depict the degree of interaction with the system's environment. There is nothing to indicate how the system interacts with its environment, nor anything to show the observer how well the system is operating. There are no controls present in the system.

The Need for Control

In a dynamic environment it is very difficult to predict what effect changes will have on an open system. Because it is difficult to predict the effects of change, it is also difficult to predict the behavior of a system. Anticipated behavior may not be forthcoming because of three general types of risks associated with system operation. The first risk is conceptual. If the viewer's concept of the system or the environment is erroneous, the system performance will differ from that anticipated. The second risk is administrative. A perfectly conceptualized system that is not implemented properly will not operate correctly. Environmental risk is the third. Unanticipated changes in the environment may take place after the system is set in motion. These changes cause the system to operate differently than anticipated (3;17-18). Each of the above risks, however, can be anticipated and dealt with through application of controls to the system.

Control is "that function of the system which provides adjustments in conformance of the plan, the maintenance of variations within allowable limits [10:74]." To relate this definition to the three risks, control provides information on the true operation of the system to allow adjustments in conceptualization of the system. It provides information on the implementation of concepts to allow adjustments in operation of the system. It also provides information on environmental changes which affect system behavior and thereby allows the maintenance of variations within allowable limits. A significant point in this explanation is the repeated use of <u>information</u>. Information is the medium of control (13:505) and, in the open system, information is provided through feedback.

The Feedback System

"An information feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions [4:41]." An information feedback system is the method by which all control over the system is accomplished. The method is a continuous loop, a regenerative process that provides information from the output side of the system back through the input side to tell the system how it is operating. Feedback provides information both on the internal operation of the processor and on the external forces of the environment. Systems of information feedback are fundamental to the operation of an open system (4:15).

As noted earlier, the dynamic open system is not necessarily well-behaved. In order for the information feedback system to be effective it must provide relevant data on all behavior, or misbehavior, of the system. To allow control, the feedback system must be at least as complex as the process about which it provides information. It must be organized, specific, and relevant. A complex information feedback system designed by happenstance or in accordance with what may be intuitively obvious will usually be unstable or ineffective(10:15). Stability and effectiveness are provided to information feedback and control systems through specific processes and mechanisms.

The entire field of communication and control theory, whether in machine or in animals, is called cybernetics and is concerned with information (feedback) flow in complex systems(27:2). The cybernetic process involves measuring the feedback information to determine how the system is operating with relation to some standard, calculating the amount of correction necessary to bring the system back into prescribed limits, and selecting the appropriate response to the calculation to insure the process is once again operating close in on the goal (18:203).

The mechanism of the feedback control process is sometimes called a servomechanism. Mechanically, "a servomechanism is an automatic feedback control system in which the motion of an output member is constrained to follow closely the motion of an input member [18:55]." This concept can be related to other than mechanical control processes, however, and in the open system model the servomechanism is the controlling agent to measure feedback, estimate the amount of correction required, make the correction, re-estimate the residual error, and so on.

The feedback and control process, then is a system unto itself. It requires input, which is the feedback information supplied, from the output side of the open system; it requires a processor, which is the servomechanism that measures, calculates, and selects required correction; and it requires output, which is the amount of control that regulates the flow of input to the major system. As with the major system it is controlling, the feedback and control system may be influenced by environmental factors from outside the system. As will be discussed later, this environmental data may be purely a result of the system's environment or it may be forced upon the system by the user. Schematically, the feedback system is represented in Figure 1-2. In the Parkman model, the cybernetic process is shown as having a reduced standard being fed into a computer process for automatic measurement, calculation, and selection. The two functions have been combined in this model to show the relationship of the servomechanism to the open system.

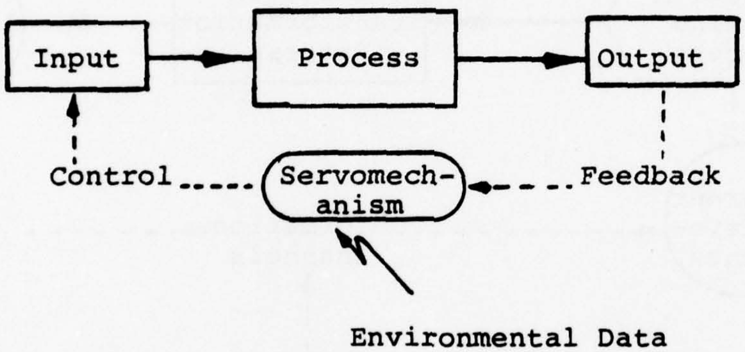


Figure 1-2. The Feedback Environmental Data System (16:161)

Within the feedback and control process, specific activities take place to attempt to make the system conform to prescribed standards of operation. Although there are many theories and explanations as to the workings of the process, the example most relevant to this presentation is Roberts' "Control System Structure of Organization [19:675]," depicted in Figure 1-3.

Control System Structure of Organization

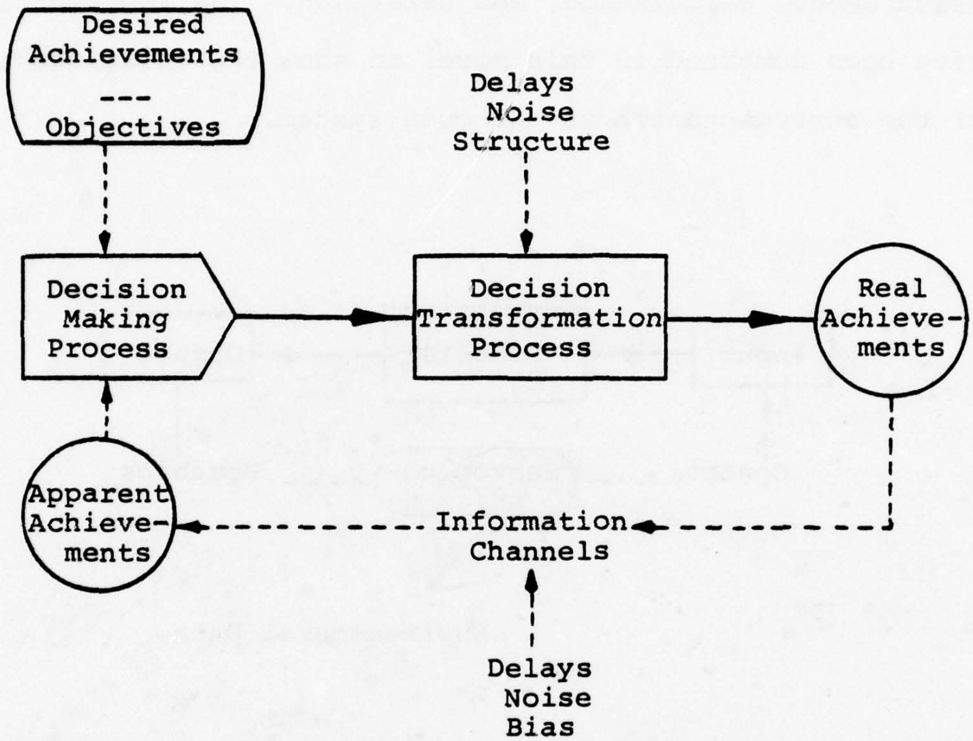


Figure 1-3. Control System Structure of Organization [30:675]

Roberts' control system model portrays the information channels of the control process. These channels lead into the decision-making process from desired achievements--objectives and apparent achievements. A third information channel delivers feedback from real achievements to apparent achievements. Decisions are formulated through comparison of Desired Achievements--Objectives with apparent achievements and then are input into the decision transformation process. The results of those decisions take shape within the transformation process and become real achievements.

Even well-contructed decisions seldom result in the exact achievement of desired objectives. These less than maximum results are due to "numerous sources of noise or random behavior and ... often lengthy time delays between cause and effect [19:674]," or to the nature of the organizational structure. These forces are depicted in Figure 1-3 acting upon the decision transformation process.

Of special note in Roberts' control system model is his use of the term "apparent achievements." This is a departure from other cybernetic models and is worthy of discussion. In describing his model, Roberts stated:

> The real situation is translated into the apparent through information and communication channels which contain delays, noise, and bias. These sources of error may be the inadvertent features of an organization system which sacrifices accuracy for compactness... [19:674].

In a discussion of policies and decisions presented in <u>Industrial Dynamics</u>, Jay W. Forrester proposed:

> There is the <u>apparent</u> state of <u>actual</u> conditions. In other words, our available information leads us to certain observations that we believe represent the present state of the system. These apparent conditions may be either close or far removed from the actual present state, depending on the information flows

> that are being used and the amount of time lag and distortion in these information sources [4:96].

Forrester formulated an important observation in these statements. The observation of resultant conditions created by injection of variants into a system is merely perception of actuality. If quantitative methods are used to measure the output, sampling techniques, even when carefully applied, seldom exactly replicate actuality. Even when the total quantitative results can be reasonably measured, the measure of the results is only as good as the measurement tool or method. As a simple example, if three technicians use the same set of calipers to measure the inside diameter of a pipe, there is low probability that any two of the technicians will determine the same exact numerical value. Furthermore, if the manager must depend upon indexing techniques to quantify the output, or if the output is not quantifiable, his analysis of results is based upon strictly subjective observations. This is the distortion which Forrester stipulated and the bias in Roberts' model.

Secondly, time lag in cybernetics is of extreme importance in the decision process. Since this process is continuous, if observations of results are slow to reach the decision-maker, the decision-maker may deduce that any discrepancy reflected between results and desired conditions may be due to variants injected into the system after the observations were made. These later variants, in fact, were not at all the cause of the noted discrepancies.

In the next section a general open system model will be presented. It incorporates Roberts' control system structure model and Parkman's feedback system model. Hopefully this new model will better serve the purpose of analysis of the economic impacts of an USAF base upon a local community.

A Controlled Open System Model

Figure 1-4 is a general open system model including the control process introduced in the last section.

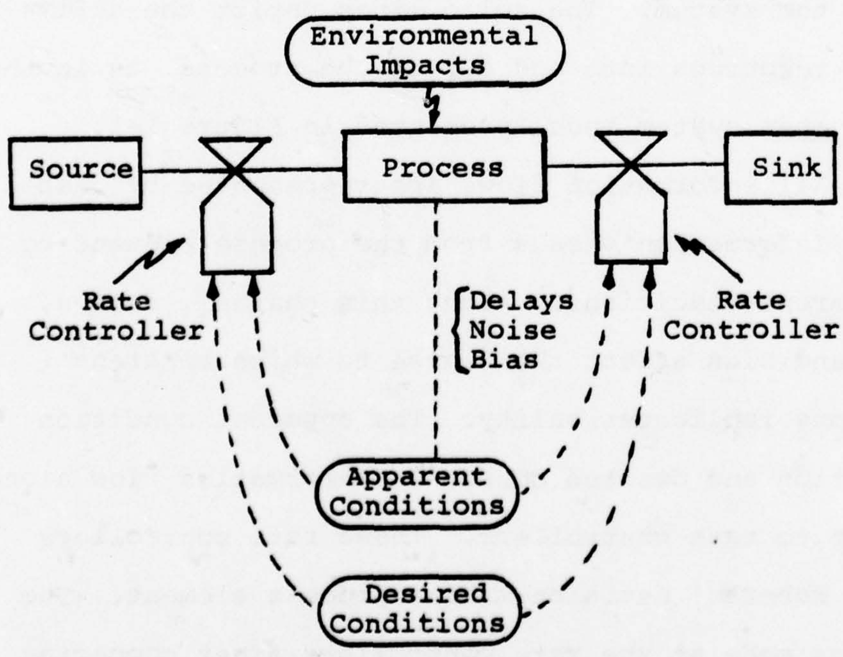


Figure 1-4. A Controlled Open System Model

this model is presented in symbology similar to that which will be utilized in the flow charting of the base-community system in the remainder of this paper. This symbology is extracted from Study Notes in Systems Dynamics (5).

The source replaces Parkman's "input" and originates from outside the environmental boundaries. Similarly, the sink symbolizes the passage of "output" to the outside of the system. The environmental impacts depict Roberts' "delays, noise, and structure" acting upon the decision transformation process, represented in this model by the process element. In addition, the environmental impacts element portrays forces acting upon the system from outside the system. The solid lines depict the active flow of resources into and out of the process, as in the general open system model presented in Figure 1-1.

All information flows are represented by dashed lines. Information passes from the process element to the apparent conditions. Along this channel, delays, noise, and bias affect the degree to which apparent conditions replicate reality. The apparent condition information and desired condition information flow along channels to rate controllers. These rate controllers replace Roberts' decision-making process element. The decisions made at the rate controllers after comparing apparent and desired conditions affect the rate at which inputs and outputs enter and exit the system.

This open system model can be used to represent base-community system. The military base and local community are the process. Inputs to this system are changes in resources flowing into the base and the community forced upon the system from outside sources. The rate at which these inputs affect the process is controlled by decisions made within the base-community system. These decisions are made, based upon comparison of base-community desired conditions versus apparent (perceived) conditions. The second rate controller represents decisions as to the rate at which resources are allowed to depart the base-community system. The environmental impacts, as depicted by the model, represent such things as outside pressure to use resources wisely and predictions of doom if large reductions are made in resources input to the system.

Justification

Since a dynamic model can portray the behavior of the base-community system over time, the model can be used as a tool in the prediction of the effects and impact trends of mission changes from first announcement of the action through such time as the mission changes no longer affect the dynamics of the community. Secondly, the model can be used by various levels of the DOD, as well as community planners, in order to determine the probable effects of contermeasures to be used in economic recovery attempts. Thirdly, once the model is validated, its use can help to belie unjustified apprehension about the negative impacts of DOD mission changes upon the local community. These fears currently run rampant when worst-case predictions are made concerning community economic behavior.

Research Questions

In order to resolve the problem of inadequate economic forecasts relative to impacts of DOD mission changes the following research questions were addressed:

A. Can pertinent dynamic interrelationships within the local environment (base interaction with the community) be determined?

B. Can the causes and effects of these interrelationships be traced?

C. Can the control process be formulated to describe how decisions result from available information streams?

D. Can a mathematical model of the process, information sources, and interactions of the base-community system components be constructed so as to generate simulation of behavior through time of the base-community system as described by the model?

Research Objectives

The following specific objectives for this research were formulated in order to provide answers to the research questions:

A. Determine pertinent dynamic interrelationships within the local environment (base interaction with the community),

B. Trace the causes and effects of these inter-relationships,

C. Formulate the control process to describe how decisions result from available information streams,

D. Construct a mathematical model of the process, information sources, and interactions of the base-community system somponents,

E. Generate simulation of behavior, through time, of the base-community system as described by the model, and

F. Test the validity of the mathematical model with historical data.

Succeeding chapters follow the development of the model in conformance with the research objectives. Chapter II addresses the methodology of the research and provides a primer on System Dynamics. Chapter III outlines the determination of dynamic interrelationships and faces their causes and effects. The next two objectives, formulation of the control processes and construction of the mathematical model, are discussed in Chapter IV. Generation of system behavior and validation of the model are presented in Chapter V. Chapter VI is a summary of the effort with discussion of conclusions and recommendations drawn from the research.

Chapter II

METHODOLOGY

The research objectives listed in Chapter I are an adaptation of the design process in the System Dynamics approach to system study (10:13). The methodology of this research, then is a progression through the steps required in developing dynamic models. Before that progression is initiated, however, and explanation of the choice of the System Dynamics method as the method for this research is required.

System Dynamics as a System Modeling Methodology

"Systems Dynamics and its complementary computer system simulation language, DYNAMO, have been designed primarily to aid the modeling and simulation of complex dynamic feedback systems [14:186]. First, it enables the researcher to maintain a one-to-one correspondence between verbal descriptions of the real-world system of cause and effect and a flow diagram representing a causal chain. It also maintains the relationship between the flow diagram and a set of equations in the computer program to simulate the model of causality. Second, a flow diagram provides an excellent vehicle for communication with actors in various parts of the actual system in order to solicit their perceptions of how the system works. Third, a rapid feedback of results from the simulation program provides further clues to the researcher as to the aptness of the emerging model. These new insights can, then, be transformed into redrawn flow diagrams and modified computer simulation programs. Finally, the DYNAMO language is easy to learn, provides excellent diagnostics to the programmer, and, through simplicity, gives the researcher time to concentrate on conceptualizing the parts of the system under study and on mapping their interrelations. Since determining interrelationships was the first objective of this research, the discussion of specific methodology continues from here.

Dynamic Interrelationships

From the discussion of systems in Chapter I it was established that the structure of a dynamic system is based upon the concept of a bounded system of interrelated parts. These parts comprise the essential system states and activities that characterize gross economic behavior with the system's environment (14:187). For example, the level of employment in a community can be conceptualized as a system state that changes from one time period to the next in response to system activities, such as the inflow and outflow of people to the employment level. The movement of people in and out of the level of employment might be a function of any number of components which cause people to move--one of which, obvious to the purpose of this research, is mission changes at military installations. The dynamic feedback characteristic of the system is imparted by the component interrelationships.

> The art in this kind of modeling lies in choosing a level of conception and system boundary that includes the smallest number of components that will accurately describe the system... in its environment [14:187].

Determining sectors. Initial views of the base-community system indicated that the total system was composed of just the two interacting parts; the base and the local community. The interaction appeared to be a flow of activity and "things" between the two. However, it became evident, early on, that one essential element to economic activity, money, did not flow directly from the community to the base. Although money could be seen to flow directly from the base to the community, the reverse was not true. It was, therefore, necessary to conceptually go outside the system's local environment to determine what element of a larger system brought money from the community to the base.

The macro system. By moving above the level of the local system being studied, it became evident that the sector which allows continuous mutual interaction between the military and civilian sectors was a sector labeled, for purposes of this research, the political sector. The political sector defines all those activities which allow decisions and policies to be converted to activities and "things" within the other two sectors. It includes executive and legislative decision, influence, power, and budgetary constraints. The sectors of macro interaction, as viewed by this study, are civilian, defense (military) and political. These sectors are basic to the dynamics of the base-community system and provide the vehicle for interrelationships among system components. Figure 2-1 depicts the continuous mutual interaction among the three sectors. The diagram represents the concept of civilian sector activity influencing political activity which, in turn, influences activity in the defense sector. Defense sector activity influences civilian sector activity, and so on. The mechanics of the diagram provide a point of departure for the second objective of this research, the tracing of cause and effect relationships among systems components.

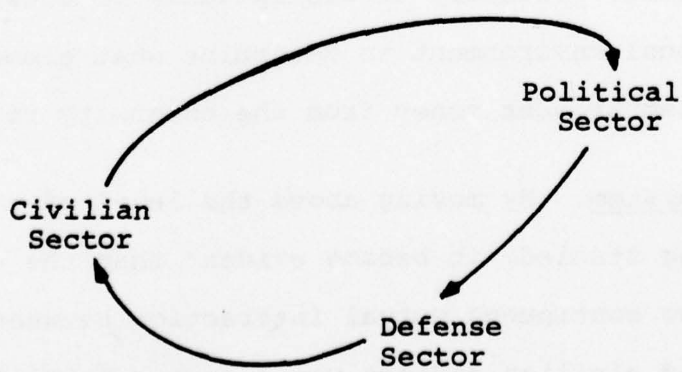


Figure 2-1. Sector Interaction

Tracing Cause and Effect

Feedback loops. As noted earlier, system dynamics focuses on the structure and behavior of a system's interrelated parts and environment. An essential element of that interrelationship is the activity within the feedback loop structures of the system. To understand how the system operates, one must understand how the feedback loops operate. One method of reaching that understanding is through the development of causal-loop diagrams. Causal loop diagrams identify the principal feedback loops of a system and play two important roles in system dynamics studies:

> First, during model development, they serve as preliminary sketches of causal hypotheses. Second, causal-loop diagrams can simplify illustration of a model. In both capacities, causal-loop diagrams allow the analyst to quickly communicate structural assumptions underlying his model [12:5].

Causal loop example. Figure 2-2 is a causal loop diagram describing the feedback relationships between civilian jobs on a military base and the community population. The diagram incorporates simple causal hypotheses relating to underlying system behavior. These hypotheses include:

1. Job availability attracts people to the community.
2. New arrivals to the base increase community population.
3. Population absorbs available jobs, decreasing the level of job availability.
4. A decrease in jobs available on base will have a tendency to influence people to leave the community, thereby decreasing the population.

For simplicity (in this portion of the paper), Figure 2-2 ignores the type of employment and other determinants of migration such as housing, location, and taxes. The step-by-step development of this diagram will illustrate the mechanics of loop diagramming.

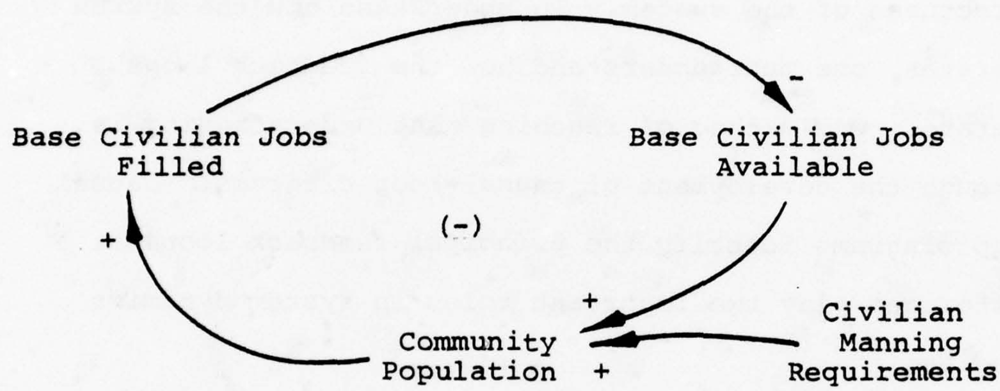


Figure 2-2. A Causal Loop Diagram (12:1-11)

<u>Representing causal loop relationships</u>. To diagram the loop structure of a system, the pair-wise relationships of relevant variables must be established. The relevant variables, as previously discussed, are those at the highest level of the system which capture the essence of system activity. In this example, the variables are the four depicted in Figure 2-2 and are defined as follows:

Base Civilian Jobs Filled	-Total number of occupied civilian jobs on base
Base Jobs Available	-Total number of vacant civilian jobs on base

Community Population	-Total number of people residing in the local community, including those who live on base
Civilian Manning Requirements	-Total jobs on base (filled or vacant)

Having identified the variables relevant to the subsystem, logical assumptions about their pair-wise relationships are made. For example, it is assumed that as the number of civilian base jobs available increases community population will increase, through attraction of employment-seeking people to the community. The causal representation for this assumption appears below:

Figure 2-3. Positive Civilian Base Jobs Available Community Population Link

The arrow indicates the direction of influence, the sign (plus or minus), the type of influence. An increase in jobs available will produce an increase in community population. Two general rules apply to the determination of pair-wise relationships:

1. If, all other things being equal, a change in one variable generates a change in the same direction in the second variable relative to its prior value, then the relationship between the two variables is positive.
2. A negative relation denoted by a minus sign occurs when a change in one variable produces a change in the opposite direction in the second variable [12:7].

Figure 2-4 illustrates a negative relationship in the base employment model.

Figure 2-4. Negative Jobs Filled--Jobs Available Link

Figure 2-4, like Figure 2-3, embodies a causal assumption. It is assumed that as the number of base civilian jobs filled increases (more people are hired), the number of base civilian jobs available decreases. This assumption ignores the relationship of all other variables except the pair in question. "The assumption that all other impinging variables remain constant during determination of causal polarity is central to causal analysis [12:8]."

<u>Causal loops</u>. Figure 2-2 combined the relationships among base civilian jobs filled, base civilian jobs available, and community population. The determinants of the level of base civilian jobs available lie outside the loop boundary in the form of civilian manning requirements.

"To determine the polarity of the entire loop, we trace the consequences of an arbitrary change in one loop variable [12:9]." Assume, for example, that the level of jobs available on base were to suddenly and sharply decrease (as with a mission change). This decrease would lead to a decrease in community population (out-migration to look for new jobs) which would in turn lead to a decrease in the number of base jobs filled (people leaving jobs to find jobs elsewhere) which would, in turn, lead to an increase in total jobs available (at the new level). Thus, the loop in Figure 2-2 attempts to maintain availability at a fixed value or goal despite external influences to the contrary.

> When a feedback loop response to a variable change opposes the original perturbation, the loop is negative or goal-seeking. When a loop response reinforces the original perturbation, the loop is positive [12:9].

One intuitive consideration in the development of causal loop diagram is that some variables do not immediately respond to the stimulus of another variable.

Delays. In the example in Figure 2-2, it was shown that community population was positively linked to base jobs available. Obviously, however, the community population does not immediately react to increases or decreases in jobs. The reaction is delayed by the perceived variable change (how soon the change is recognized) and by motivational barriers (how quickly people react once the change is recognized). Inclusion of delays in the diagram is important to adequate understanding of the system's operation and later in developing the mathematical equations for system simulation. Figure 2-5 illustrates the causal relationship between base civilian jobs available and community population with the inclusion of a perception delay symbol.

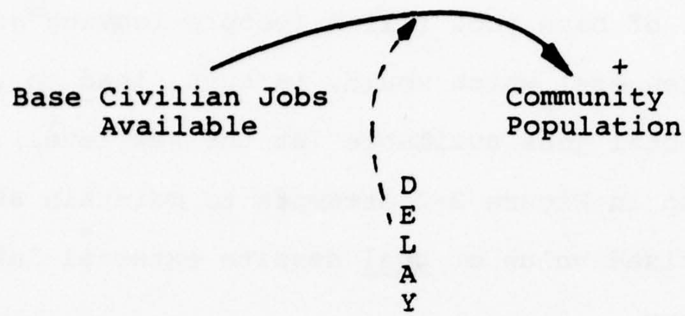


Figure 2-5. Positive Link with Delay Element

The description of the mechanics involved in causal loop diagramming is therefore completed with the illustration of one of the causal interactions for the base-community system in the example which opened the subject, Figure 2-2.

Flow diagramming is a natural follow-on to causal loop diagramming. However, an introduction to difference equations is necessary before beginning the flow diagram discussion.

Difference Equations

Referring back to the open system model depicted in Figure 1-1, and using an inventory system as an example, a basic difference equation can be formed. If the "transformation system" represents the stockpiling of supplies, a level of supplies is maintained in the "transformation system". Input and output represent the number of supplies passing into and out of the level of supplies, respectively. A difference equation representing the change in supply level (CSL) is:

$$CSL = Input-Output$$

Now, representing a time period as Delta Time (DT), and using the source--decision transformation process--sink resource flow in Figure 1-4, a more sophisticated difference equation can be represented. The rate controllers imposed on the resource flow in Figure 1-4 determine the number of supply items passing into and out of the level in each time period. Letting "t" represent the current time, and "SL_t" the supply level at "t", Then:

$SL_t = SL_{t-1}$+Input-Output; where

Input = number of supplies into the system per time period, and

Output = number of supplies out of the system per time period.

This type of equation is graphically portrayed in Figure 2-6, and a method of forecasting using difference equations is discussed next. In Figure 2-6, "K" is the current time; "J" is the current time minus a standard time interval, "DT"; and "L" is current time plus "DT". The levels at "J" and "K" can be measured, used in an equation to describe how input and output will behave during the period "K-L", with a resultant level at "L" as a forecast.

Moving to the second line of labels on the time axis, the former "K" becomes the new "J", etc. Basing predictions for input and output during the new "K-L" upon the measurement of the level made previously at the new "J" and the prediction of the level at the new "K", a prediction of the new "L" can be made. From integral calculus, as "DT" is made smaller, the trace of an equation, defining a level, will become smoother (10:73-75).

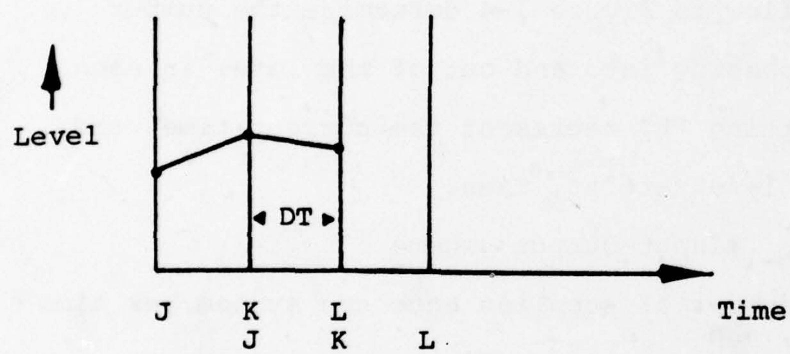


Figure 2-6. Graph of a Difference Equation

Difference equations form the basis of the system dynamics translation of causal loop diagrams to flow diagrams and then to mathematical equations. The DYNAMO computer package utilizes difference equations to generate predictions of system behavior through time. Before creating the mathematical equations, the causal loops must be transformed into flow diagrams.

Flow Diagramming

Flow diagramming serves as an important visual transition from the conceptual model of a system to the mathematical equations of that system. In describing the flow diagramming methods in Industrial Dynamics, Forrester stated,

> Experience from teaching the formulation of industrial dynamics models has demonstrated that a pictorial representation of an equation system is highly desirable. A diagram that displays the interrelationships between equations helps to lend clarity to the system formulation. Many people visualize the interrelationships better when these are shown in a flow diagram than they do from a mere solving of equations...[10:81].

In describing flow diagramming methods, it is first necessary to present a description of the symbology used in the flow diagrams. The next section defines these symbols.

Flow diagram symbology. Figures 2-7A/B comprise a list of symbols used in flow diagrams utilized in the methodology of this research. This section defines the symbols presented in the list, adapted from Industrial Dynamics (10:81-85).

Flows of resources represent the passage of people, money, materials, or other units of resources into or out of a level within the system. These flows are represented by solid arrows in the flow diagram.

Flows of information describe the information feedback links within the system. These links are represented by dashed lines and arrows in the system flow diagram.

Levels represent the aggregation of resources

Symbols	Symbol Names
1.	Resource Flow
2.	Information Flow
3.	Level
4.	Decision Function
5.	Source or Sink

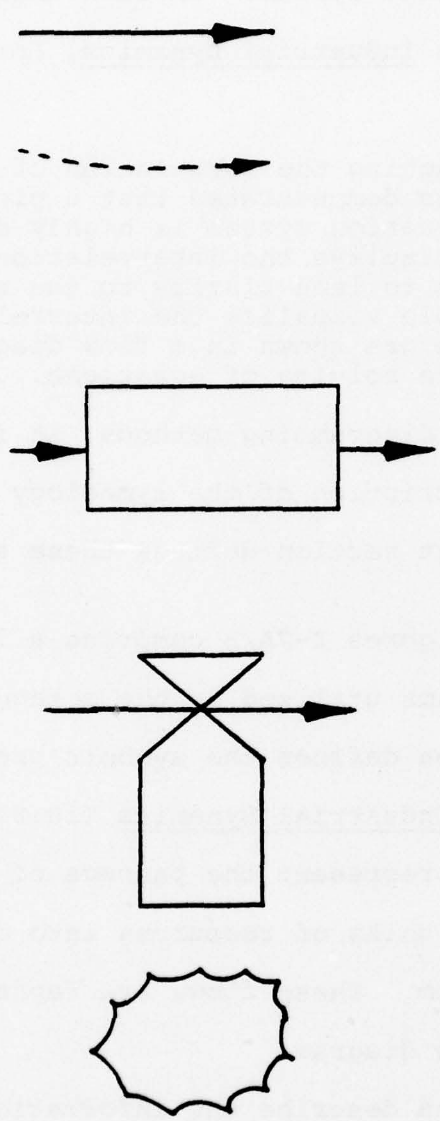


Figure 2-7A. Flow Chart Symbology (10:81-85)

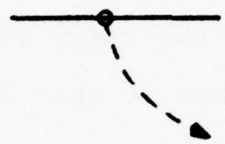
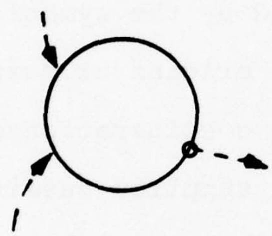
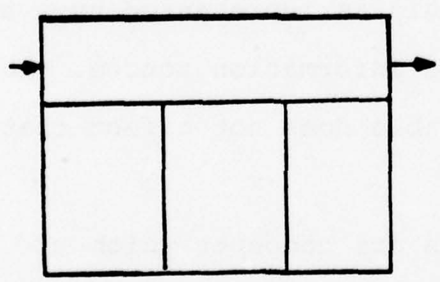
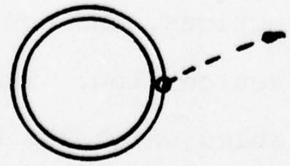
Symbol	Symbol Names
6. 	Information Source
7. 	Auxiliary Variable
8. 	Delay Function
9. 	Exogenous Variable

Figure 2-7B. Flow Chart Symbology (10:81-85) within the system, analogous to the inventory of a supply system. The levels are represented by rectangular boxes.

Decision functions determine the rates of flow within the system. The symbol attaches to that flow which the decision function controls. The symbol also shows the attachment of information flows which supply the information to the decision process represented by the symbol.

Sources or sinks represent origins or destinations of resources which lie outside the consideration of the model. For example, the origin of supplies passing into an inventory and the destination of the supplies departing may not lie within the system of interest.

Information takeoffs represent the origin of an information flow. The origin is represented by a small circle on the border of the information source. The taking of information from a variable does not affect that variable.

Auxiliary variables are concepts which are set aside from decison functions because they have independent meaning. They lie in information flow channels between levels and decision functions, and contribute in the formulation of rates of resource flow. The information sources symbol identifies variables which lie within other element flow diagrams or constants which remain unchanged throughout the operation period of the system simulation. The symbol provides continuity when flow diagrams must be subdivided on separate pages.

Delays are represented by a subdivided level symbol. In a description of delays, Forrester stated,

> A delay is essentially a conversion process that accepts a given inflow rate and delivers a resulting flow rate at the output. The outflow may differ instant by instant from the inflow rate under dynamic circumstances where the rates are changing in value. This necessarily implies that the delay contains a variable amount of the quantity in transit. The content of the delay increases whenever the inflow exceeds the outflow, and vice versa [10:86].

An example for which the delay symbol could be used is boxes on a conveyor. The rate at which boxes leave the conveyor is dependent upon the rate at which the boxes are placed on the conveyor. Additionally, as the boxes are placed on the conveyor at a higher rate, if they are not removed at an increasing rate, the number of boxes on the conveyor will increase.

In the top box of the symbol, the variable aggregated in the delay is identified. The lower left box identifies the order of the delay (shape of the delay function). The center lower box identifies the variable name of the output rate. The lower right box depicts a constant name whose value is the average length of time required to traverse the delay.

These symbols are used in the next portion of this paper to present the flow diagram of the "Base Civilian Jobs Available" element of the conceptual model presented in Figure 2-2. The next section of the paper is a verbal description of the flow diagram.

Example of Flow Diagramming

Figure 2-8 depicts the Base Civilian Jobs Available portion of the causal loop diagram example introduced in Figure 2-2. The following relationships are presented by way of example only. The logic involved in their formation is reserved for Chapter IV.

The initial point of interest in the flow diagram is the level, Base Civilian Jobs (BCJ), within the delay symbol. This level is the number of non-military jobs which are vacant at the base. It is determined by a relationship of the previous vacancy level to the current rate at which vacant jobs are filled, the base civilian jobs filled rate (BCJCR) and the rate at which people depart the jobs, the base civilian jobs departure rate (BCJDR). The rate at which jobs are filled is determined by the relationships between base civilians available (BCA) and base civilians desired (BCD). Base civilians available, the number of unemployed people who want jobs on base, is a function of the labor force available (LFA) and the base job desirability multiplier (BJDM). Desirability is a function of the community jobs available (CJA) and the current number of base jobs available. The base civilians desired (BCD) is a function of the current level of base civilian jobs desired (BCJD), which is exogenously

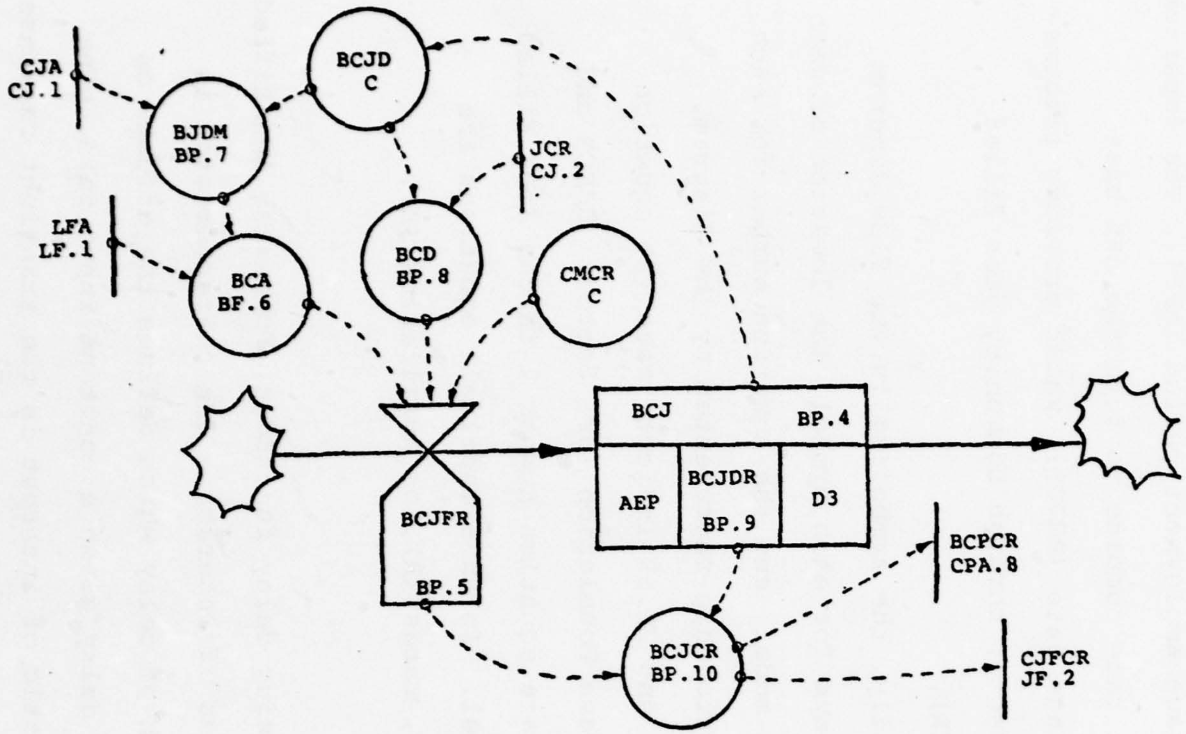


Figure 2-8. Base Civilian Jobs Available

determined from the mission requirements of the base.

The rate at which civilians depart base jobs (BCJDR) is a delay function of the rate at which they fill jobs and the average employment period (AEP). The departure rate and the fill rate combine to form the net base civilian jobs change rate (BCJCR), which provides information to another sector through community jobs filled change rate (CJFCR).

Mechanically, the symbolism in the flow diagram provides the acronym for each symbol, the location of each symbol within the model, and the equation number for each mathematical relationship represented by the diagram. For example BCJFR and BP.5R indicate rate (R) equation number 5 in the Base Population (BP) Sector. CJFCR and JF.2,R indicate rate equation number 2 in the Jobs Filled Sector of the model. In this model all equations are either levels (L), rates (R), or Auxiliaries (A).

Delay Functions

In discussing delay functions, Forrester identified two characteristics of interest. One characteristic is the average length of delay which defines the effects on the system of the delay given a constant input rate. The second characteristic of interest is the transient response which explains the time shape of the outflow relative to the time shape of a changing input rate (10:87).

Placing orders from a mail-order catalogue serves as a good example in describing how these two characteristics are used in the creation of mathematical formulas for the description of a system, using the systems dynamics approach. For the purposes of this example, it is assumed that ten items are ordered, and the average time between placing an order and receiving a shipment is 10 days. This, then, establishes a cumulative distribution function of arrivals as depicted in Figure 2-9, if instantaneous delivery can be assumed to be possible.

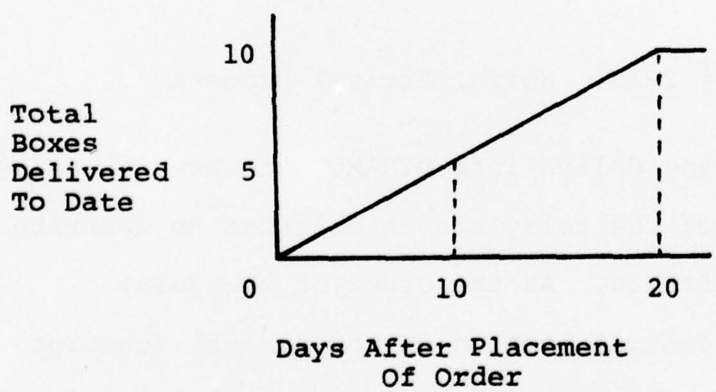


Figure 2-9. Smooth Arrival Process

This smooth arrival function is not likely. First of all, instantaneous delivery is not normally possible. Secondly, deliveries are seldom uniformly distributed. The more normal occurence is a minimum delay until the first delivery is made, and a large number of deliveries being made near the average delay time. The cumulative distribution for this more normal process is depicted in Figure 2-10.

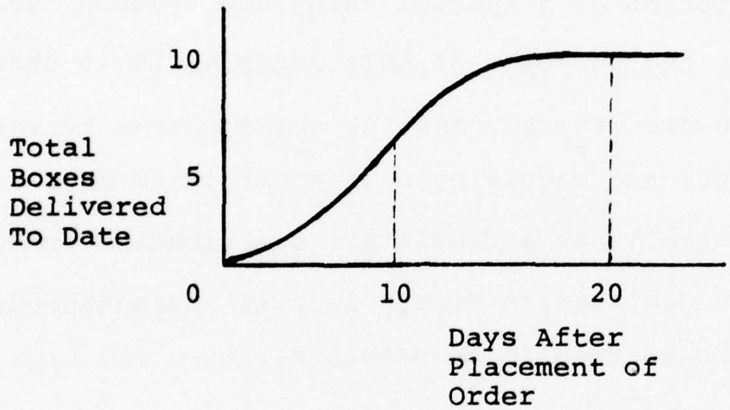


Figure 2-10. Normal Arrival Process

In placing delays into DYNAMO, the average delay time and order of the delay are established to describe the delay characteristics. As the order of the delay increases, the central portion of the arrival function becomes steeper. For the "Base Civilian Jobs" element in Figure 2-8, a third order delay is assumed with an average delay time equal to the average period of employment (AEP). A third order delay causes occurences to follow a normal distribution.

Formulation of mathematical equations to describe the system can be made once the flow diagram is completed. The next section develops the mathematical equations for "Base Civilian Jobs" element.

Mathematical Equations

In developing the equations which describe a system being simulated by DYNAMO, reference to the "J--K--L" time progression utilized in the difference equations discussion of this paper is necessary. "K" is the current time. "J" is one time period in the past. "L" is one time period in the future. The value of a particular variable at a given time is identified by the variable name and the name of the time period, i.e. "CJF.K" represents the current value of "CJF". Rates must be identified as occuring between specific points in time. The representation of the value of "BCJFR" between times "K" and "L" is "BCJFR.KL", which is a rate per standard time period where the standard time period may be other than "DT". The length of time between "J" and "K", and "K" and "L", is represented as "DT", which is a ratio multiplier of the standard time period. Constants are identified by their names alone, i.e. "JOBS" (10:73-80).

Five classes of equations are utilized when simulating the behavior of a system with DYNAMO. These five classes are:

1. Level Equations,
2. Rate Equations,
3. Auxiliary Equations,
4. Supplementary Equations, and
5. Initial-Value Equations (10:76-79).

Level equations define the varying contents of resource variables. Rate equations define the input and output rates to the levels. Auxiliary equations define subdivisions of rate equations in order to correspond more closely to activity relevant to the rate. Initial-value equations are used to define initial values of all levels, and some rates, that must be computed before the initial cycle of simulation. For instance, in the "Base Civilian Jobs" element, "BCJ.J" initially is set equal to a constant which reflects the number of occupied jobs at time "J". Figure 2-11 depicts the equations which describe the "Base Civilian Jobs" element flow diagram, Figure 2-8. Three classes of equations are represented. These classes are the level, rate, and auxiliary classes. The supplementary class of equations is not present since supplementary equations are not relevant to this model.

Figure 2-11 illustrates the mathematical equations derived from the Base Civilian Jobs element example. This figure also provides an example of the format of the DYNAMO program used throughout the remainder of this paper.

The first segment of each line is the program line number and the type of equation which follows. The next segment is the mathematical equation and the final segment is the equation reference number. Therefore, the first line of Figure 2-11 is a level equation on line 580 which is the fourth equation in the Base Population Sector of the model. An "X" after a line number indicates a continuation of the previous line. An asterisk signifies a

```
0580L    BCJ.K=BCJ.J+DT*(BCJFR.JK-BCJDR.JK)              BP.4
0590R    BCJFR.KL=MIN(BCA.K,BCD.K)                       BP.5
0600A    BCA.K=BJDM.K*LFA.K                              BP.6
0610A    BJDM.K=BCJD/CJA.K                               BP.7
0620A    BCD.K=BCJD-BCJ.K+CMCR                           BP.8
0630R    BCJDR.KL=DELAY3(BCJFR.JK,AEP)                   BP.9
0640A    BCJCR.K=BCJFR.JK-BCJDR.JK                       BP.10
0650*
0660*      BMJ=BASE MILITARY JOBS (PEOPLE)
0670*      BMJCR=BASE MILITARY JOBS CHANGE RATE (PEOPLE)
0680*      APCSR=AVERAGE PCS RATE
0690*      PCSC=PCS CYCLE
0700*      MMCR=MILITARY MISSION CHANGE RATE
0710*      BCJ=BASE CIVILIAN JOBS (PEOPLE)
0720*      BCJFR=BASE CIVILIAN JOBS FILLED RATE
0730*      BCA=BASE CIVILIANS AVAILABLE (PEOPLE)
0740*      BCD=BASE CIVILIANS DESIRED (PEOPLE)
0750*      CMCR=CIVILIAN MISSION CHANGE RATE (PEOPLE)
0760*      BCJD=BASE CIVILIAN JOBS DESIRED
0770*      BCJDR=BASE CIVILIAN JOBS DEPARTURE RATE
0780*      AEP=AVERAGE EMPLOYMENT PERIOD
0790*      BCJCR=BASE CIVILIAN JOBS CHANGE RATE
0800*      BJDM=BASE JOBS DESIRABILITY MULTIPLIER
```

Figure 2-11. DYNAMO Equation Example

a comment line not acted upon by computation and the letters N and C denote initial values (N) and constants (C) relative to a specific base-community system. Again, Figure 2-11 is an example of specific formulations to be presented in Chapter IV. Comparison of Figure 2-8 with 2-11 demonstrates that representations of relationships in the flow diagrams can be transferred directly to the model equations.

One final explanation is necessary to conclude the discussion of mathematical equations. Some situations exist within dynamic systems wherein the relationship between dependent and independent variables change with the situation. An example would be a case where different decisions are made under different conditions. Mathematically, there is no directly proportional relationship among variables. In DYNAMO, these situations are represented by graph functions. Figure 2-12 illustrates an example of variable decisions within the model. The dependent variable Business Population Magnet (BPM) is a curvilinear function of the independent variable Business Activity Rate (BAR). For varying values of BAR, BPM increases or decreases based on a predefined table function, Business Population Magnet Function (BPMF). The graph function and ranges for both variables are defined by the specific base-community system being modeled. Thus, CP.10 is the table function of CP.9 which describes the relationship between BPM and BAR.

```
0110A   BPM.K=TABHL(BPMF,BAR.JK,-1,1,1)              CP.7
0120T   BPMF=-.1/.1/.3                               CP.8
```

Figure 2-12. DYNAMO Graph Function

The system of equations defines the current levels, the rates during the "K--L" period and auxiliary variable values at time "L". Before the next simulation cycle, the old "K" becomes the new "J", the old "L" becomes the new "K", and the new values of all variables are recomputed. This iteration process generates predictions of system element levels, and rates, thus system behavior, over time.

The simulation of system behavior is an experimental process (10). In this research, once the initial model design was complete, simulations were executed. During each simulation, historical data relative to an existing base-community system were used to initialize the model and the output was logically analyzed relative to system behavior. If unexpected model behavior occured the source of that behavior was traced and necessary changes in the flow diagrams, the equations, or both were made. This process was repeated until the operation of the model was consistent with expected behavior. An extensive mission change was then injected into the model and the resulting behavior was observed. Results of this analysis are presented in Chapter V.

Data Collection

Data necessary to construct and simulate the base-community system model are historical in nature and can be obtained from numerous sources. In researching the problem of predicting economic impacts of mission changes at military installations, the primary agencies contacted have been AFCEC/DEVP, DOD/OEA, and the Construction Engineering Research Laboratory. These sources have gathered time-series data relative to the economic characteristics of base-community systems (15,26,and 36). The data compiled by these agencies were gathered by Federal, state, and local government agencies. In addition, local Chambers of Commerce, historical groups, and other non-governmental agencies have provided inputs to these data collections. This data was used to design the base-community system model and in the simulations made with the model.

Although statistical techniques were not required in the development of the model (10:17), simple linear regression and multiple linear regression were applied as aids in the development of the auxiliary equations and the choice of delay functions used in the model. These techniques were used, initially, in an attempt to determine if statistically significant relationships existed between variables (22). The universe under consideration in gathering data for these analyses consisted of all base-community systems in the contiguous United States (CONUS) as of 1974. The sample population consisted of selected economic characteristics exhibited by a stratified random sample of thirty CONUS base-community systems. The systems were stratified on the ratio of military to civilian on-base employees. This stratification was made in order to insure a wide distribution of economic impacts due to the base payroll, as injected into the local economy. Office of

Economic Adjustment personnel, indicated that the nature in which money flows into the local community from the base payroll is dependent upon this military to civilian ratio (26).

OEA personnel also provided a means of developing algorithms which describe occurences such as the propensity of base-employed civilians to leave a region after a base closure. These experts have demonstrated an ability to accurately predict such occurences through review of regional characteristics (26). These predictive efforts were captured in the model and used to pulse the model relative to the mission change experiment.

Model Validation

Validation of the base-community dynamic system model was conducted using historical data. Retrospective tests were made by introducing initial values at a point in time before a mission change occurred and, then, pulsing the system at time intervals to reproduce the phase-down of the base as it actually occurs. Observation of model-predicted system behavior and comparison of the model-generated behavior to actual system behavior were made to determine model validity.

Model validation completes the discussion of the research methodology. The presentation of the fulfillment of the research objectives begins in Chapter III with the determination of dynamic interrelationships and the tracing of their causes and effects.

Chapter III

CAUSE AND EFFECT RELATIONSHIPS

As outlined in the preceding chapter, the formulation of cause and effect relationships creates the foundation upon which the dynamic model is built. Therefore, an analysis of the logic behind the relationships, either implicit or explicit in model development, is necessary to establish this firm basis for understanding the model and for facilitating the model's manipulation. This discussion will begin where the model began. An understanding of the economic relationships between the base-community system and its environment was the objective which guided early development. The economic relationships important to the system are discussed first.

The Base-Community System

The entire causal structure of the base-community system model is represented by Figure 3-1. The reasons for initiating this presentation with the overall model structure are twofold. First, this system structure demonstrates the interdependence of the components of the system and emphasizes the fact of implicit relationships. Implicit relationships are those in which the direct pair-wise cause and effect chain is not present in the

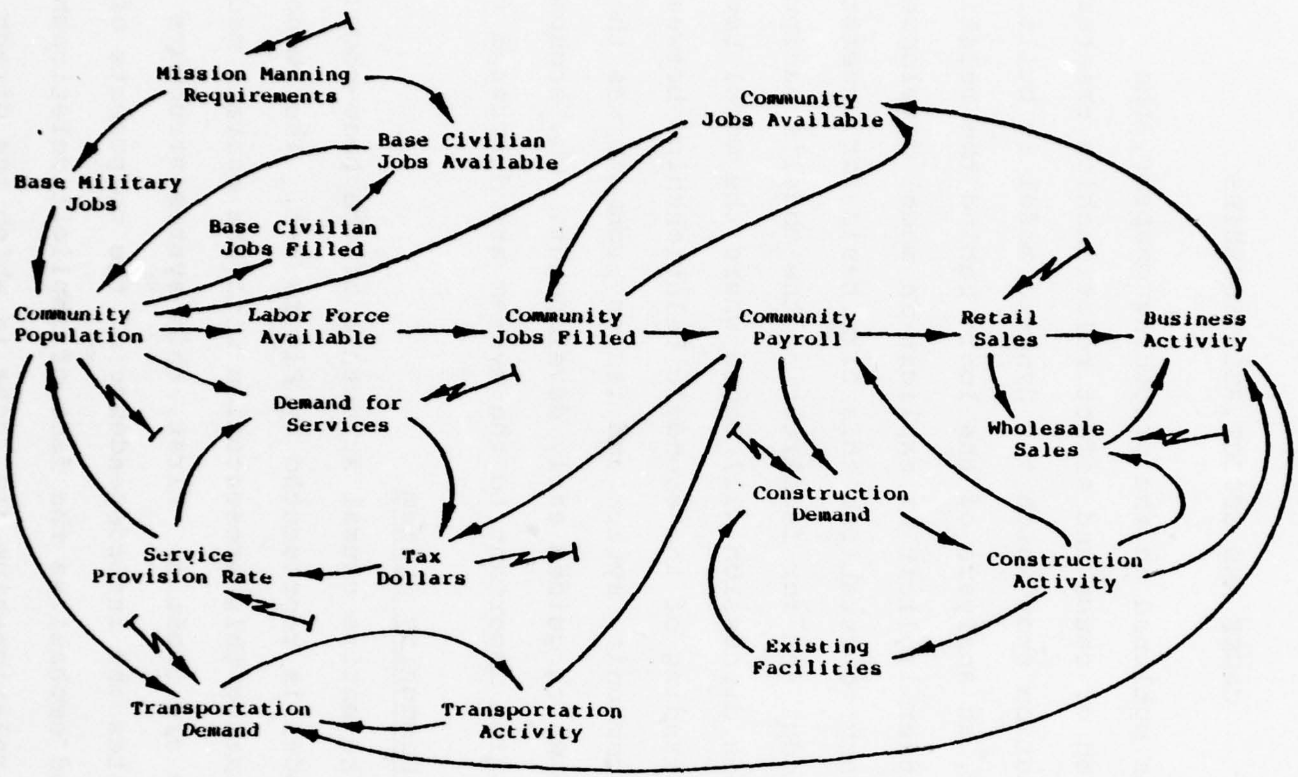


Figure 3-1. The Base-Community System

diagram but is indirectly established in the system. For example, a direct pair-wise relationship from business activity to construction activity is not in the system causal loop diagram. It is, however, implied in the relationship from business activity to jobs available to jobs filled to payroll to demand for construction and finally to construction activity. In the causal loop diagram of the Construction Sector, this relationship will be presented as a direct pair-wise cause and effect. The second reason for early introduction of the overall causal structure is to illustrate the interaction of the base community subsystem with a higher level national political--economic system: the macro system introduced in Chapter II. The system causal loop diagram illustrates, through the convention of jagged arrows, the influences across the boundaries of the two systemic levels.

The macro system is influenced from the community by tax dollars and political pressure through the population. The community is affected exogenously through direct dollar support in the form of subsidies, and through population influences by way of job creation. Because the concept of a macro system was so important to model development, a causal representation of the macro system was created.

Macro System Interrelationships

Figure 3-2 depicts the causal interaction of elements within the macro system which allows the exchange of information, money, and authority across system boundaries. The purpose of the diagram is to show the interaction between executive and legislative authority at national levels. For the purpose of this model, that interaction results in a Federal budget. The DOD portion of the Federal budget is determined through legislative decisions established in the Planning--Programming--Budgeting System (29).

The monies provided to DOD are transformed into capabilities in the form of people and hardware. This Defense money is the point of departure for base capabilities. As military capabilities change, the perceived danger to the country changes through an analysis of power balance. As the perceived threat changes, political pressure to reduce the Defense budget is counteractive. It was assumed in this model that allocated money would all be spent. Thus, when the DOD budget is changed, other portions of the Federal budget move in the opposite direction, i.e., DOD cuts do not historically result in overall budget cuts (24:128-149). The changes in non-DOD budgets are transferred to communities. The communities, in turn, change constituent pressure based upon a perceived "proper" balance between Defense and other Federal dollars

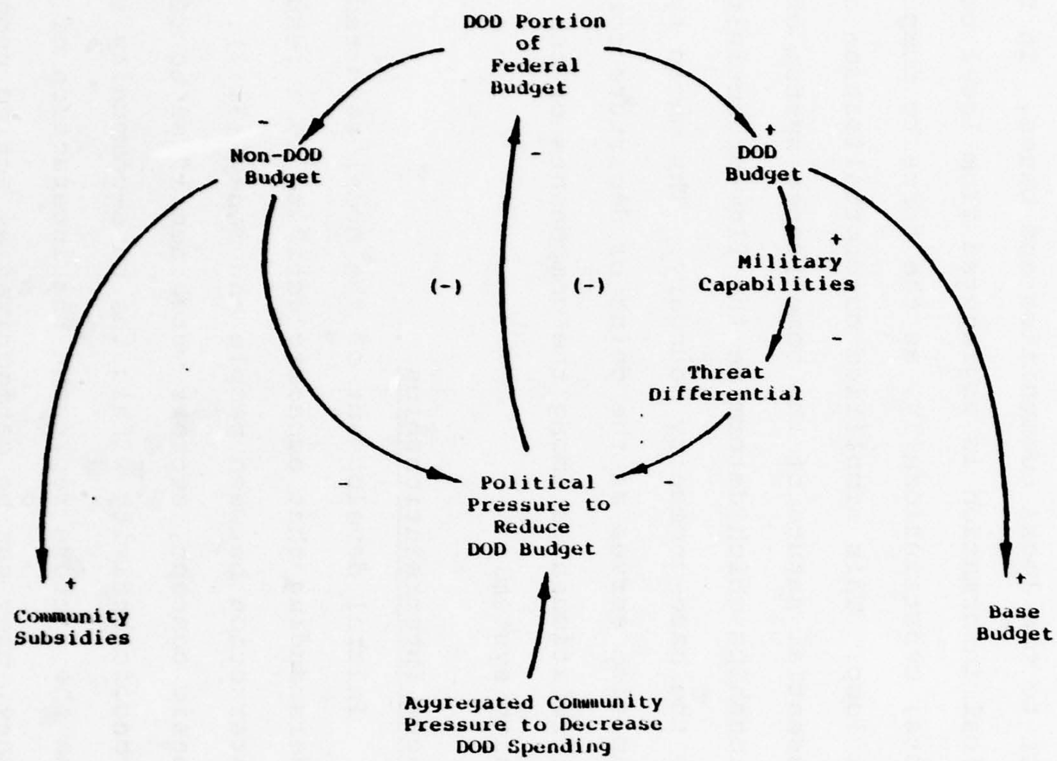


Figure 3-2. Macro System Interrelations

in the community.

The important point in this presentation is not the sector model itself, but the fact that decisions and money flow from the national civilian and defense sectors to the local communities and bases. In turn, political information is aggregated from local communities and acts, constitutionally, as the force to complete the causal loop. This simplified conceptualization captures the essential nature of the complicated system of interrelationships which determine the flow of activities across the base-community boundary. The macro system diagram also serves as the point of departure for the causal relationships among the components of the base-community system.

Component Interrelationships

Initial development of the model resulted from an understanding that economic activity is a result of the interaction between people and money (31:3). From that basic concept, sectors were identified to represent the economic activity within the base-community system. Because the sectors represent the interaction of people and money, they can be categorized as acting upon one or the other. The sectors acting primarily upon people include Community Population, Base Population, Labor Force, Total Community Jobs, and Community Jobs Filled. Those acting upon money are Retail Sales, Wholesales Sales, Construction, Transportation, Business Activity, Taxes/ Services, and Community Payroll. These sectors are totally interdependent and their interdependence results in economic activity. The following paragraphs describe the individual sectors as conceptualized for the base-community economic model. Each description includes a causal loop diagram, and explanation of the pair-wise relationships, and a discussion of the logic behind the conceptual framework. The fact emerges throughout the discussion that the causal loops show direct interrelationships among variables within several sectors and, in most cases, a variable in one sector cannot be introduced without the presence of the same variable in several other sectors.

Community Population Sector

Figure 3-3 depicts the causal relationships among activities which comprise the community population. Population increases and decreases are functions of how likely people are to migrate to and from the community (disregarding the obvious effects of birth and death rates for the time being). The causal loop, therefore, was established around a Community Desirability variable which becomes a measure of migration likelihood (8:222). Each may increase or decrease over time, and their combined

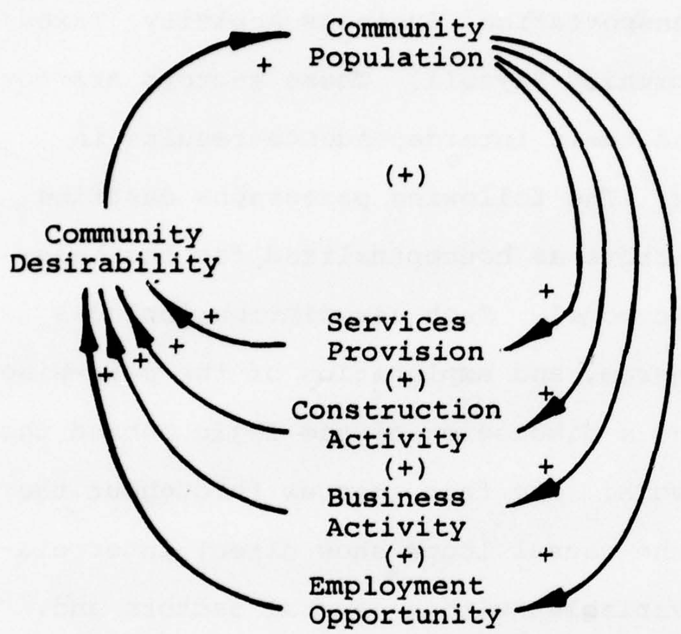


Figure 3-3. Community Population Sector Causal Loop

effect serves to increase or decrease the population. Services provision is the capability of the community, through taxes and government subsidies, to provide protection, comfort and aid to the population (11:7-13). Construction activity was segregated from other business activities because of its strong individual drawing effect on population. The higher the level of construction activity, the higher is the perceived level of housing and thus, the magnetism or desirability, of the community (7:30-36). This relationship also implies the magnetic effect of other types of business activity which, for this causal loop, are combined into one. Finally, Employment

Opportunity represents the probability of obtaining work in a community, a variable which has a strong effect on community desirability. The Community Population Sector, then, is actually four individual loops whose combined strength tends to determine population growth. Although birth and death rates are not depicted in this loop diagram, they are important to the model and are discussed fully in Chapter IV.

Base Population Sector

The Base Population Sector is the first encounter with the direct effects of activity exogenous to the system. As illustrated in Figure 3-4, the causal loop representation cannot be closed without the previously established flows of information across system boundaries. The information flows from the DOD sector to mission manpower requirements. Mission manpower is the number of military and civilian personnel required to perform the assigned base mission. Once the mission manning requirements are established, the specific number of base civilian jobs available and base military jobs can be determined. There is no difference in this model between the number of military jobs available and filled because military personnel are assigned from outside the system. Decisions within the base-community system do not control military manning requirements. The base civilian jobs,

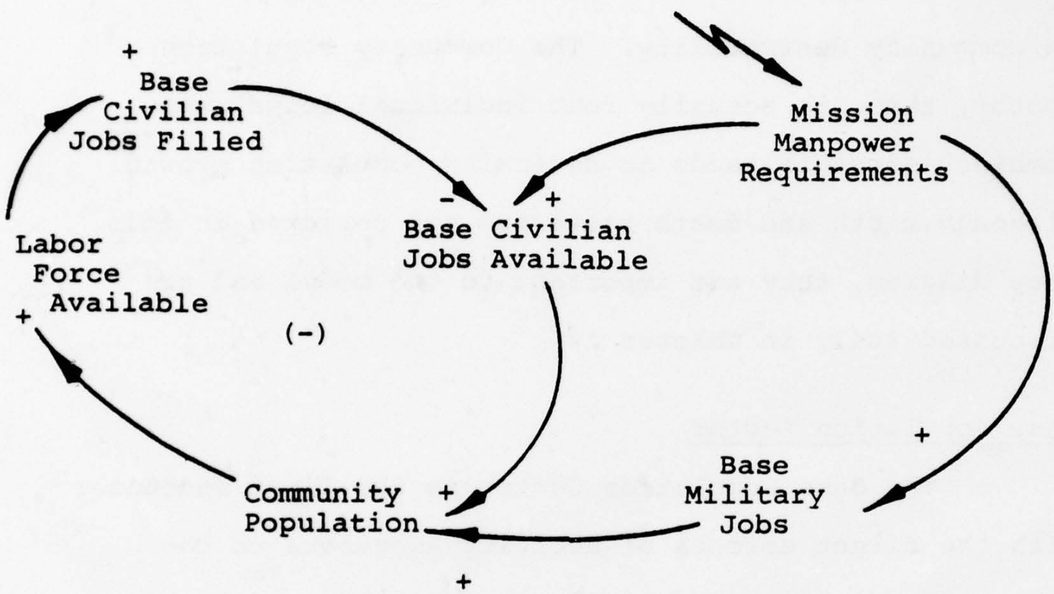


Figure 3-4. Base Population Sector Causal Loop

however, do provide a causal relationship between jobs available and filled. Although the number filled is, for the most part, a product of the local community labor force available. The labor force is some fraction of the total community population. When the population increases as a result of inputs from military personnel and their families, and from the magnetic effect of civilian jobs available, the total labor force available in the community increases. The availability of labor force tends to increase the number of base civilian jobs filled which in turn reduces the number of jobs available and hence reduces the magnetic effect on population.

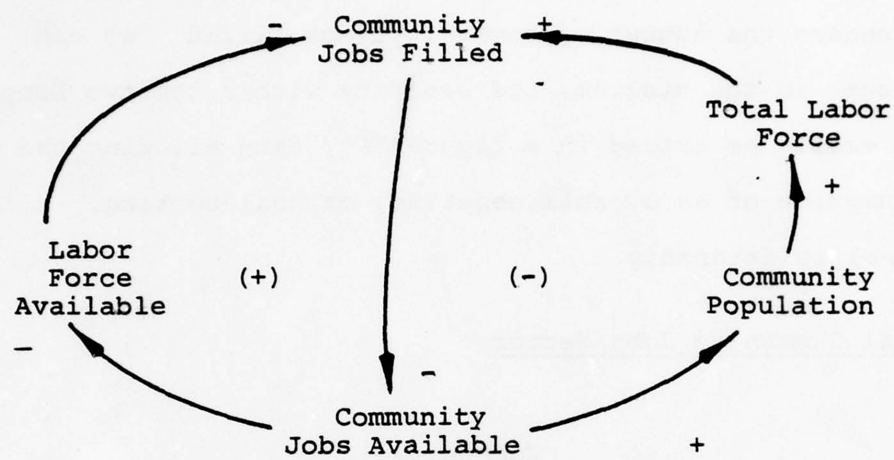


Figure 3-5. Labor Force Sector Causal Loop

Labor Force Sector

The Labor Force Sector again illustrates the relationships among jobs filled, jobs available, and community population. The causal diagram shows the effect of opposing activities serving to bring one activity into stability (Figure 3-5). The diagram is essentially two loops with counteractive effects upon jobs. As community population increases due to people filling available jobs, the total labor force increases through the fractional component of community desirability. However, increasing jobs filled decreases jobs available which closes the negative loop. On the other side, as community jobs available increase, the number of people in the available labor force declines, i.e., as people take jobs, fewer people are unemployed. This, in turn, increases the number of community jobs filled. As can be seen in the diagram, the activity within the two loops can easily be traced in a figure "8", thus allowing the assumption of an overall negative, or goal-seeking, causal relationship.

Total Community Jobs Sector

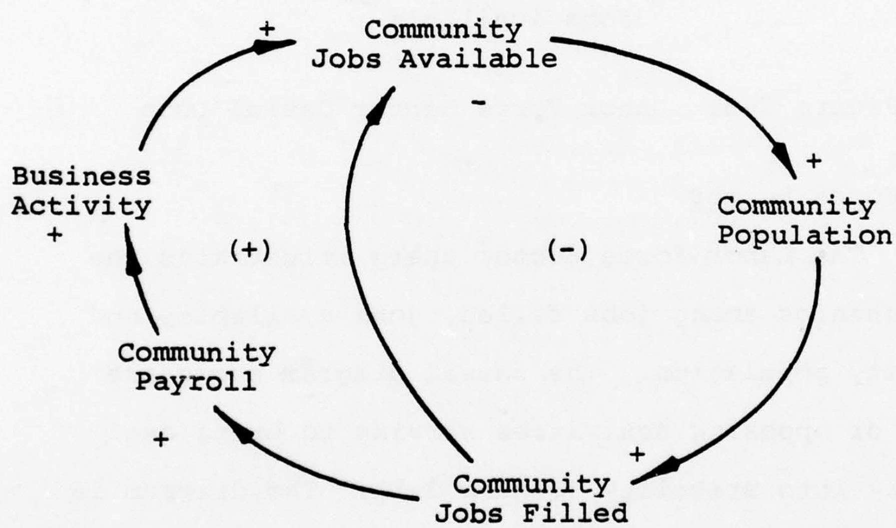


Figure 3-6. Total Community Jobs Sector Causal Loop

The Total Community Jobs Sector introduces a concept important to the development of the entire model. Initially, the right-hand side of the loop shown in Figure 3-6 depicts the direct relationship among jobs filled, jobs available, and community population. However, there exists another causal relationship between jobs filled and jobs available through the Payroll and Business Sectors. As the number of jobs filled increases, the total community payroll increases. When payroll increases, the amount of money spent in the community increases, thereby increasing business activity. Similarly, as business activity increases, merchants are prone to enlarge their businesses, creating more jobs (31:255-267). The overall movement of the causal loop is toward growth, even with the modulating effect of the smaller "jobs" loop. The next two sectors provide the transition from sectors in which people are the main element to the sectors where money is the main concern. The patterns emphasize again the important concept of interdependence of activities within dynamic systems (12:11-12).

Jobs Filled Sector

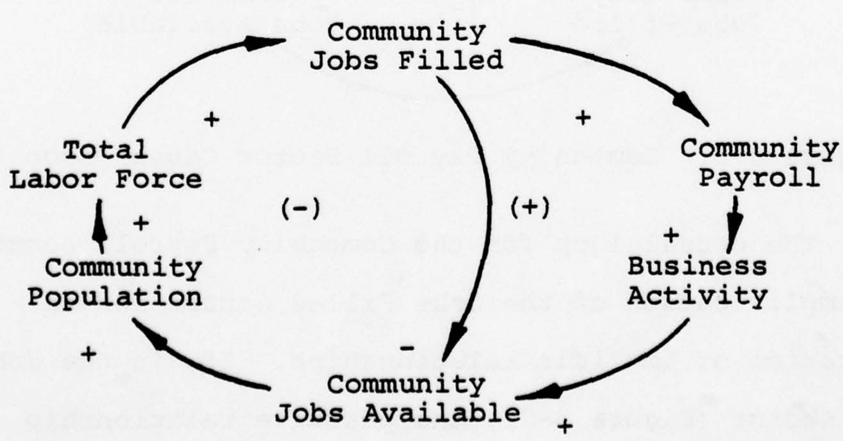


Figure 3-7. Jobs Filled Sector Causal Loop

The Jobs Filled Sector, as seen in Figure 3-7, is a combination of the business side of the Total Community Jobs Sector and the population side of the Total Labor Force Sector. This combination follows from an observation that the number of jobs filled in a community is the money available through business melding with people seeking employment (31:263). Each of the relationships in the loop has been discussed earlier. The propensity of the causal relationship is toward growth because the major causal loop is positive.

Community Payroll Sector

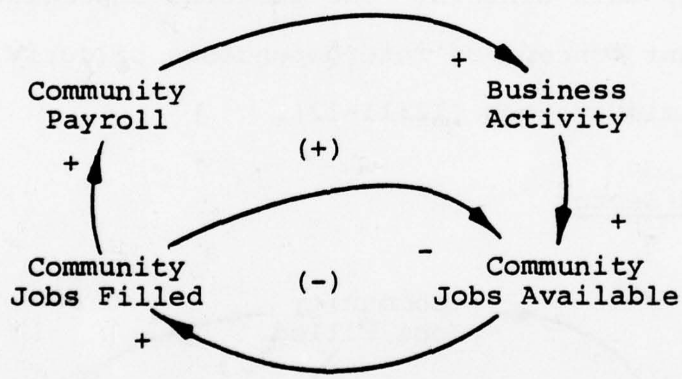


Figure 3-8. Community Payroll Sector Causal Loop

The causal loop for the Community Payroll Sector is a simplification of the Jobs Filled Sector and an illustration of implicit relationships. If, in the Jobs Filled Sector (Figure 3-7), the positive relationship from jobs available to jobs filled were shown as a direct pair-wise relationship with the flow through population and labor force only implied, the new diagram would represent the Community Payroll Sector (Figure 3-8). The remainder of the causal loops are of sectors dealing primarily, but not exclusively, with money.

Retail Sales Sector

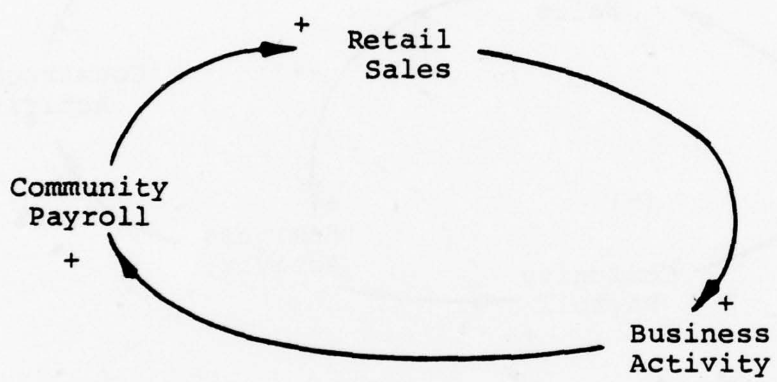


Figure 3-9. Retail Sales Sector Causal Loop

The Retail Sales Sector is another sector which incorporates the concept of implicit relationships. Throughout the first portion of this chapter, a direct cause and effect pattern between business activity and community payroll has been shown. Retail Sales is the sector which provides the reason for that pattern. Figure 3-9 shows a simple relationship among three activities. Increased payroll increases retail sales which provide direct stimulation to business activity. Business activity affects payroll through increased employment. This same pattern of relationships between payroll and business will continue throughout the model. In fact, with two modifications, the Retail Sales Sector loop becomes the Wholesale Sales Sector loop.

Wholesale Sales Sector

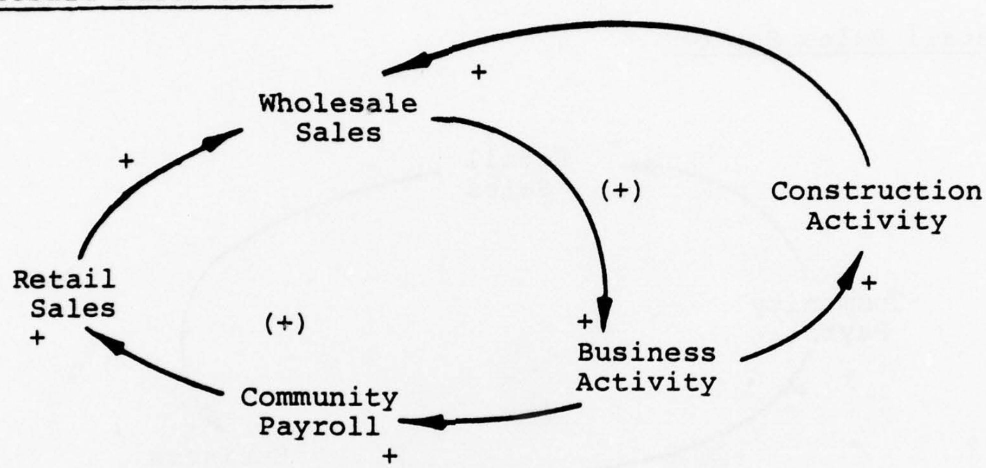


Figure 3-10. Wholesale Sales Sector Causal Loop

The inclusion of the variables, Wholesale Activity and Construction Activity in the Retail Sales Sector creates the conceptual framework for the system's Wholesale Sales Sector shown in Figure 3-10. As noted in the Retail Sales Sector, some dollars go directly to business activity in the form of retail purchases. However, part of the retail money is directed toward wholesale business in the form of orders for retail stock replenishment. The level of wholesale sales is also acted upon positively by the level of construction activity. This discrimination of construction from other business, again was made because of the significant impact that constuction activity places on the level of economic activity (7:36-41). The overall effect of wholesale sales is toward growth. The pair-wise relationship between business activity and construction activity follows in the next sector.

Construction Sector

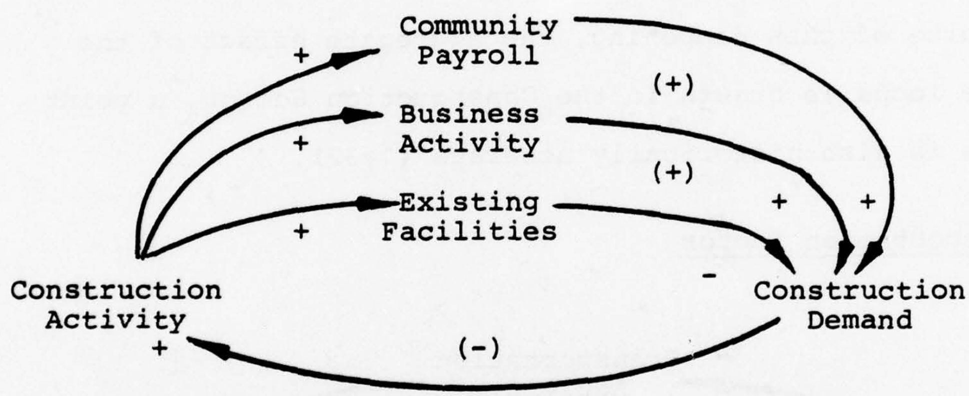


Figure 3-11. Construction Sector Causal Loop

Similar to the parallel relationship of the Community Population Sector, the Construction Sector is three contiguous causal loops in one. The loops are shown in Figure 3-11. As either or both community payroll and business activity change, a desire for new facilities is created through a demand for construction. For example, an increase in the money available in the community results in both the private citizen and the businessman expressing a desire for homes, roads, warehouses, etc., (9:651-655). The construction demand is answered through a relative change in the construction activity. The two outer loops are closed through the creation of new jobs and the positive influence of construction activity on business activity. A dampening effect occurs when available facilities begin to exceed demand. As the level of existing facilities increases, the perceived need for facilities decreases and construction demand decreases. In spite of this dampening, the aggregate effect of the three loops is growth in the Construction Sector, a point which is also historically accurate (7:32).

<u>Transportation Sector</u>

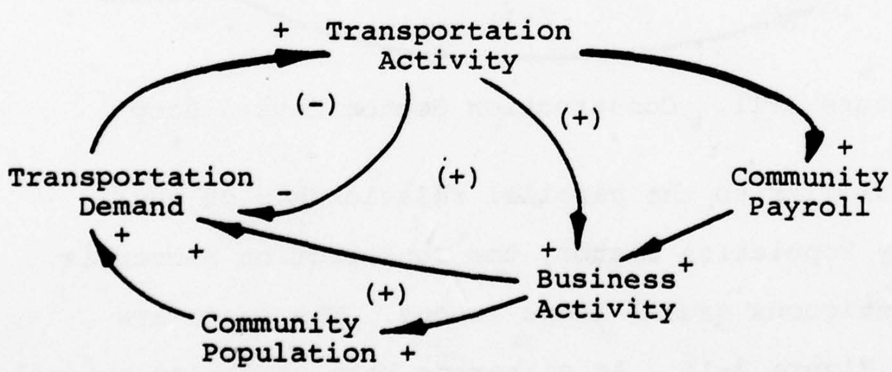


Figure 3-12. Transportation Sector Causal Loop

The Transportation Sector loop represents many types of activity within one business. The relationship (Figure 3-12) between population and demand has already been established, as has been the dampening effect between activity and demand. The parallel relationships between transportation activity and business activity was included to illustrate both individual and combined demands.

<u>Business Activity Sector</u>

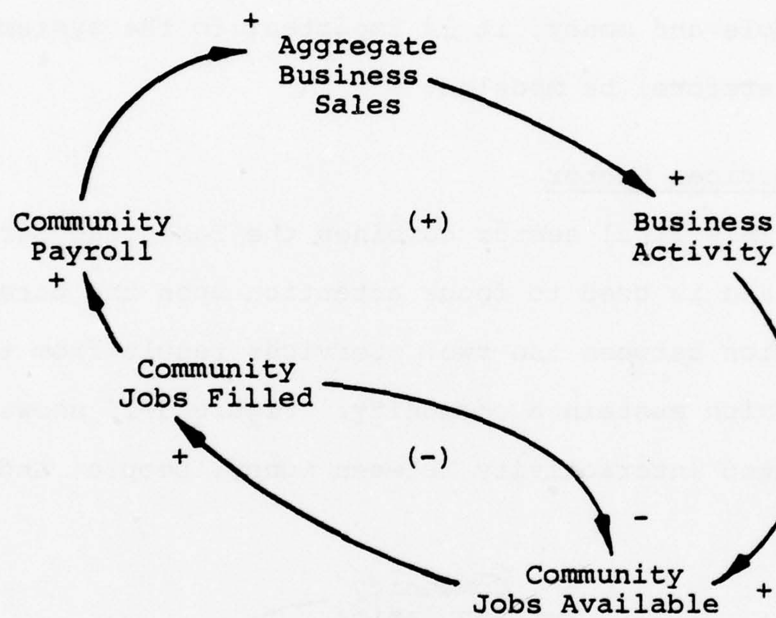


Figure 3-13. Business Activity Sector Causal Loop

Only one new variable is required to illustrate the causal relationships in the Business Activity Sector. That variable represents aggregation of all individual business activities. This concept has already been implied throughout this discussion, but the nature of the Aggregate Business Sales variable (Figure 3-13) is to show the activity implicit between community payroll and business activity. With the exception of the

Aggregate Business Sales variable, this sector is identical to the Community Payroll Sector. The Business Activity Sector depicts the fact that people spend their salaries. This obvious fact may seem too simple to include in the discussion but, although implicit in a relationship between people and money, it is important to the system and must, therefore, be modeled.

<u>Taxes/Services Sector</u>

This final sector combines the Taxes and Services Sectors and is used to focus attention upon the direct interaction between the two. Services result from the tax monies which sustain a community. Figure 3-14 shows the complicated interactivity between money, people, and jobs.

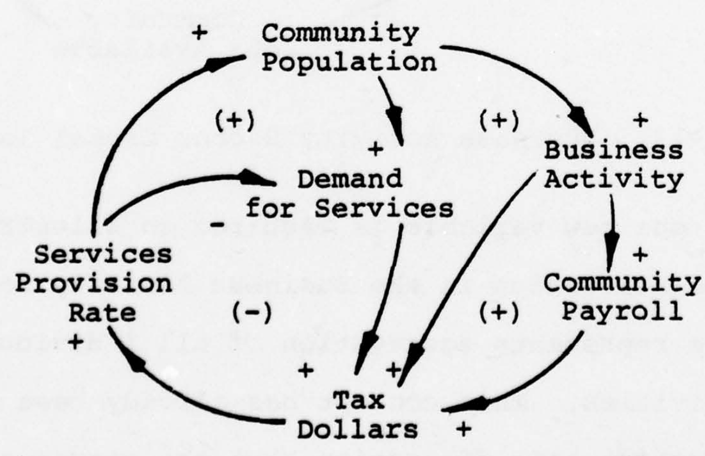


Figure 3-14. Taxes/Services Sector Causal Loop

The loops display the fact that people serve themselves (11:7). The only variable which has not been previously explained is the one labeled Tax Dollars. This component is both a function of money available through payrolls and business and the demand expressed through people by way of representative governments. An important point in this concept, and one which recent history has borne out, is that taxes are not simply a function of people and money, but also of the people's need to be taxed (3). If a society is to serve itself, it must be willing to pay for the services. Thus, the internal negative loop from Tax Dollars to Services Provision Rate to Demand for Services and back is significant to the system's operation. With this explanation of the final causal loop, the entire system of causal relationships can be tied together to again form the base-community system as depicted in Figure 3-1.

The conceptualization of the causal relationships of the base-community system formed the basis for the development of the necessary flow diagrams and mathematical equations which became the working, dynamic model. That development is discussed in the following chapter.

Chapter IV

THE MATHEMATICAL BASE-COMMUNITY MODEL

Flow diagrams of the resource and information transformations within the base-community model, and the DYNAMO mathematical equations are developed in this chapter. Each of the twelve sectors, whose causal loops were presented in the previous chapter, is described individually with a flow diagram, the mathematical equations describing the sector, in the DYNAMO language (28), and an account of the logic supporting each equation. The development of each sector begins with a flow chart portrayed in the symbology presented in Chapter II. Following the flow chart, the mathematical equations are presented with a word description of the sector. The word description of the mathematical equations is initiated with a description of the primary level equation followed by descriptions of the supporting level, rate, and auxiliary equations within the sector. Discussion of constants, initiatives of variable values, and the parameters entered via the graph functions within the base-community model is reserved for Chapter V. Descriptions of the qualitative nature of model parameters are included in this chapter to aid in the development of the logic involved in formulation of each of the equations. The Community Population Sector is the first to be described because of its pivotal nature within the model.

Community Population Sector

```
0050L    CP.K=CP.J+DT*CPCR.JK                          CP.1
0060R    CPCR.KL=PM.K+GG.K+MFG.K                       CP.2
0070A    GG.K=CP.K*(BR-DR)                             CP.3
0080A    MFG.K=BMJCR.JK*MFSM                           CP.4
0090A    PM.K=CP.K*NM*DELAY3(CDM.K,24)                 CP.5
0100A    CDM.K=BPM.K+SPMA.K+COPMA.K+EPM.K              CP.6
0110A    BPM.K=TABHL(BPMF,BAR.JK,-1,1,1)               CP.7
0120T    BPMF=-.1/.1/.3                                CP.8
0130A    SPMA.K=TABHL(SPMF,PSPR.K,4,104,50)            CP.9
0140T    SPMF=-.1/.1/.3                               CP.10
0150A    PSPR.K=SPR.JK/CP.K                           CP.11
0160A    COPMA.K=TABHL(COPMF,PCOSR.K,41,141,50)       CP.12
0170T    COPMF=-.2/.2/.6                              CP.13
0180A    PCOSR.K=COSR.JK/CP.K                         CP.14
0190A    EPM.K=TABHL(EPMF,UEMP.K,0,.16,.08)           CP.15
0200T    EPMF=1.8/.6/-.6                              CP.16
0210A    UEMP.K=LFA.K/LFT.K                           CP.17
0220*
0230*      CP=COMMUNITY POPULATION (PEOPLE)
0240*      CPCR=COMMUNITY POPULATION CHANGE RATE (PEOPLE)
0250*      GG=GENETIC GROWTH (PEOPLE)
0260*      BR=BIRTH RATE
0270*      DR=DEATH RATE
0280*      MFG=MILITARY FAMILY GROWTH (PEOPLE)
0290*      MFSM=MILITARY FAMILY SIZE MULTIPLIER
0300*      PM=POPULATION MIGRATION (PEOPLE)
0310*      NM=NORMAL MIGRATION
0320*      CDM=COMMUNITY DESIRABILITY MULTIPLIER
0330*      BPM=BUSINESS POPULATION MAGNET
0340*      BPMF=BUSINESS POPULATION MAGNET FUNCTION
0350*      SPMA=SERVICES POPULATION MAGNET
0360*      SPMF=SERVICES POPULATION MAGNET FUNCTION
0370*      PSPC=PER CAPITA SERVICES PROVISION RATE
0380*      COPMA=CONSTRUCTION POPULATION MAGNET
0390*      COPMF=CONSTRUCTION POPULATION MAGNET FUNCTION
0400*      PCOSR=PER CAPITA CONSTRUCTION SALES RATE
0410*      EPM=EMPLOYMENT POPULATION MAGNET
0420*      EPMF=EMPLOYMENT POPULATION MAGNET FUNCTION
0430*      UEMP=UNEMPLOYMENT RATE
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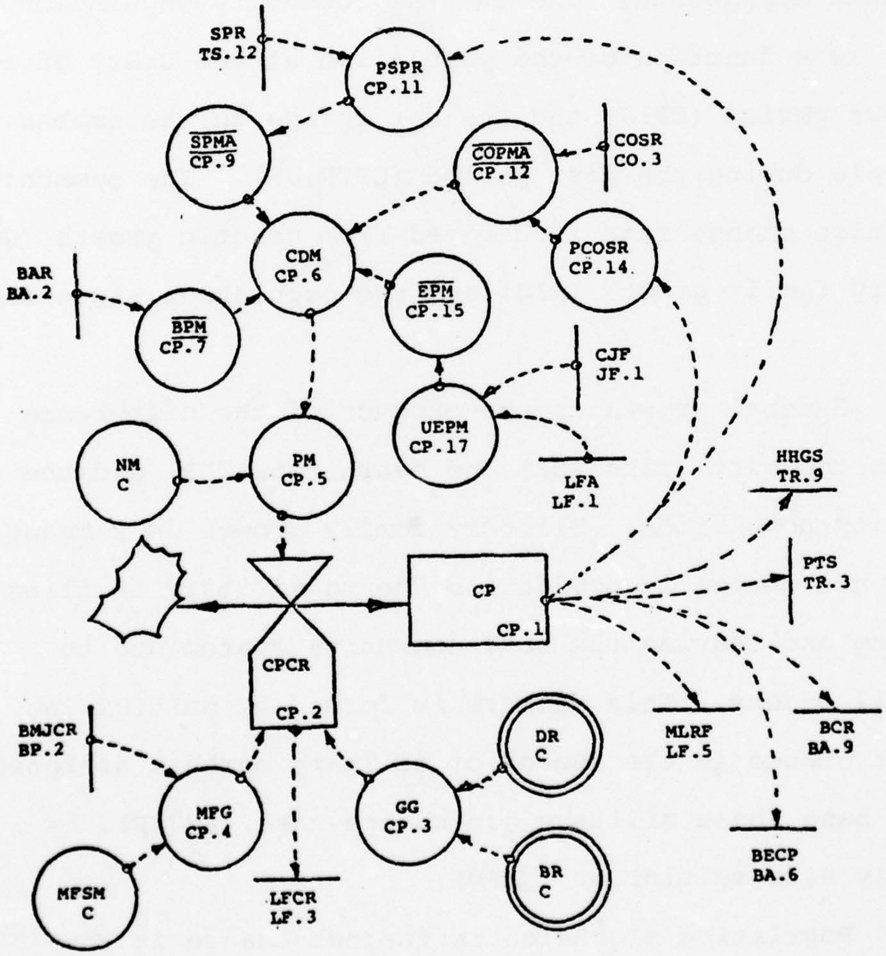

Figure 4-1. Community Population Sector

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The Community Population sector accumulates people living in the base-community system, and is pictured in Figure 4-1. This level of people includes all local citizens, including military personnel assigned to the base and their dependents. The current community population (CP.K) is a function of the population at the start of the previous period (CP.J) and the net change in the number of people during the last period (CPCR.JK). The community population change rate is derived from genetic growth (GG), military family growth (MFG) and the population migration (PM).

General growth is the product of the difference between the birth rate (BR) and death rate (DR) and the community population. Military family growth is a measure of the net change in population due to military families entering and leaving the base-community system due to official orders. This measure is formed by multiplying the net change in the number of military members assigned to the base, base military job change rate (BMJCR), by a family size multiplier (MFSM).

Population migration is the net change in the population due to civilians entering and leaving the system. This change in the number of civilians in the base-community system is determined, within the model, by considering four primary causes for community population change. These causes are the rate of business sales in the system, service provision rate, construction sales rate, and the rate of unemployment. The influence of these factors upon migration is injected into the sytem as a multiplier of the normal migration rate (NM) and the community population. The multipliers are aggregated in a community desirability multiplier (CDM). The CDM is applied in the population migration equation with a delay function. This delay is caused by a natural lag in perception of information about the community.

The business population magnet (BPM) is a measure of community attractiveness and is dependent upon the magnitude of business sales in the community. This magnitude is formed as a ratio of the current aggregated per capita sales to a normal level of per capita sales. The services population magnet (SPMA) is dependent upon the current per capita services provision rate (PSPR) as compared to a normal rate. The construction population magnet (COPMA) is formed by comparison of the current per capita construction sales rate (PCOSR) to a normal rate. Finally, the employment population magnet (EPM) is a result of the current unemployment rate (UEMP) in comparison to a normal unemployment rate. Current unemployment is a ratio of the labor force available (workers occupying jobs) to the total labor force (LFT). The graph functions used to formulate these population magnets are specific to the base-community under consideration and are discussed in Chapter V.

A primary input to the Community Population Sector is the migration of military personnel to and from the military base. Therefore, the Base Population Sector is described as the second major part of the base-community system model.

Base Population Sector

```
0550L   BMJ.K=BMJ.J+DT*BMJCR.JK                          BP.1
0560R   BMJCR.KL=2*APCSR*PCSC.K+MMCR                     BP.2
0570A   PCSC.K=SIN(24*TIME.K)                            BP.3
0580L   BCJ.K=BCJ.J+DT*(BCJFR.JK-BCJDR.JK)               BP.4
0590R   BCJFR.KL=MIN(BCA.K,BCD.K)                        BP.5
0600A   BCA.K=BJDM.K*LFA.K                               BP.6
0610A   BJDM.K=BCJD/CJA.K                                BP.7
0620A   BCD.K=BCJD-BCJ.K+CMCR                            BP.8
0630R   BCJDR.KL=DELAY3(BCJFR.JK,AEP)                    BP.9
0640A   BCJCR.K=BCJFR.JK-BCJDR.JK                       BP.10
0650*
0660*      BMJ=BASE MILITARY JOBS (PEOPLE)
0670*      BMJCR=BASE MILITARY JOBS CHANGE RATE (PEOPLE)
0680*      APCSR=AVERAGE PCS RATE
0690*      PCSC=PCS CYCLE
0700*      MMCR=MILITARY MISSION CHANGE RATE
0710*      BCJ=BASE CIVILIAN JOBS (PEOPLE)
0720*      BCJFR=BASE CIVILIAN JOBS FILLED RATE
0730*      BCA=BASE CIVILIANS AVAILABLE (PEOPLE)
0740*      BCD=BASE CIVILIANS DESIRED (PEOPLE)
0750*      CMCR=CIVILIAN MISSION CHANGE RATE (PEOPLE)
0760*      BCJD=BASE CIVILIAN JOBS DESIRED
0770*      BCJDR=BASE CIVILIAN JOBS DEPARTURE RATE
0780*      AEP=AVERAGE EMPLOYMENT PERIOD
0790*      BCJCR=BASE CIVILIAN JOBS CHANGE RATE
0800*      BJDM=BASE JOBS DESIRABILITY MULTIPLIER
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The Base Population Sector accumulates people who occupy military and civilian jobs on the military installation. Base military jobs (BMJ) is the level of

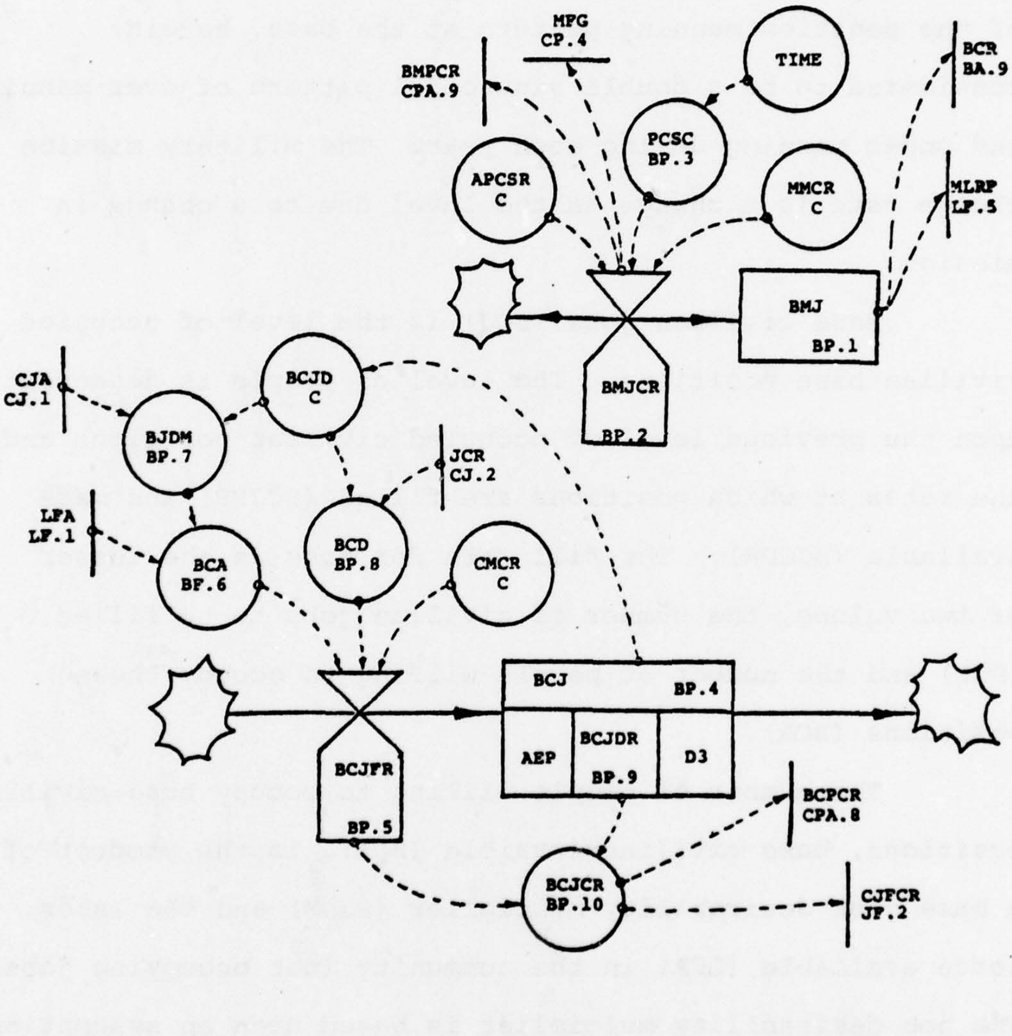

Figure 4-2. Base Population Sector

people occupying military jobs at the base. This level is determined by adding the net change in the occupied positions (BMJCR) during the last period and any military manning change (MMCR) to the previous level of occupied positions. The base military jobs change rate is a result of the position manning pattern at the base, herein considered to be a double sinusoidal pattern of over manning and under manning during each year. The military mission change rate is a change in the level due to a change in mission.

Base civilian jobs (BCJ) is the level of occupied civilian base positions. The level of people is dependent upon the previous level of occupied civilian positions and the rates at which positions are filled (BCJFR) and made available (BJCDR). The fill rate for jobs is the lesser of two values, the number of civilian jobs to be filled (BCD) and the number of people willing to occupy these positions (BCA).

The number of people willing to occupy base civilian positions, base civilians avaible (BCA), is the product of a base jobs desirability multiplier (BJDM) and the labor force available (LFA) in the community (not occupying jobs). The job desirability multiplier is based upon an assumption that seekers of employment act as sellers in a perfectly competitive market (face an elastic demand curve) and seek employment in each sector at the same ratio as jobs occur in the community. Therefore, the desirability multiplier is the ratio of base civilian positions to the total number of community jobs available (CJA).

The number of base civilians desired (BCD) is equal to the number of unoccupied civilian positions. The number of unoccupied positions is the difference between the number of total civilian base jobs (BCJD+CMCR) and the number of base civilian jobs occupied (BCJ). The rate at which civilians depart base jobs (BCJDR) is a delay function of the job fill rate, and the average employment period (AEP). The base civilian job change rate (BCJCR) is a measure of the net change in occupied base civilian positions and is the difference between the job fill rate and the departure rate.

Prior to considering sectors involving community jobs, the manner in which people seek employment is necessary. As a natural successor to the discussion of population, the Labor Force Sector is presented next.

Labor Force Sector

The Labor Force Sector accumulates levels of workers in the base-community model. The current labor force available (LFA) is the sum of the magnitude of the level prior to the last period and the net change in labor available during the period (LFACR). The labor force available change rate is the difference between the net change in the total labor

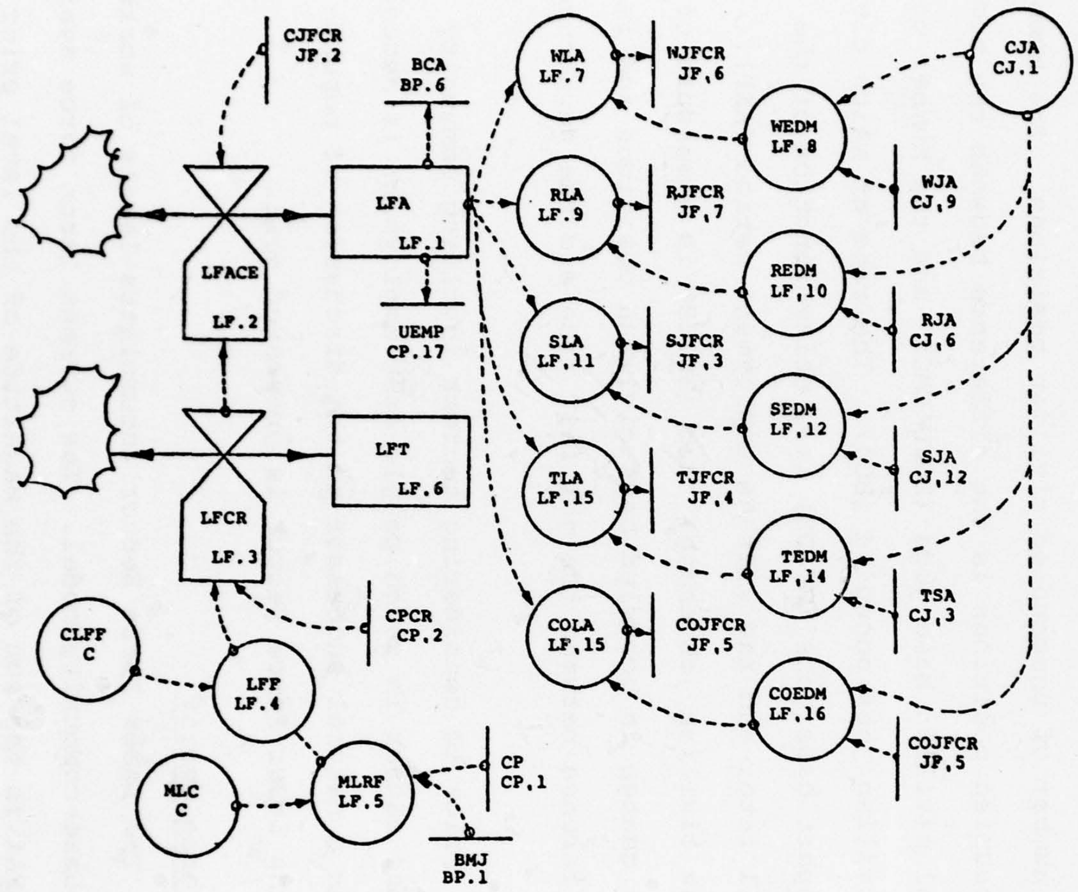

Figure 4-3. Labor Force Sector

force (LFCR) and the community jobs filled change rate (CJFCR). The labor force change rate is the product of a labor force fraction (LFF) and the community population change rate (CPCR).

```
0940L   LFA.K=LFA.J+DT*LFACR.JK                          LF.1
0950R   LFACR.KL=LFCR.JK-CJFCR.JK                        LF.2
0960R   LFCR.KL=LFF.K*CPCR.JK                            LF.3
0970A   LFF.K=CLFF-MLRF.K                                LF.4
0980A   MLRF.K=MLC*(BMJ.K/CP.K)                          LF.5
0990L   LFT.K=LFT.J+DT*LFCR.JK                           LF.6
1000A   WLA.K=WEDM.K*LFA.K                               LF.7
1010A   WEDM.K=WJA.K/CJA.K                               LF.8
1020A   RLA.K=REDM.K*LFA.K                               LF.9
1030A   REDM.K=RJA.K/CJA.K                              LF.10
1040A   SLA.K=SEDM.K*LFA.K                              LF.11
1050A   SEDM.K=SJA.K/CJA.K                              LF.12
1060A   TLA.K=TEDM.K*LFA.K                              LF.13
1070A   TEDM.K=TJA.K/CJA.K                              LF.14
1080A   COLA.K=COEDM.K*LFA.K                            LF.15
1090A   COEDM.K=COJA.K/CJA.K                            LF.16
1100*
1110*      LFA=LABOR FORCE AVAILABLE (PEOPLE)
1120*      LFACR=LABOR FORCE AVAILABLE CHANGE RATE (PEOPLE)
1130*      LFCR=LABOR FORCE CHANGE RATE (PEOPLE)
1140*      LFF=LABOR FORCE FRACTION (PEOPLE)
1150*      CLFF=CIVILIAN LABOR FORCE FRACTION
1160*      MLRF=MILITARY LABOR REDUCTION FACTOR
1170*      LFT=LABOR FORCE TOTAL (PEOPLE)
1180*      WLA=WHOLESALE LABOR FORCE AVAILABLE (PEOPLE)
1190*      WEDM=WHOLESALE EMPLOYMENT DESIRABILITY MULT.
1200*      RLA=RETAIL LABOR FORCE AVAILABLE (PEOPLE)
1210*      REDM=RETAIL EMPLOYMENT DESIRABILITY MULT.
1220*      SLA=SERVICES LABOR FORCE AVAILABLE (PEOPLE)
1230*      SEDM=SERVICES EMPLOVMENT DESIRABILITY MULT.
1240*      TLA=TRANSPORTATION LABOR AVAILABLE (PEOPLE)
1250*      TEDM=TRANSPORTATION EMPLOYMENT DESIRABILITY MULT.
1260*      COLA=CONSTRUCTION LABOR FORCE AVAILABLE (PEOPLE)
1270*      COEDM=CONSTRUCTION EMPLOYMENT DESIRABILITY MULT.
```

The labor force fraction is a measure of the fraction of the total population which is capable of employment. This fraction is formulated as the function of a community labor force fraction (CLFF) and a military labor reduction factor. The community labor force fraction is the normal ratio of workers to community population. This fraction is reduced by the fraction of the total population which comprises military members who do not seek community jobs (MLRF).

The remaining equations in this sector describe the number of workers seeking employment in the community business and services sectors. Each of the sets of two auxiliary equations is comprised of an equation which formulates the desirability multiplier for the sector. The labor available in each sector is the product of that sector's desirability multiplier and the total labor force available. The worker is considered to be perfectly competitive, as in the Base Population Sector, and, therefore, seeks employment in the same ratio as jobs are available in the community.

Total Community Jobs Sector

The level of community jobs available (CJA) is the sum of the previous level of available jobs and the net change in jobs available during the period (JCR). The job change rate is the sum of the job change rates of each of the business sectors, the services job change rate (SJCR) and the civilian mission change rate (CMCR). The civilian mission change rate is a measure of the number of civilian positions added or deleted at the military base during the

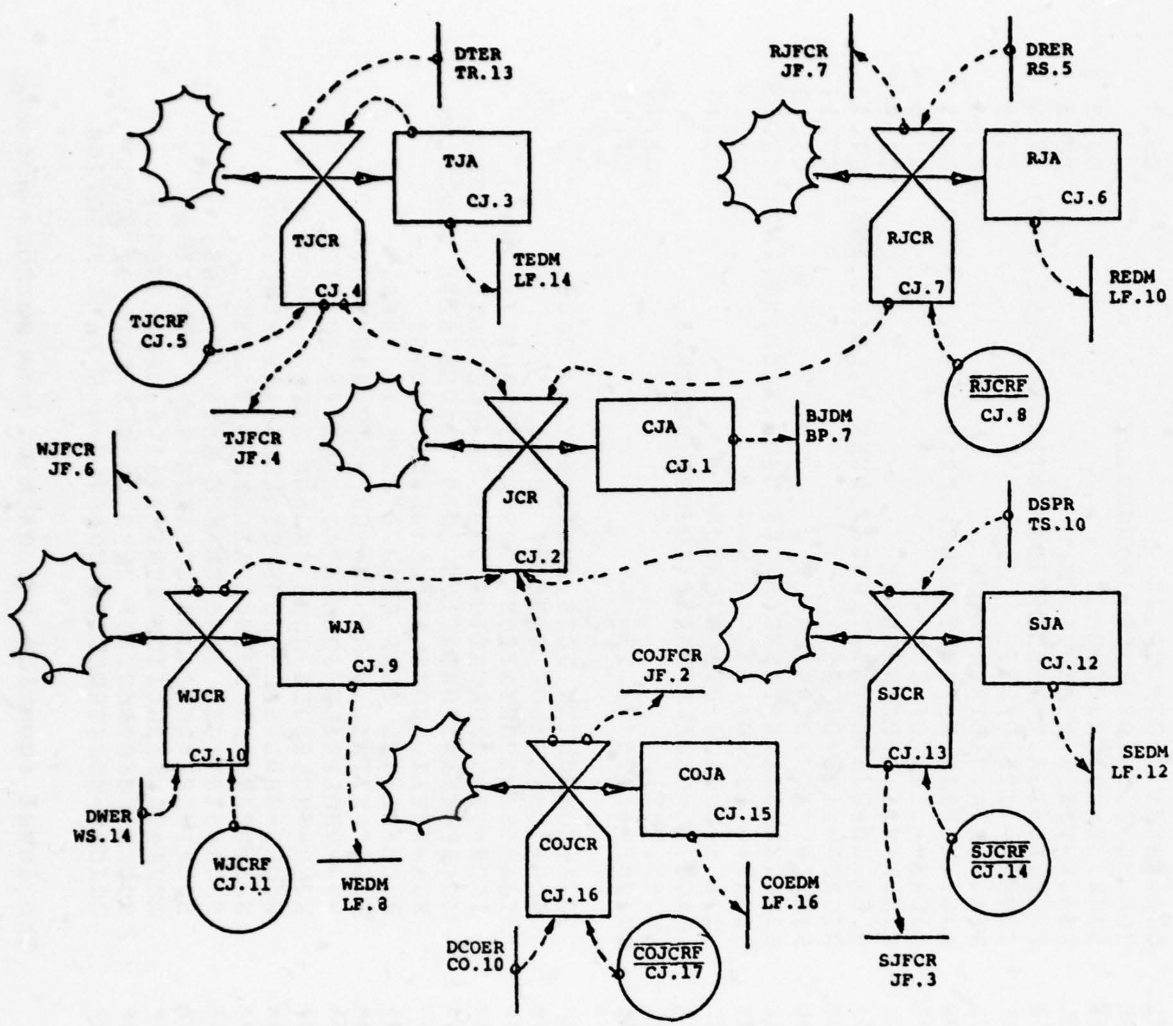

Figure 4-4. Total Community Jobs Sector

period due to a mission change. The job change rate for each of the other sectors involved are described by a level and a rate equation.

```
1360L    CJA.K=CJA.J+DT*JCR.JK                          CJ.1
1370R    JCR.KL=TJCR.JK+RJCR.JK+WJCR.JK+
1380X    SJCR.JK+COJCR.JK+CMCR                          CJ.2
1390L    TJA.K=TJA.J+DT*TJCR.JK                         CJ.3
1400R    TJCR.KL=TJA.K*TABXT(TJCRF,DTER.K,LO,HI,INT)    CJ.4
1410T    TJCRF=-.125/0/.25                              CJ.5
1420L    RJA.K=RJA.J+DT*RJCR.JK                         CJ.6
1430R    RJCR.KL=RJA.K*TABXT(RJCRF,DRER.K,LO,HI,INT)    CJ.7
1440T    RJCRF=-.125/0/.25                              CJ.8
1450L    WJA.K=WJA.J+DT*WJCR.JK                         CJ.9
1460R    WJCR.KL=WJA.K*TABXT(WJCRF,DWER.K,LO,HI,INT)    CJ.10
1470T    WJCRF=-.125/0/.25                              CJ.11
1480L    SJA.K=SJA.J+DT*SJCR.JK                         CJ.12
1490R    SJCR.KL=SJA.K*TABXT(SJCRF,DSPR.K,LO,HI,INT)    CJ.13
1500T    SJCRF=-.125/0/.25                              CJ.14
1510L    COJA.K=COJA.J+DT*COJCR.JK                      CJ.15
1520R    COJCR.KL=COJA.K*TABXT(COJCRF,DCOER.K,
1530X    LO,HI,INT)                                     CJ.16
1540T    COJCRF=-.125/0/.25                             CJ.17
1550*
1560*      CJA=COMMUNITY JOBS AVAILABLE (# JOBS)
1570*      JCR=JOB CHANGE RATE (# JOBS)
1580*      TJA=TRANSPORTATION JOBS AVAILABLE (# JOBS)
1590*      TJCR=TRANSPORTATION JOBS CHANGE RATE (# JOBS)
1600*      TJCRF=TRANSPORTATION JOBS CHANGE RATE FUNCTION
1610*      RJA=RETAIL JOBS AVAILABLE (# JOBS)
1620*      RJCR=RETAIL JOBS CHANGE RATE (# JOBS)
1630*      RJCRF=RETAIL JOBS CHANGE RATE FUNCTION
1640*      WJA=WHOLESALE JOBS AVAILABLE (# JOBS)
1650*      WJCR=WHOLESALE JOBS CHANGE RATE (# JOBS)
1660*      WJCRF=WHOLESALE JOBS CHANGE RATE FUNCTION
1670*      SJA=SERVICES JOBS AVAILABLE (# JOBS)
1680*      SJCR=SERVICES JOBS CHANGE RATE (# JOBS)
1690*      SJCRF=SERVICES JOBS CHANGE RATE FUNCTION
1700*      COJA=CONSTRUCTION JOBS AVAILABLE (# JOBS)
1710*      COJCR=CONSTRUCTION JOBS CHANGE RATE (# JOBS)
1720*      COJCRF=CONSTRUCTION JOBS CHANGE RATE FUNCTION
```

The level equation for each of the sectors accumulates the number of total jobs in the sector. This level of jobs is the sum of the previous level of jobs and the net change in the number of jobs during the period. The rate of change of jobs in any sector is the product of the level of jobs and the change in expense rate for the sector. The specific shapes of the job change rate function graphs is reserved for Chapter V.

The Total Community Jobs Sector describes the manner in which jobs are created, but does not address the filling of these positions. The Jobs Filled Sector is the catalyst which allows for information from the Labor Force Sector and the Total Community Jobs Sector to combine and describe how jobs are filled.

<u>Jobs Filled Sector</u>

```
1860L   CJF.K=CJF.J+DT*CJFCR.JK                        JF.1
1870R   CJFCR.KL=BCJCR.K+SJFCR.K+TJFCR.K+
1880X   COJFCR.K+WJFCR.K+RJFCR.K                       JF.2
1890A   SJFCR.K=MIN(SJCR.JK,SLA.K)                     JF.3
1900A   TJFCR.K=MIN(TJCR.JK,TLA.K)                     JF.4
1910A   COJFCR.K=MIN(COJCR.JK,COLA.K)                  JF.5
1920A   WJFCR.K=MIN(WJCR.JK,WLA.K)                     JF.6
1930A   RJFCR.K=MIN(RJCR.JK,RLA.K)                     JF.7
1940*
1950*     CJF=COMMUNITY JOBS FILLED (# JOBS)
1960*     CJFCR=COMMUNITY JOBS FILLED CHANGE RATE (# JOBS)
1970*     SJFCR=SERVICES JOBS FILLED CHANGE RATE (# JOBS)
1980*     TJFCR=TRANSPORTATION JOBS FILLED CHANGE RATE
1990*           (# JOBS)
2000*     COJFCR=CONSTRUCTION JOBS FILLED CHANGE RATE
2010*           (# JOBS)
2020*     WJFCR=WHOLESALE JOBS FILLED CHANGE RATE (# JOBS)
2030*     RJFCR=RETAIL JOBS FILLED CHANGE RATE (# JOBS)
```

The level of community jobs filled (CJF) is an accumulator of the number of occupied job positions in the community. The level of jobs is the sum of the previous

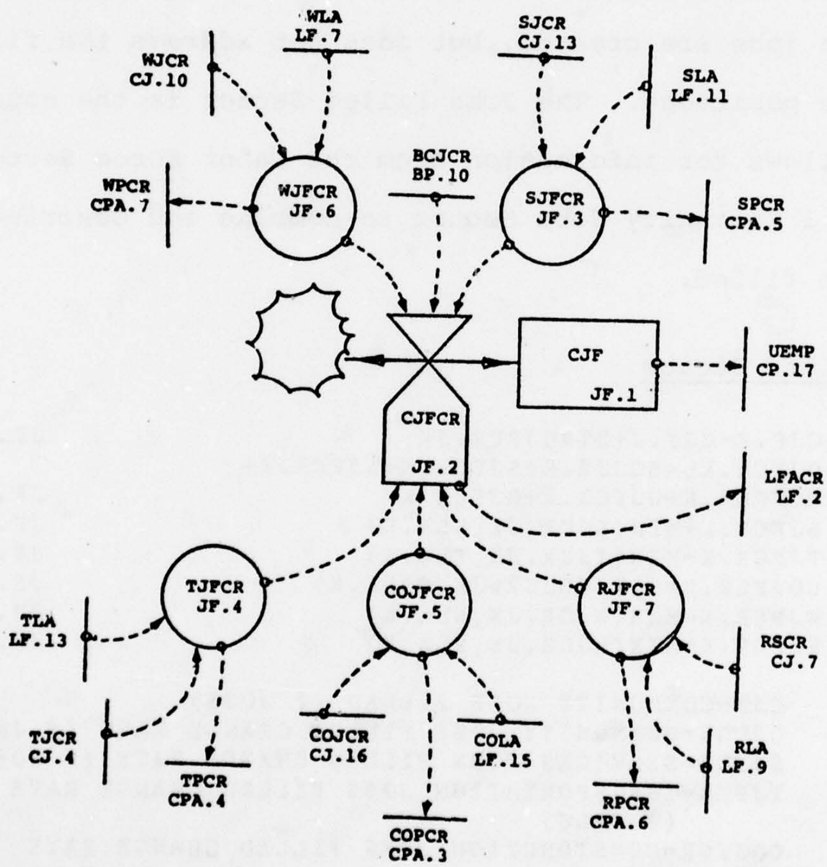

Figure 4-5. Jobs Filled Sector

level of filled positions and the net change in occupied jobs during the period, community jobs filled change rate (CJFCR). CJFCR is the sum of the net changes in the number of occupied positions in each of the business sectors, the Taxes/Services Sector, and the civilian portion of the Base Population Sector. The jobs filled change rate in each sector is derived by a comparison of the job change rate in the sector and people willing to take jobs in that sector; labor available. The resultant rate is the minimum of the two values.

The first five sectors of the base-community model deal primarily with people and their jobs. In order to provide a closed loop system these jobs must be transformed into economic terms. This transformation is accomplished in the Community Payroll Sector.

Community Payroll Sector

Total community payroll (TCP) accumulates salaries and wages paid to individuals for their labor. This level of money is the amount of money paid to individuals per month and is the sum of the level of payroll prior to the previous period and the net change in salaries and wages during the period (PCR). The payroll change rate is the sum of the net changes in payroll in each of the business sectors, the Taxes/Services Sector, and the Base Population Sector. Each of these net changes in payroll is the

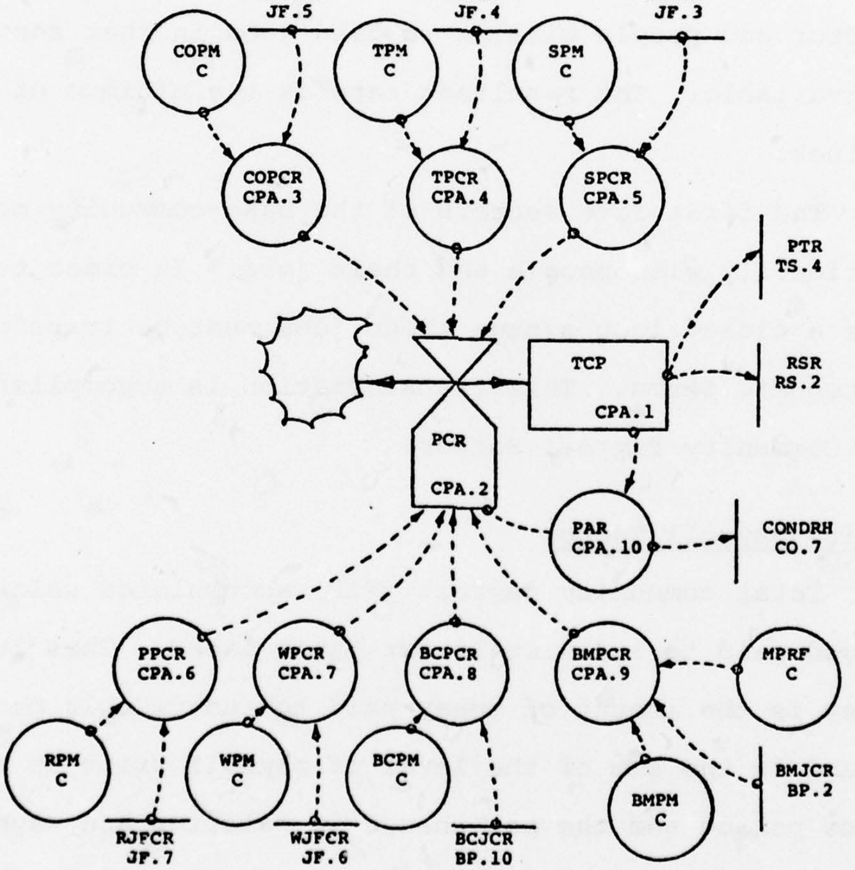

Figure 4-6. Community Payroll Sector

product of the jobs filled change rate in that sector and a payroll multiplier (average monthly salary). The base military payroll change rate (BMPCR) is slightly different from the other payroll change rates. A military pay reduction factor (MPRF) is employed to reduce the effect of this money upon the local community. This reduction is necessary because of base exchange and commissary privileges available to military members.

```
2090L   TCP.K=TCP.J+DT*PCR.JK                              CPA.1
2100R   PCR.KL=COPCR.K+TPCR.K+SPCR.K+RPCR.K+
2110X   WPCR.K+BCPCR.K+BMPCR.K                             CPA.2
2120A   COPCR.K=COPM*COJFCR.K                              CPA.3
2130A   TPCR.K=TPM*TJFCR.K                                 CPA.4
2140A   SPCR.K=SPM*SJFCR.K                                 CPA.5
2150A   RPCR.K=RPM*RJFCR.K                                 CPA.6
2160A   WPCR.K=WPM*WJFCR.K                                 CPA.7
2170A   BCPCR.K=BCPM*BCJCR.K                               CPA.8
2180A   BMPCR.K=BMPM*BMJCR.JK*MPRF                         CPA.9
2190A   PAR.K=TCP.K/NCP                                   CPA.10
2200*
2210*     TCP=TOTAL COMMUNITY PAYROLL (DOLLARS)
2220*     PCR=PAYROLL CHANGE RATE (DOLLARS)
2230*     COPCR=CONSTRUCTION PAYROLL CHANGE RATE (DOLLARS)
2240*     COPM=CONSTRUCTION PAY MULTIPLIER
2250*     TPCR=TRANSPORTATION PAYROLL CHANGE RATE (DOLLARS)
2260*     TPM=TRANSPORTATION PAY MULTIPLIER
2270*     SPCR=SERVICES PAYROLL CHANGE RATE (DOLLARS)
2280*     SPM=SERVICES PAY MULTIPLIER
2290*     RPCR=RETAIL PAYROLL CHANGE RATE (DOLLARS)
2300*     RPM=RETAIL PAY MULTIPLIER
2310*     WPCR=WHOLESALE PAYROLL CHANGE RATE (DOLLARS)
2320*     WPM=WHOLESALE PAY MULTIPLIER
2330*     BCPCR=BASE CIVILIAN PAYROLL CHANGE RATE (DOLLARS)
2340*     BCPM=BASE CIVILIAN PAY MULTIPLIER
2350*     BMPCR=BASE MILITARY PAYROLL MULTIPLIER (DOLLARS)
2360*     BMPM=BASE MILITARY PAY MULTIPLIER
2370*     MPRF=MILITARY PAY REDUCTION FACTOR
2380*     NCP=NORMAL COMMUNITY PAYROLL
```

The final equation in the Community Payroll Sector is a relative measure of the current level of payroll to a normal community payroll (NCP). This payroll activity rate (PAR) is used as input information for the Construction Sector, and will be further discussed in the description of that sector.

The total community payroll is a direct input to the Retail Sales Sector. This direct link to the business sectors suggests that the Retail Sales Sector is a natural starting point for discussion of the business sectors.

<u>Retail Sales Sector</u>

```
2530L   RRL.K=RRL.J+DT*(RSR.JK-RER.JK)                    RS.1
2540R   RSR.KL=TCP.K*RPRM+BRPR.K                          RS.2
2550A   BRPR.K=BB*RPMF                                    RS.3
2560R   RER.KL=RER.JK*(1+DRER.K)                          RS.4
2570A   DRER.K=TABHL(DRERF,RPR.K,-.25,.25,.1)             RS.5
2580T   DRERF=-.083/-.075/0/0/.15/.275                    RS.6
2590A   RPR.K=(RSR.JK-RER.JK)/RER.JK                      RS.7
2600*
2610*     RRL=RETAIL REVENUE LEVEL (DOLLARS)
2620*     RSR=RETAIL SALES RATE (DOLLARS)
2630*     BRPR=BASE RETAIL PROCUREMENT RATE (DOLLARS)
2640*     BB=BASE BUDGET
2650*     RPRM=RETAIL PROPORTION MULTIPLIER
2660*     RPMF=RETAIL PROCUREMENT MILITARY FRACTION
2670*     RER=RETAIL EXPENSE RATE (DOLLARS)
2680*     DRER=DELTA RETAIL EXPENSE RATE
2690*     DRERF=DELTA RETAIL EXPENSE RATE FUNCTION
2700*     RPR=RETAIL PROFIT RATE
```

The retail revenue level (RRL) can be considered as an accumulator of profits. Information from this level is not used elsewhere in the model. The major components of this sector are the Retail Sales Rate (RSR) and the Retail Expense Rate (RER). The retail sales rate is the sum

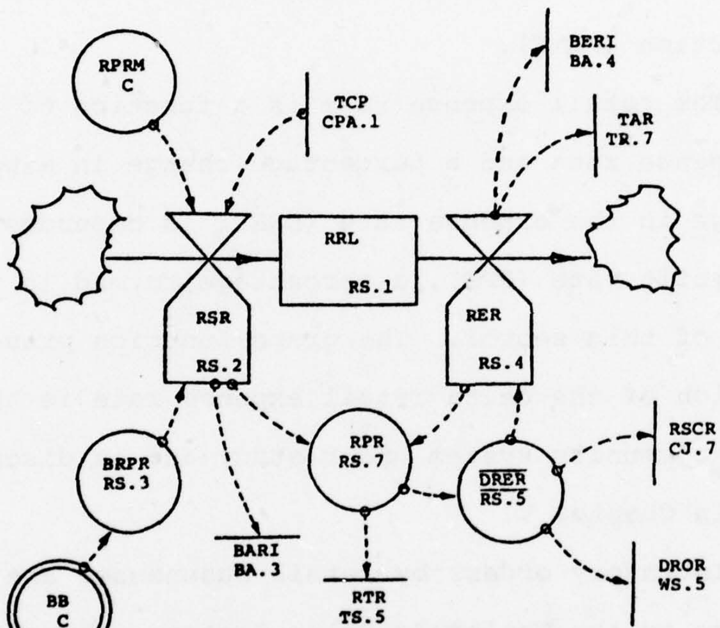

Figure 4-7. Retail Sales Sector

of the product of the total community payroll and a retail proportion multiplier (RPRM), and the base retail procurement rate (BRPR). The retail proportion multiplier is a measure of the ratio of retail sales to total community payroll. The base retail procurement rate is the amount of money spent for the purchase of retail goods by the base and is the product of the base budget (BB) and a retail procurement fraction (RPMF).

The retail expense rate is a function of the previous expense rate and a percentage change in expense rate. The change in the expense rate (DRER) is dependent upon the retail profit rate (RPR), a percentage formed in the final equation of this sector. The graph function presented in formulation of the delta retail expense rate is specific to the base-community system under study and is discussed further in Chapter V.

Inventory orders by retail busunesses are the primary inputs to the Wholesale Sales Sector. Therefore, the Wholesale Sales Sector is the next to be presented.

Wholesale Sales Sector

The first level in the Wholesale Sales Sector is an Inventory Order Level (IOL). This level of money is the value of orders placed but not yet delivered. The level of orders is the sum of the previous inventory order level and the value of orders placed during the period, inventory

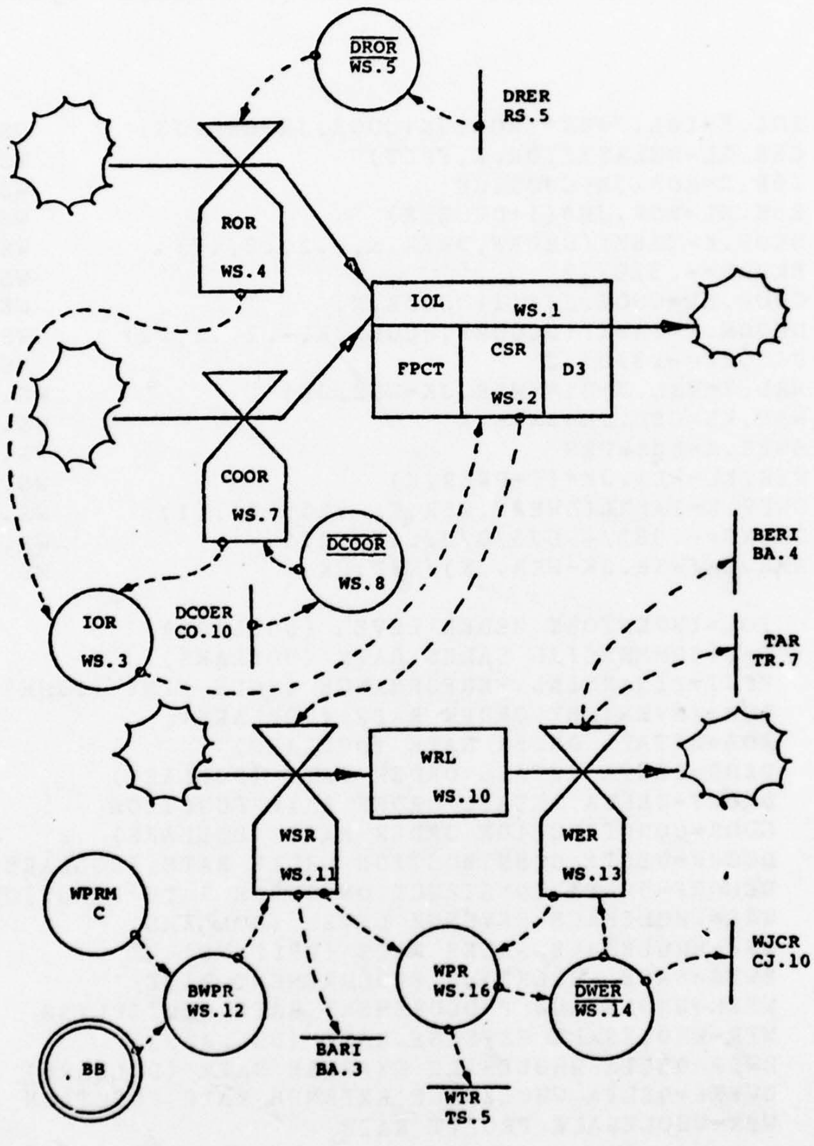

Figure 4-8. Wholesale Sales Sector

order rate (IOR), less the value of orders delivered, commercial sales rate (CSR). The commercial sales rate is a function of the inventory order rate based on an average delivery and payment time, financial performance cycle time (FPCT).

```
2800L    IOL.K=IOL.J+DT*(ROR.JK+COOR.JK-CSR.JK)         WS.1
2810R    CSR.KL=DELAY3(IOR.K,FPCT)                      WS.2
2820A    IOR.K=ROR.JK+COOR.JK                           WS.3
2830R    ROR.KL=ROR.JK*(1+DROR.K)                       WS.4
2840A    DROR.K=TABXT(DRORF,DRER.K,-.2,.2,.2)           WS.5
2850T    DRORF=-.3/0/.2                                 WS.6
2860R    COOR.KL=COOR.JK*(1+DCOOR.K)                    WS.7
2870A    DCOOR.K=TABXT(DCOORF,DCOER.K,-.2,.2,.2)        WS.8
2880T    DCOORF=-.3/0/.2                                WS.9
2890L    WRL.K=WRL.J+DT*(WSR.JK-WER.JK)                WS.10
2900R    WSR.KL=CSR.JK+BWPR.K                          WS.11
2910A    BWPR.K=BB*WPRM                                WS.12
2920R    WER.KL=WER.JK*(1+DWER.K)                      WS.13
2930A    DWER.K=TABHL(DWERF,WPR.K,-.25,.25,.1)         WS.14
2940T    DWERF=-.083/-.075/0/0/.15/.275                WS.15
2950A    WPR.K=(WSR.JK-WER.JK)/WER.JK                  WS.16
2960*
2970*      IOL=INVENTORY ORDER LEVEL (DOLLARS)
2980*      CSR=COMMERCIAL SALES RATE (DOLLARS)
2990*      FPCT=FINANCIAL PERFORMANCE CYCLE TIME (TIME)
3000*      IOR=INVENTORY ORDER RATE (DOLLARS)
3010*      ROR=RETAIL ORDER RATE (DOLLARS)
3020*      DROR=DELTA RETAIL ORDER RATE (DOLLARS)
3030*      DRORF=DELTA RETAIL ORDER RATE FUNCTION
3040*      COOR=CONSTRUCTION ORDER RATE (DOLLARS)
3050*      DCOOR=DELTA CONSTRUCTION ORDER RATE (DOLLARS)
3060*      DCOORF=DELTA CONSTRUCTION ORDER RATE FUNCTION
3070*      WRL=WHOLESALE REVENUE LEVEL (DOLLARS)
3080*      WSR=WHOLESALE SALES RATE (DOLLARS)
3090*      BWPR=BASE WHOLESALE PROCUREMENT RATE
3100*      WPRM=WHOLESALE PROCUREMENT RATE MULTIPLIER
3110*      WER=WHOLESALE EXPENSE RATE (DOLLARS)
3120*      DWER=DELTA WHOLESALE EXPENSE RATE (DOLLARS)
3130*      DWERF=DELTA WHOLESALE EXPENSE RATE FUNCTION
3140*      WPR=WHOLESALE PROFIT RATE
```

The inventory order rate is the sum of the order rates from retail sales (ROR) and construction (COOR). The order rates exhibited by the Retail Sales and Construction Sectors are functions of the previous order rates and the percentage change in order rates during the period (DROR and DCOOR). The changes in order rates, in turn, are dependent upon changes in expense rates encountered in the Retail Sales and Construction Sectors (DRER and DCOER).

The remaining equations in the Wholesale Sales Sector describe the financial activity of the sector in a similar manner to that described for the Retail Sales Sector. The wholesale revenue level is a profit accumulator and is not used as input information in any other sector. This level of money is the sum of the previous level and the sales during the period less expenses incurred during the period. The wholesale sales rate (WSR) is the sum of the commercial sales rate (CSR) and the base wholesale procurement rate (BWPR), an exogenous injection of money into the local economy from DOD activity at the military installation. BWPR is formulated as a portion of the total base budget (BB), using a multiplication of the base budget by the wholesale procurement rate multiplier (WPRM).

The wholesale expense rate (WER) is a function of the previous expense rate and the percentage change in expenses during the period (DWER). The change in wholesale expense rate is dependent upon the wholesale profit rate (WPR). WPR is expressed as a percentage of the expense rate and is formulated in the last equation of the sector.

The Construction Sales Sector provides the second primary input to the Wholesale Sales Sector. This input is the rate at which supplies and materials are ordered through local wholesale outlets. The Construction Sector is discussed in the next section.

Construction Sector

```
3260L    VEF.K=VEF.J+DT*(COSR.JK-FDR.JK)                    CO.1
3270R    FDR.KL=DELAY3(COSR.JK,FDP)                         CO.2
3280R    COSR.KL=CONDB.K+CONDH.K                            CO.3
3290A    CONDB.K=DELAY3(CONDRB.K,COBD)                      CO.4
3300A    CONDRB.K=BERI.K*CONDBN                             CO.5
3310A    CONDH.K=DELAY3(CONDRH.K,COHD)                      CO.6
3320A    CONDRH.K=PAR.K*CONDHN                              CO.7
3330L    COR.K=COR.J+DT*(COSR.JK-COER.JK)                   CO.8
3340R    COER.KL=COER.JK*(1+DCOER.K)                        CO.9
3350A    DCOER.K=TABHL(DCOERF,COPR.K,-.25,.25,.1)          CO.10
3360T    DCOERF=-.083/-.075/0/0/.15/.275                   CO.11
3370A    COPR.K=(COSR.JK-COER.JK)/COER.JK                  CO.12
3380*
3390*      VEF=VALUE OF EXISTING FACILITIES (DOLLARS)
3400*      FDR=FACILITIES DEVALUATION RATE (DOLLARS)
3410*      FDP=FACILITIES DEVALUATION PERIOD (TIME)
3420*      COSR=CONSTRUCTION SALES RATE (DOLLARS)
3430*      CONDB=CONSTRUCTION DEMAND BY BUSINESS (DOLLARS)
3440*      CONDRB=CONSTRUCTION DEMAND RATE BY BUSINESS
3450*             (DOLLARS)
3460*      CONDBN=NORMAL CONSTRUCTION DEMAND RATE
3470*             BY BUSINESS (DOLLARS)
3480*      COBD=BUSINESS CONSTRUCTION DELAY (TIME)
3490*      CONDH=CONSTRUCTION DEMAND FOR HOUSING (DOLLARS)
3500*      CONDRH=CONSTRUCTION DEMAND RATE FOR HOUSING
3510*             (DOLLARS)
3520*      CONDHN=NORMAL CONSTRUCTION DEMAND RATE FOR
3530*                 HOUSING (DOLLARS)
3540*      COHD=HOUSING CONSTRUCTION DELAY (TIME)
3550*      COR=CONSTRUCTION REVENUE (DOLLARS)
3560*      COER=CONSTRUCTION EXPENSE RATE (DOLLARS)
3570*      DCOER=DELTA CONSTRUCTION EXPENSE RATE
3580*      DCOERF=DELTA CONSTRUCTION EXPENSE RATE FUNCTION
3590*      COPR=CONSTRUCTION PROFIT RATE
```

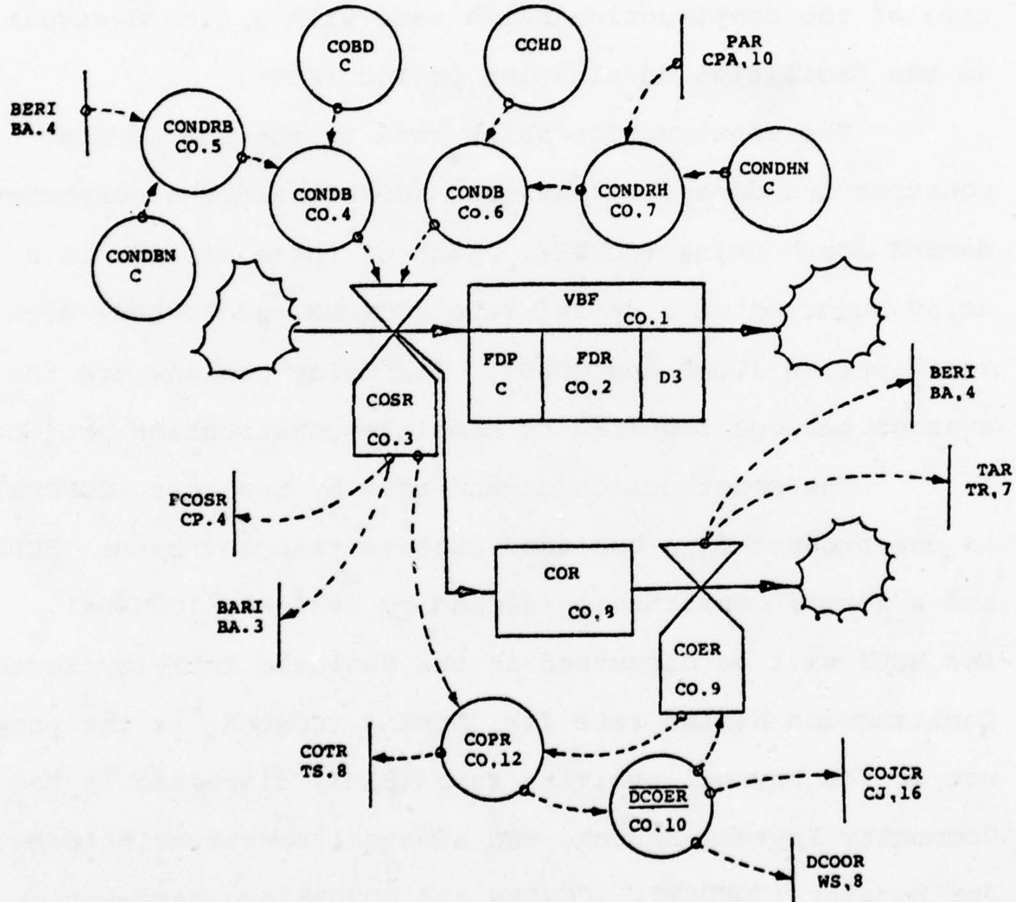

Figure 4-9. Construction Sector

The initial level equation in the Construction Sector concerns the value of existing facilities (VEF). This level of money is the sum of the previous VEF and the construction sales rate (COSR) during the previous period minus the facilities devaluation rate (FDR) during the period. The facilities devaluation rate is a delay function of the construction sales rate with a time designated as the facilities devaluation period (FDP).

The construction sales rate is the sum of the construction demand by business (CONDB) and the construction demand for housing (CONDH). Each of these demands is a delay function of a demand rate (CONDRB and CONDRH) with a delay period (COBD and COBH). The delay periods are the average periods required to complete construction projects.

The construction demand rate by business (CONDRB) is the product of a business expense rate indicator (BERI) and a normal construction demand by business (CONDBN). The BERI will be discussed in the Business Activity Sector. Construction demand rate for housing (CONDRH) is the product of the payroll activity rate (PAR), discussed in the Community Payroll Sector, and a normal construction demand for housing (CONDHN). CONDBN and CONDBH are parametric inputs to the model.

Construction revenue (COR) is the profit accumulator for the Construction Sector. COR is the sum of the previous level of money and the construction sales rate (COSR) during the period less the construction expense rate (COER) during the period. COER is the rate at which the construction industry expends its money for resources. The current expense rate is a function of the previous expense rate and the percentage change in expenses (DCOER). The change in construction expense rate is dependent upon the percentage of profits (COPR) as formulated in the last equation of the sector. The last of four business sectors is the Transportation Sector. Inputs to the sector have origins in each of the first three business sectors and the Community Population Sector.

Transportation Sector

The profit accumulator for the Transportation Sector is Transportation Revenue (TR). As with the previous business sectors, this level of money is the sum of the previous level and the sales rate (TSR) minus the expense rate (TER). The transportation sales rate is the sum of three sales segments, passenger transportation (PTS), general cargo (GCS), and household goods (HHGS).

The passenger transportation segment is the product of the passenger transportation multiplier (PTM), a measure of per capita transportation expenditure, the community population, and a military passenger procurement multiplier (MPPM). The MPPM is determined by specific investigation of the difference in travel pattern from the travel habits of the civilian population. The independent variable in the

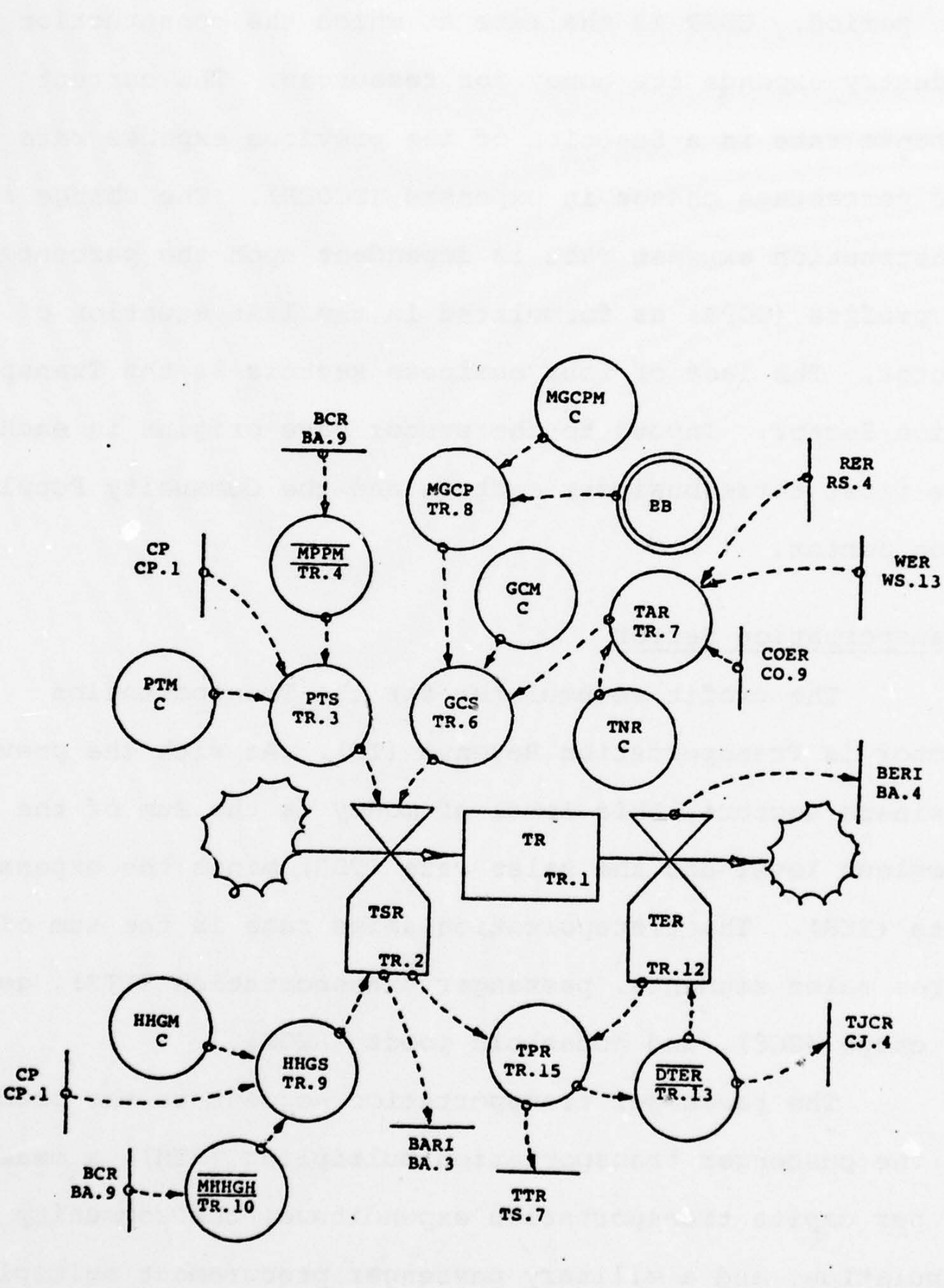

Figure 4-10. Transportation Sector

determination of MPPM is the Base/Community Ratio (BCR) and will be discussed in the Business Activity Sector.

```
3760L   TR.K=TR.J+DT*(TSR.JK-TER.JK)                      TR.1
3770R   TSR.KL=PTS.K+GCS.K+HHGS.K                         TR.2
3780A   PTS.K=PTM*CP.K*MPPM                               TR.3
3790A   MPPM.K=TABHL(MPPMF,BCR.K,0,1,.5)                  TR.4
3800T   MPPMF=1/1.1/1.2                                   TR.5
3810A   GCS.K=GCM*TAR.K+MGCP                              TR.6
3820A   TAR.K=(RER.JK+WER.JK+COER.JK)/TNR                 TR.7
3830A   MGCP.K=MGCPM*BB                                   TR.8
3840A   HHGS.K=HHGM*CP.K*MHHGM                            TR.9
3850A   MHHGM.K=TABHL(MHHGMF,BCR.K,0,1,.5)               TR.10
3860T   MHHGMF=1/1.5/2                                   TR.11
3870R   TER.KL=TER.JK*(1+DTER.K)                         TR.12
3880A   DTER.K=TABHL(DTERF,TPR.K,-.25,.25,.1)            TR.13
3890T   DTERF=-.083/-.075/0/0/.15/.275                   TR.14
3900A   TPR.K=(TSR.JK-TER.JK)/TER.JK                     TR.15
3910*
3920*     TR=TRANSPORTATION REVENUE (DOLLARS)
3930*     TSR=TRANSPORTATION SALES RATE (DOLLARS)
3940*     PTS=PASSANGER TRANSPORTATION SEGMENT
3950*     PTM=PASSANGER TRANSPORTATION MULTIPLIER
3960*     MPPM=MILITARY PASSENGER PROCUREMENT MULTIPLIER
3970*     MPPMF=MILITARY PASSENGER PROCUREMENT MULTIPLIER
3980*           FUNCTION
3990*     GCS=GENERAL CARGO SEGMENT
4000*     GCM=GENERAL CARGO MULTIPLIER
4010*     TAR=TRANSPORTATION ACTIVITY RATE
4020*     TNR=TRANSPORTATION NORMAL RATE
4030*     MGCP=MILITARY GENERAL CARGO PROCUREMENT
4040*     MGCPM=MILITARY GENERAL CARGO PROCUREMENT
4050*           MULTIPLIER
4060*     HHGS=HOUSEHOLD GOODS SEGMENT
4070*     HHGM=HOUSEHOLD GOODS MULTIPLIER
4080*     MHHGM=MILITARY HOUSEHOLD GOODS MULTIPLIER
4090*     MHHGMF=MILITARY HOUSEHOLD GOODS MULTIPLIER
4100*            FUNCTION
4110*     TER=TRANSPORTATION EXPENSE RATE (DOLLARS)
4120*     DTER=DELTA TRANSPORTATION EXPENSE RATE
4130*     DTERF=DELTA TRANSPORTATION EXPENSE RATE FUNCTION
4140*     TPR=TRANSPORTATION PROFIT RATE (DOLLARS)
```

The general cargo segment is dependent upon the transportation activity rate (TAR), a relative measure of business expense rates in comparison to a normal expense rate (TNR), and a constant, General Cargo Multiplier (GCM), which is the money expended for this type of transportation by businesses under normal conditions. In addition, military general cargo procurement (MGCP) is a direct input to the GCS and is a proportionate share of the base budget, determined by the military general cargo procurement multiplier (MGCPR).

The household goods segment (HHGS) is determined in the same manner as the passenger segment. HHGS is the product of a per capita household goods multiplier (HHGM), the community population, and a military household goods multiplier (MHHGM) which is dependent upon the base/community ratio.

The remaining equations of the Transportation Sector describe the financial activity within the sector with respect to expenses and profits. These rates (TER and TPR) are formulated with relationships identical to the expense and profit relationships in the previous business sectors.

The financial health of the base-community system is an aggregate of the states of health of each of the business sectors. This financial health is presented in the Business Activity Sector.

Business Activity Sector

The business activity level (BAL) is used to absorb

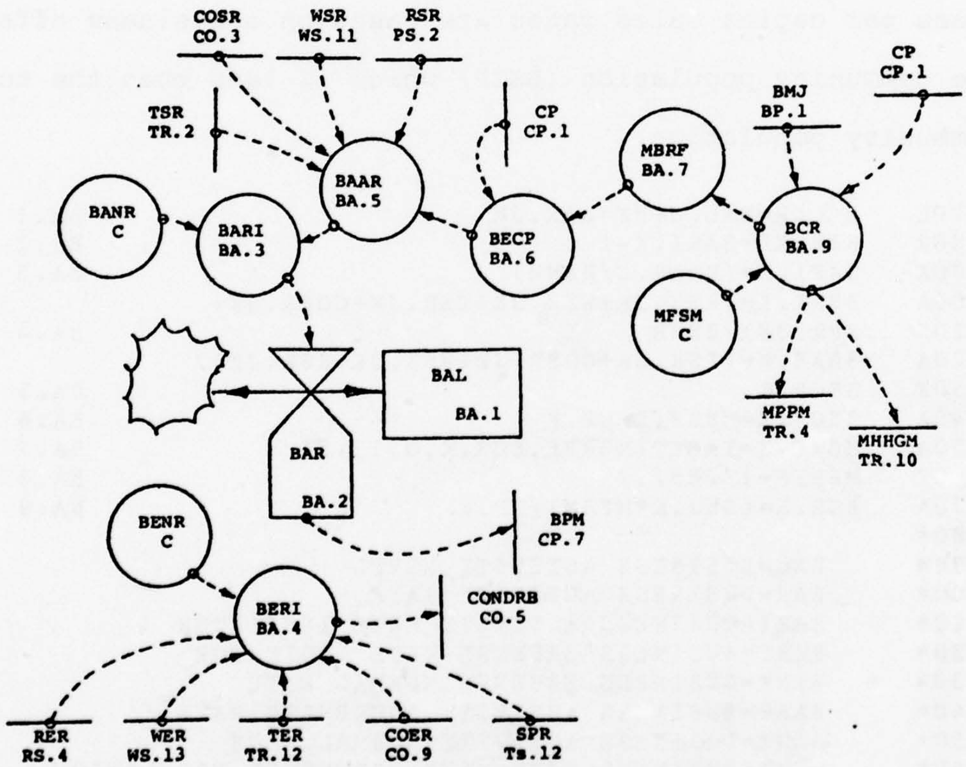

Figure 4-11. Business Activity Sector

the values exhibited by the business activity rate (BAR) and possesses no informational value within the model. The business activity rate is a relative measure of the health of sales in the four business sectors and is dependent upon the business activity rate indicator (BARI). The BARI is a ratio relationship of the total per capita sales in the community (BAAR) to a normal per capita sales rate (BANR). These per capita sales rates are based on a business effective community population (BECP) which is less than the total community population.

```
4270L    BAL.K=BAL.J+DT*BAR.JK                               BA.1
4280R    BAR.KL=BARI.K-1                                     BA.2
4290A    BARI.K=(BAAR.K/BANR)                                BA.3
4300A    BERI.K=(RER.JK+WER.JK+TER.JK+COER.JK+
4310X    SPR.JK)/BENR                                        BA.4
4320A    BAAR.K=(TSR.JK+COSR.JK+WSR.JK+RSR.JK)/
4330X    BECP.K                                              BA.5
4340A    BECP.K=MBRF.K*CP.K                                  BA.6
4350A    MBRF.K=TABXT(MBRFF,BCR.K,0,1,.5)                    BA.7
4360T    MBRFF=1/.85/.7                                      BA.8
4370A    BCR.K=(BMJ.K*MFSM)/CP.K                             BA.9
4380*
4390*      BAL=BUSINESS ACTIVITY LEVEL
4400*      BAR=BUSINESS ACTIVITY RATE
4410*      BARI=BUSINESS ACTIVITY RATE INDICATOR
4420*      BERI=BUSINESS EXPENSE RATE INDICATOR
4430*      BENR=BUSINESS EXPENSE NORMAL RATE
4440*      BAAR=BUSINESS ACTIVITY AGGREGATE RATE
4450*      BANR=BUSINESS ACTIVITY NORMAL RATE
4460*      BECP=BUSINESS EFFECTIVE COMMUNITY POPULATION
4470*      MBRF=MILITARY BUSINESS REDUCTION FACTOR
4480*      MBRFF=MILITARY BUSINESS REDUCTION FACTOR FUNCTION
4490*      BCR=BASE/COMMUNITY RATIO
```

The BECP is determined by the product of the community population and a military business reduction factor (MBRF) which is dependent on the ratio of military members and their dependents to the total community population (BCR). Business effective community population is used in order to recognize the fact that many of the buying needs of military families are met outside the local community.

The business expense rate indicator (BERI) is an input to the Construction Sector, but is formulated here because it, too, is a relative measure of the expenditure rates of the four business sectors and the Taxes/Services Sector to a business expense normal rate (BENR).

The last of the base-community model sectors is the Taxes/Services Sector. This sector absorbs information from many of the other sectors. The Taxes/Services Sector describes the collection of taxes and subsidies and dispersal of these funds through provision of governmental services.

Taxes/Services Sector

The community tax fund (CTF) accumulates tax dollars collected but not yet spent. This level of money is the sum of the previous level and the aggregate tax rate (ATR) less the services provision rate (SPR), a measure of dispersals made by the local government during the period. The aggregate tax rate is the sum of taxes collected from assessments (ATRA) and the government matching fund rate (GMFR), a sum contributed by state and Federal agencies. The aggregate tax rate for assessments is the sum of monies collected

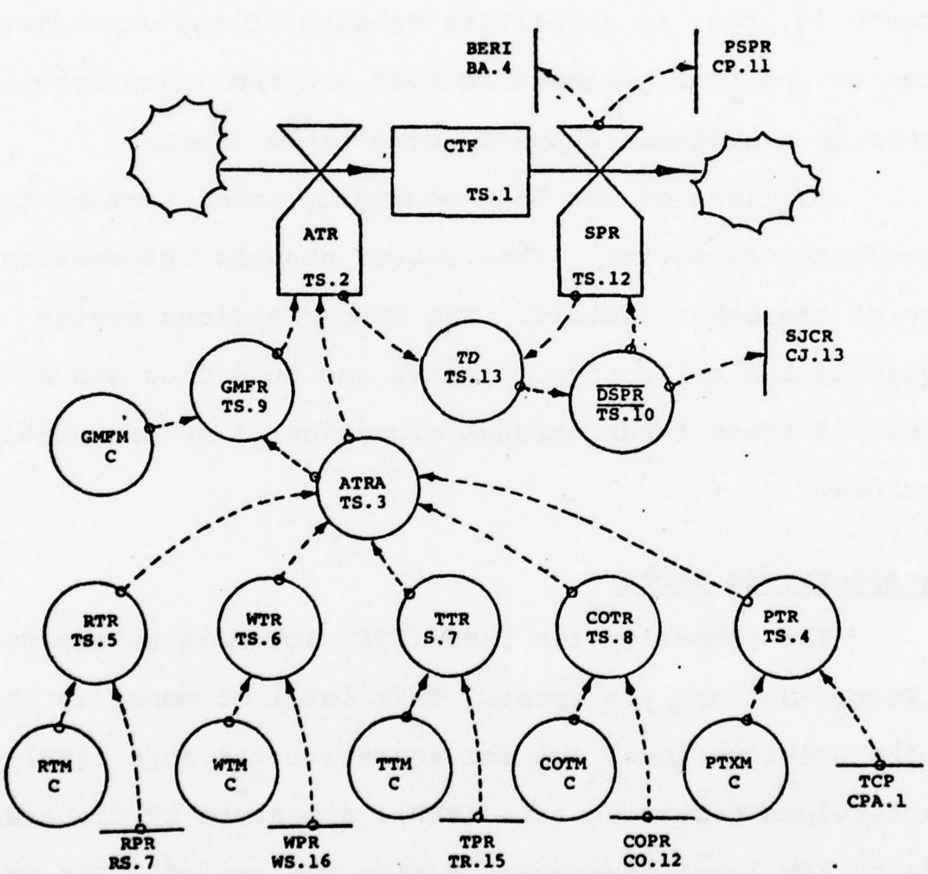

Figure 4-12. Taxes/Services Sector

through personal taxes and taxes on the profits of each of the four business sectors.

```
4570L   CTF.K=CTF.J+DT*(ATR.JK-SPR.JK)                  TS.1
4580R   ATR.KL=ATRA.K+GMFR.K                            TS.2
4590A   ATRA.K=PTR.K+RTR.K+WTR.K+TTR.K+COTR.K           TS.3
4600A   PTR.K=PTXM*TCP.K                                TS.4
4610A   RTR.K=(RSR.JK-RER.JK)*RTM                       TS.5
4620A   WTR.K=(WSR.JK-WER.JK)*WTM                       TS.6
4630A   TTR.K=(TSR.JK-TER.JK)*TTM                       TS.7
4640A   COTR.K=(COSR.JK-COER.JK)*COTM                   TS.8
4650A   GMFR.K=GMFM*(PTR.K+RTR.K+WTR.K+
4660X   TTR.K+COTR.K)                                   TS.9
4670A   DSPR.K=TABHL(DSPRM,TD.K,-1,1,.5)                TS.10
4680T   DSPRM=-.375/-.125/0/.5/1                        TS.11
4690R   SPR.KL=SPR.JK*(1+DSPR.K)                        TS.12
4700A   TD.K=(ATR.JK-SPR.JK)/SPR.JK                     TS.13
4710*
4720*      CTF=COMMUNITY TAX FUND (DOLLARS)
4730*      ATR=AGGREGATE TAX RATE (DOLLARS)
4740*      ATRA=AGGREGATE TAX RATE ASSESSMENTS
4750*      PTR=PERSONAL TAX RATE (DOLLARS)
4760*      PTXM=PERSONAL TAX MULTIPLIER
4770*      RTR=RETAIL TAX RATE (DOLLARS)
4780*      RTM=RETAIL TAX MULTIPLIER
4790*      WTR=WHOLESALE TAX RATE (DOLLARS)
4800*      WTM=WHOLESALE TAX MULTIPLIER
4810*      TTR=TRANSPORTATION TAX RATE (DOLLARS)
4820*      TTM=TRANSPORTATION TAX MULTIPLIER
4830*      COTR=CONSTRUCTION TAX RATE (DOLLARS)
4840*      COTM=CONSTRUCTION TAX MULTIPLIER
4850*      GMFR=GOVERNMENT MATCHING FUND RATE (DOLLARS)
4860*      GMFM=GOVERNMENT MATCHING FUND MULTIPLIER
4870*      SPR=SERVICES PROVISION RATE (DOLLARS)
4880*      DSPR=DELTA SERVICES PROVISION RATE
4890*      DSPRM=DELTA SERVICES PROVISION RATE
4900*            MULTIPLIER
4910*      TD=TAX DIFFERENTIAL
```

The personal tax rate (PTR) is determined by applying a taxation multiplier (PTXM) to the total community payroll. The tax rate for each of the business sectors is the result of applying a taxation multiplier to the sector's profit (sales minus expenses). The government matching fund rate is the product of a government matching fund multiplier (GMFM) and the aggregate tax rate from assessments.

The services provision rate (SPR) is dependent on the tax differential (TD) and is determined by a relationship similar to the relationships used to determine expense rates in the business sectors. The tax differential is a percentage value relative to the service provision rate.

The mathematical structure of the base-community model was developed in this chapter. In order to operate the model, in reference to a particular base-community system, specific investigation of that system is required to provide parametric information. Chapter V discusses the areas of investigation which are required and possible data sources.

Chapter V

MODEL VALIDATION

Since validation has been described as the process of establishing confidence in a model (4), this chapter deals with gathering information to build confidence in the model and its ability to provide predictive aids to decisions concerning base mission changes. Specifically, the chapter poses and answers five questions relative to validation, performance and analysis (5:182). Two types of validation are relevant to this model. First, internal validation concerns whether or not the model conforms to the intent of the designers; if the model is what its developers wanted it to be. Second, external validation concerns the ability of the model to replicate the system it represents. It tests whether or not the design was correct. External validation is covered in the final chapter. The subject of this chapter, in answering the five questions, is internal validation. The first question deals with the boundaries imposed upon the model.

System Boundaries

Validation of the model began with the question: "Is the system boundary correct?" Throughout the investigation of base-community relationships, the assumption of subsystem and macro-system interactivity as presented in Chapter II was found to be justified by historical information. The base-community system is open in the economic environment through political influence from the community and through money influences from national policy decisions. The economic boundaries established for the model represent a wide range of aggregation and dissemination of information and resources. Once the information or resources cross into the base-community system, however, the system is free to act upon and with the resources through decisions internal to the system. By the definitions established in Chapter I, the system has control over activity within its boundaries once the environmental inputs have been established. From this reasoning it was concluded that system boundaries were properly conceptualized and were correct for this model. The second question then dealt with the reasonableness of the model.

Model Reasonableness

This question is simply, "Are there any gross errors in the model?" "Gross errors" means including relationships in the model which simply do no exist in reality. To answer this question, the conceptual basis for the model (the causal loops) were submitted to comparison with actual economic relationships. The research upon which the model was based, as presented in Chapter III, coupled with this additional review, revealed no gross errors. Each of the relationships and causal activities within the model did in fact conform to economic activity in the actual system's economic environment. The natural follow-on to this question was to determine the appropriateness of the model's structure.

Model Correspondence

The question here deals with the physical aspects of the conceptualized model: "Is there correspondence between the model structure and the system?" As conceptualized the model includes two primary components, the base and the community, and twelve sectors of interactivity as identified in Chapter III. To answer this question it was necessary to recall early portions of the research to determine why the sectors were so selected and why they were either expanded or limited to twelve. The answers lay, again, in the basic conceptualization of the system. The model deals with the economic interactivity between a base and a community with the accompanying indfuence across system boundaries. It must, therefore, be assumed that the two-component structure of the model is correct at least for this research. The twelve sector structure of the model corresponds to and reflects real system activity. Within both components of the system there exist two essential characteristics of economic activity, money and people. The people on base and the people within the community combine to form a third characteristic which provides a translation from people to money; labor. On the money side, dollar activity from wholesale and retail sales in conjunction with physical activities in transportation and construction combine to form an aggregate dollar flow called business activity. Business activity in dollars combines with manpower to form jobs filled and jobs available. The combination of people and money also forms the means of providing the continuing description of the base-community model. There is, therefore, physical correspondence between the model and the actual system. Having answered the question of model correspondence, research attention was focused on model parameters.

Parameter Values

The most difficult question in the validation phase of this model was simply, "Are the parameter values correct?" Many of the parameter values required by the model were available from varying sources. Information about base and community populations, gross incomes, levels of activity in business sectors, and labor information was obtained from the U.S. Army's Construction Engineering Research Laboratory (CERL) data banks, The Handbook of Labor Statistics, and other sources (22). Information significant only to specific base-community environments was not researched during validation but rather inserted based on the size and expected levels of activity for an hypothetical community. Examples of this sort of data are birth and death rates, salaries for individual types of jobs, and family size multipliers. The primary difficulty arose when much of the information about decision variables required for operation of the model was not available. As a result, many of the important decision functions which control major activities within the model had to be formulated on the basis of reasoned analysis of study, investigation, and research. Because these decision functions are so important to the operation of the model, several examples are cited and discussed individually.

Population parameters. Within the community population sector of the model there are four graph functions, the aggregate of which form the variable called Community Desirability Multiplier. The four functions represent variable decision parameters based upon four separate independent variables. For example, as noted in the previous chapter, the business magnet, or propensity for people to enter or leave a community because of business activity, is a function of the business activity rate. As the business activity increases or decreases the "magnetism" of the community increases or decreases. Although the logic that business activity draws people to a community is of little question, the exact relationship of business to "business magnetism" is not known. Figure 5-1 shows the Business Population Magnet graph function as visualized for the model. As can be seen from the illustration, the function is simply presented as a linear relationship with a "normal" population magnet of 0.1, i.e., when business activity is stagnant (no growth in business) 0.1 will be added to the total community magnetism because of business. There is no proof readily available for this relationship. It is based upon economic analyses by the researchers. The shape of the graphs for the three remaining population magnetism functions are similar to the one for business and vary only in the magnitude of the independent variables and the weight assigned to each in relation to the total desirability function. Employment was assigned the highest value, as being nost important to migration decisions, construction was next in importance, and business and services were assigned equal value. Proof of the logic behind these assignments has yet to be established.

Community jobs parameters. The decisions which establish the number of community jobs available are functions of the

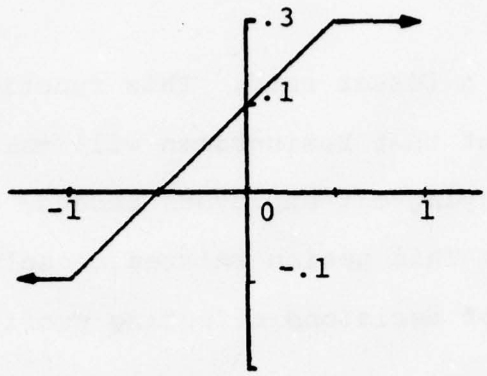

Figure 5-1. Business Population Magnet Function

change in the expense rates for each of the five business sectors, to include Taxes/Services. The reasoning behind the selection of this relationship was that businessmen would create jobs and hire more people based on a function of their total expenses. To simplify the model during validation the shapes of the graphs which represent these decisions were made identical. Again, the specific shapes of each graph has not been determined because information about the formulation of the decisions was not available. The information was not available because data on these decision processes were not available. Figure 5-2 shows the general shape of the graphs representing the creation of jobs based on changes in expense rates. As can be seen from the graph, the function was established to present varying degrees of job creation depending upon expense circumstances. If expense change rates are increasing, jobs will be created at one rate. However, if expense rates are decreasing below "normal" rate, then jobs will be deleted at a lesser rate. This function was created to represent that businessmen will take a loss in profit before laying-off employees because of the sunk costs of training. This notion relates closely to the conceptualization of decisions affecting profit and expenses.

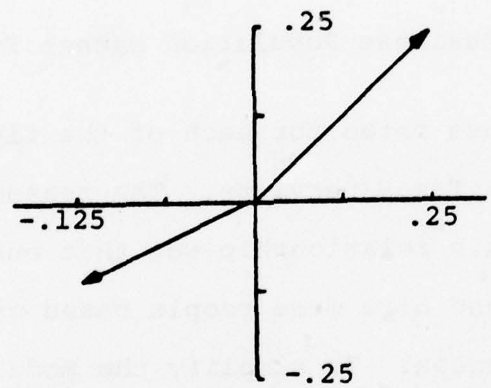

Figure 5-2. Retail Jobs Change Rate Function

Sales, expense, and profit function. The expense and profit functions are essentially the same for all four business sectors. The example will continue with the Retail Sales Sector. In each of the business sectors, profit rates are established as percentage functions of sales rates and expense rates. Changes in expense rates are, however, a graphical function of profits. In other words, the change in expenses from one period to the next is a function of the profits in that period which are in turn the results of expenses in previous periods. The logic in this example is economically sound, Profits are sales less expenses.

Current expense is a function, to some extent, of the commitment of profits from previous periods. The key to the representation of this economic phenomena is the extent to which prior profits affect current expenses. Figure 5-3 illustrates the shape of the function developed for this model. From the graph it can be seen that the response to profit depends upon the rate at which profits change. As profits increase, to a maximum of 27 1/2 per cent, retailers increase expenditures at a decreasing rate. The rate at which expenses are decreased, however, reacts more slowly to changing profits and bottoms assymptotically at eight and one third per cent. The numbers in the function are unimportant. The shape of the function is very important, however, and must be established for each base-community system to be simulated. The nature of the profit graphs in this model is to represent an assumption that merchants react strongly and quickly to growth but slowly to declines in business activity.

Although several other graph functions exist within the model, the above three examples illustrate a problem encountered in model development. Variable decision processes exist which are causes of exhibited behavior in the model and in the actual system. These processes are very important to the system operation, yet little or no information exists on the "shape" of

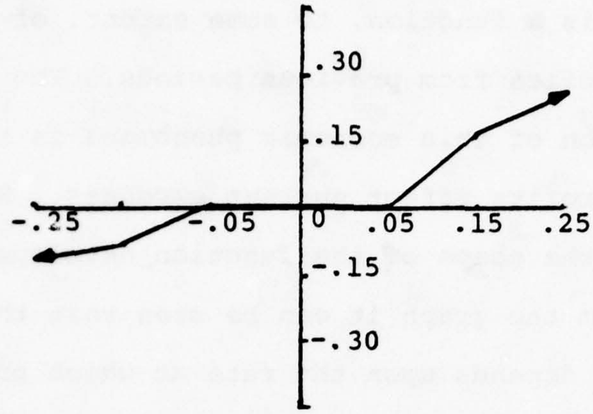

Figure 5-3. Retail Sales Expense Change Rate Function

the decision--on what the variable reactions are to variable situations. The answer to the question of model parameters, however, is positive. Within the ranges established for validation of the model, the parametric values are correct. Before the model can be verified with data from actual mission change information the shape of each decision function within the model must be determined. Establishing that the parametric values are correct leads to the final question in the validation phase of model development.

<u>Reproducing System Behavior</u>

"Does the model reproduce the system's behavior?" The answer to this final question provides the results of model formulation. Recalling from discussions in Chapter I that the basis for modeling is a representation of reality, it follows that if a model can be shown to truely represent reality there will be confidence in its ability to forecast changes in real situations. The ability of the model to predict the effects of changes of information or resources, given that the system structure remains unchanged, is a function of how well the model forecasts current activity based on past data. If the model can predict the present using information from the past, it should reasonably be able to predict future activity based on the present. The focus in answering this question, therefore, was on entering past data into the model to determine if the results would correspond to present activity. The information was entered by way of an hypothetical base-community system developed from the results of a statistical analysis relative to this research (22). Graphical results of this phase of validation are presented at Figure 5-4 with an accompanying footnoted explanation. The results show that the model does in fact correspond to the real system. A population growth pattern is present, the level of business activity is consistant with historical information about base-community systems of the same size, and the system is shown in a stable environment over the simulated 10 year period. Throughout various lengths of simulation, differing input values for population and economic

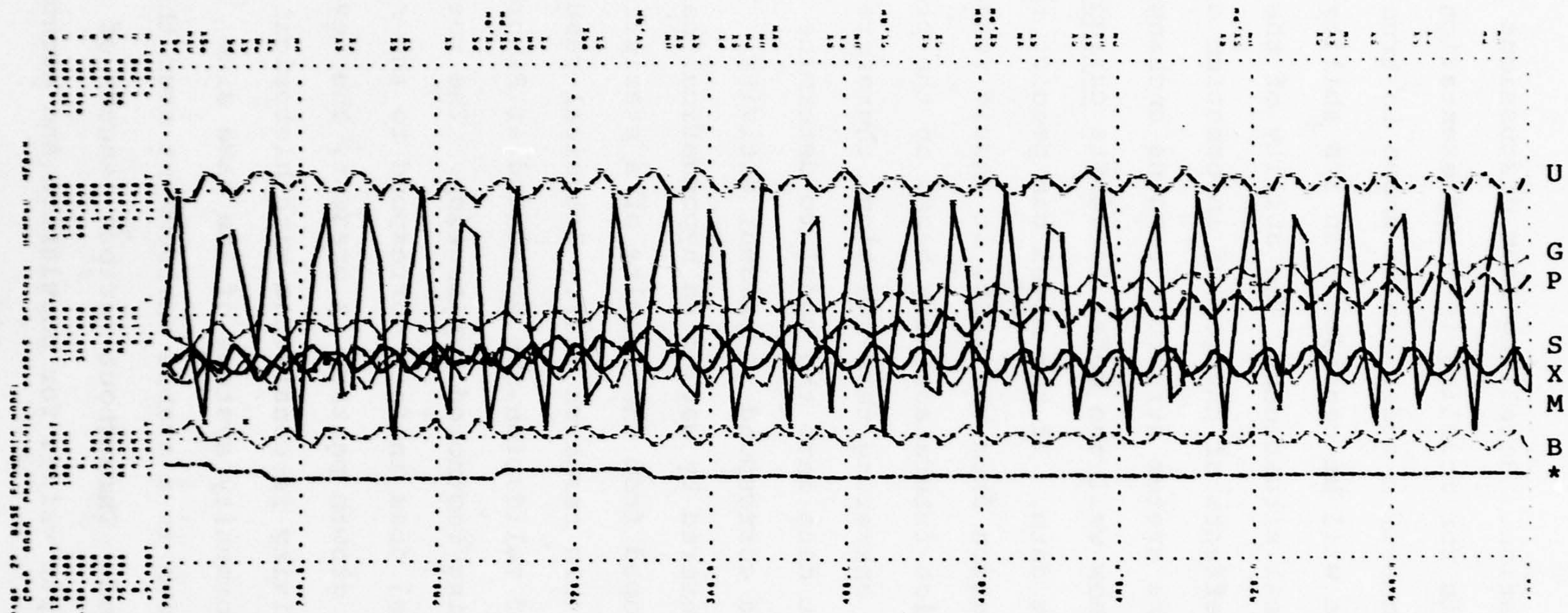

Figure 5-4. Base-Community System

variables, and for different observation time increments, the results were similar. The model demonstrated an assumption of stability and maintained growth patterns consistent with information about actual comparative communities. The next step in answering this question was to determine what happened within the model under conditions which simulated base closure in the hypothetical base-community system. Figure 5-5 shows the results of that simulation. The system initially reacts very traumatically to the change. However, over the long run the community recovers and reestablishes stability. This simple investigation into the model's ability to react to change and to simulate a mission change indicated that the model was in fact valid in its ability to reproduce expected system behavior.

With the answers to the five questions of validation, the next step in research would normally be to validate the model's external behavior; external validation being the process of entering historical data into the model to determine its ability to forecast what actually happened. As already indicated, however, before external validation of the model can be accomplished, the information required to determine the functional decision processes within the system must be acquired. Notwithstanding this inability to fulfill all of the research

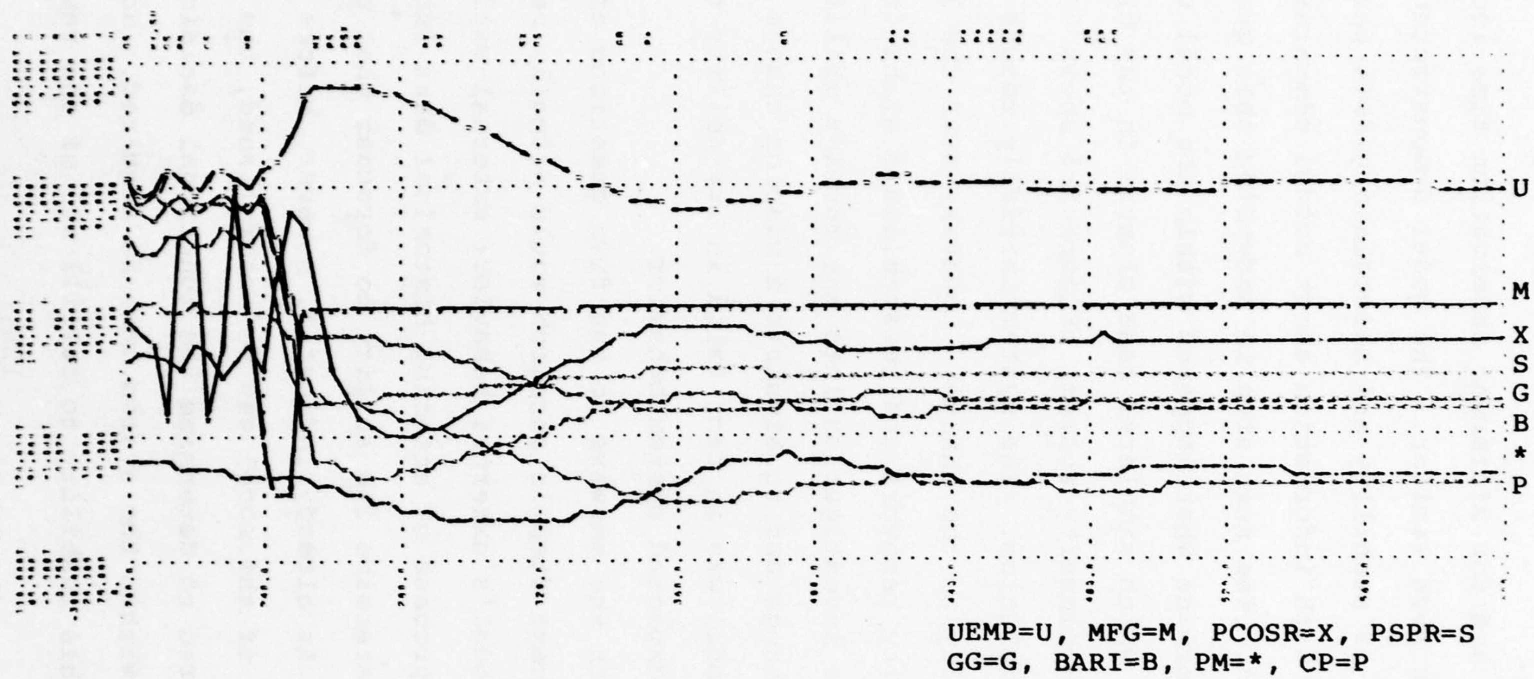

Figure 5-5. Base-Community System With Base Closure

objectives, the research has been successful in establishing that a base-community system model could be developed and that the model is capable of performing as designed. Summary remarks, conclusions drawn from the research, and recommendations as to how to continue external validation are discussed in the next chapter.

Chapter VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Early in this research effort, questions were formulated which would provide the basis for a viable base-community system model. Six research objectives were established which would fully answer the four research questions and consequently establish a useful dynamic model of the socio-economic interactions within a base-community system. A summary of the research is presented by addressing accomplishment of the research objectives.

Summary

Dynamic interrelationships. The first objective of this research was to determine pertinent dynamic interrelationships within the local environment. An in-depth study of general systems theory revealed types of dynamic interrelationships which were key elements for an accurate description of the decision structure of the socio-economic base-community system. Early in the investigation of this system it became apparent that the identified interrelationships were among those variables which create controversy when DOD mission realignments are proposed. The variables of interest were population, labor force, business activity, jobs, and the transition mechanism among these variables; payroll.

The next step in the process of interrelationship determination was an identification of components within the system between which effects upon the variables take place. Initially, these components appeared to be merely the military base and the community. However, these two components did not form a closed loop system. Thus, a third component, the political process (Planning--Programming--Budgeting sustem), was needed to allow the flow of information and money to DOD and, in turn, the base. This third component completes the transformation process. It was determined that the political process must be considered as exogenous to the base-community system, providing people, jobs, and money across a permeable boundary. This determination resulted from a realization that the community, in and of itself, constituted only a small proportion of the public pressure upon fund appropriation decisions within Congress.

Once the boundaries of the system had been determined, further study of the decision processes within the system was made, with emphasis placed upon transformation processes. During this investigation twelve sectors were identified within the base-community system which, through interaction, affect the variables of interest. Once the sectors were identified an investigation of cause and effect was required.

Cause and effect. The second research objective was to trace the causes and effects of the interrelationships among the twelve sectors. Causal loop analysis, as described in Chapter III, was used to logically investigate the specific nature of interrelationships among the sectors and, as a result, the variables of the base-community system. After cause and effect for each variable interrelationship was established, formulation of the system's control process was possible.

Control process formulation. Description of how decisions result from available information streams, through formulation of the control process of the base-community system was the third research objective. This objective was accomplished by creating the sector flow charts presented in Chapter IV. The flow charts formally identified the decision points, information tracks, and resource flows of the base-community system.

In first attempting to flow chart the system sectors, there was rapid realization that the objectives did not constitute a checklist-type algorithm for analysis of a system. It was often apparent that there existed a need to return to the loop analysis in order to reconceptualize variable relationships. This oscillation in addressing the objectives continued throughout the model design. Once initial flow charting of the base-community interrelationships was complete, the mathematical structure of the model was addressed.

<u>Construction of the mathematical model</u>. The fourth research objective was to construct a mathematical model of the process, information sources, and interactions of the base-community system components. The DYNAMO simulation language was used as the framework for the model construction. The full mathematical model is composed of two interdependent models of the base-community system.

The first of these is the conceptualization of the decision structure within the system. This is the representation of the qualitative dependencies among variables. The structural model follows directly from the causal loop analysis presented in Chapter III, and addresses all implicit and explicit relationships. The second of the interdependent models proved more difficult to express.

The second conceptualization of the mathematical model is parametric. This model expresses the quantitative nature of the qualitative dependencies addressed in the structural model. Extreme difficulty was encountered in attempting to discover the parameters of many of the variables in the base-community model. As an example, it seemed very logical to express a qualitative relationship between profits and expense rates for the business sectors. However, it proved extremely difficult to capture the quantitative nature of this relationship.

The primary reason for difficulty in determining the parametric relationships in the base-community system is that data are currently collected about the symptoms of economic activity; not about the causes. This lack of data necessitated an intuitive development of some of the model parameters in order to continue to develop the mathematical model. The data needed to construct the parametric model are present in each base-community system and likely can be extracted using known statistical and sampling techniques.

Construction of the mathematical model was completed using the flow charts presented in Chapter IV to outline the decision structure model. Parameters were extracted from currently available data sources or intuitively developed. The merging of the structural and parametric model is also presented in Chapter IV through the DYNAMO equations. Completion of the mathematical model made it possible to simulate the behavior of the hypothetical base-community system, as represented by the model.

<u>Simulation of behavior</u>. The fifth objective of the research was to operate the mathematical model. Operation of the model generated simulations of the behavior of the

base-community system. This phase of the research was repetitive. After each simulation, the model behavior was observed to determine if expected behavior was present. If, in fact, it was not, the mathematical model was analyzed to determine the causes of the unexpected behavior. Once the causes were discovered and the model corrected, the process was repeated. This process led to internal validation of the model.

Validation testing. The final objective of the research was to test the validity of the mathematical model with historical data. As outlined in Chapter V, validation is twofold; internal and external. The base-community model was found to be internally valid. The simulations generated behavior which was observed to be a stable pattern of growth with all variables acting as expected. External validation of the base-community model was prevented by the lack of available data relative to some of the causes of economic behavior in the base-community system. Until these parameters are exposed, full model validation is impossible. As a result of this inability to externally validate the model, recommendations for further study have been formulated.

Recommendations for Further Study

Throughout the latter portions of this research effort, the fact that current data collection activities do not fully address the causes of economic activity became evident. Until the parametric relationship of these causes to their effects is known, full understanding of the base-community socio-economic system is not possible. Therefore, the recommendations for further study presented here address this problem.

Business activity. Knowledge must be gained as to the parametric relationships of profit to expense and of expense to the commodities purchased with that expense. Business firms within base-community systems should be investigated to determine these relationships. It is likely that these relationships are specific to each system and that each system will need to be studied individually. There also exists the possibility that these parametric relationships change if a mission realignment is imminent. This possibility should also be investigated. A second area needing investigation is the propensity of the community to attract people.

Community desirability. The decision process resulting in migration from or to a community must be understood to fully describe the socio-economic impacts of DOD mission realignments. This understanding will not be forthcoming until the priorities and relative importance of factors resulting in population change rates is understood. Again, thorough investigation of base-community systems is required to discover these parametric relationships. The last of the recommended study areas relates to the spending patterns of individuals.

Spending patterns. While several agencies collect and analyze data relative to spending patterns, these data are usually displayed on a regional basis. In order to increase confidence in this base-community system model, the parametric values must be specific to the system under investigation. Therefore, these spending patterns should be studied as part of the environmental impact analysis process.

Conclusions

Once the parametric model of the base-community system is fully established and meshed with the structural model, the mathematical base-community model can become an excellent tool for comparison of the socio-economic impacts among alternatives. The model can first be operated assuming no mission realignment and, secondly, reapplied with the planned realignment imposed. As this process is exercised with each alternative, a trend analysis will reveal differences in impacts among alternatives.

A secondary application of the model is as a simulation experiment to determine probable outcomes of economic recovery plans. Comparison with the two previously outlined (no change and mission realignment) operations will reveal the likely benefits of recovery strategy.

A dynamic model of the base-community socio-economic system can be a valuable alternative evaluation and strategy planning tool relative DOD mission realignments. It serves as an aid to the understanding of a very complex system. When full validation of the model is complete, the model can serve both as justification for a choice among alternatives, and as an aid to planning for the economic health of impacted communities.

APPENDIX

BASE-COMMUNITY DYNAMIC MODEL

```
0030*    COMMUNITY POPULATION SECTOR
0040*
0050L    CP.K=CP.J+DT*CPCR.JK                                      CP.1
0060R    CPCR.KL=PM.K+GG.K+MFG.K                                   CP.2
0070A    GG.K=CP.K*(BR-DR)                                         CP.3
0080A    MFG.K=BMJCR.JK*MFSM                                       CP.4
0090A    PM.K=CP.K*NM*DELAY3(CDM.K,24)                             CP.5
0100A    CDM.K=BPM.K+SPMA.K+COPMA.K+EPM.K                          CP.6
0110A    BPM.K=TABHL(BPMF,BAR.JK,-1,1,1)                           CP.7
0120T    BPMF=-.1/.1/.3                                            CP.8
0130A    SPMA.K=TABHL(SPMF,PSPR.K,4,104,50)                        CP.9
0140T    SPMF=-.1/.1/.3                                            CP.10
0150A    PSPR.K=SPR.JK/CP.K                                        CP.11
0160A    COPMA.K=TABHL(COPMF,PCOSR.K,41,141,50)                    CP.12
0170T    COPMF=-.2/.2/.6                                           CP.13
0180A    PCOSR.K=COSR.JK/CP.K                                      CP.14
0190A    EPM.K=TABHL(EPMF,UEMP.K,0,.16,.08)                        CP.15
0200T    EPMF=1.8/.6/-.6                                           CP.16
0210A    UEMP.K=LFA.K/LFT.K                                        CP.17
0220*
0230*      CP=COMMUNITY POPULATION (PEOPLE)
0240*      CPCR=COMMUNITY POPULATION CHANGE RATE (PEOPLE)
0250*      GG=GENETIC GROWTH (PEOPLE)
0260*      BR=BIRTH RATE
0270*      DR=DEATH RATE
0280*      MFG=MILITARY FAMILY GROWTH (PEOPLE)
0290*      MFSM=MILITARY FAMILY SIZE MULTIPLIER
0300*      PM=POPULATION MIGRATION (PEOPLE)
0310*      NM=NORMAL MIGRATION
0320*      CDM=COMMUNITY DESIRABILITY MULTIPLIER
0330*      BPM=BUSINESS POPULATION MAGNET
0340*      BPMF=BUSINESS POPULATION MAGNET FUNCTION
0350*      SPMA=SERVICES POPULATION MAGNET
0360*      SPMF=SERVICES POPULATION MAGNET FUNCTION
0370*      PSPC=PER CAPITA SERVICES PROVISION RATE
0380*      COPMA=CONSTRUCTION POPULATION MAGNET
0390*      COPMF=CONSTRUCTION POPULATION MAGNET FUNCTION
0400*      PCOSR=PER CAPITA CONSTRUCTION SALES RATE
0410*      EPM=EMPLOYMENT POPULATION MAGNET
0420*      EPMF=EMPLOYMENT POPULATION MAGNET FUNCTION
0430*      UEMP=UNEMPLOYMENT RATE
0440N     CP=120000
0450N     CPCR=200
0460N     PM=140
0470C     BR=.0046
0480C     DR=.0038
0490C     MFSM=3
0500C     NM=.00415
0510*
```

```
0530*    BASE POPULATION SECTOR
0540*
0550L    BMJ.K=BMJ.J+DT*BMJCR.JK                      BP.1
0560R    BMJCR.KL=2*APCSR*PCSC.K+MMCR                 BP.2
0570A    PCSC.K=SIN(24*TIME.K)                        BP.3
0580L    BCJ.K=BCJ.J+DT*(BCJFR.JK-BCJDR.JK)           BP.4
0590R    BCJFR.KL=MIN(BCA.K,BCD.K)                    BP.5
0600A    BCA.K=BJDM.K*LFA.K                           BP.6
0610A    BJDM.K=BCJD/CJA.K                            BP.7
0620A    BCD.K=BCJD-BCJ.K+CMCR                        BP.8
0630R    BCJDR.KL=DELAY3(BCJFR.JK,AEP)                BP.9
0640A    BCJCR.K=BCJFR.JK-BCJDR.JK                   BP.10
0650*
0660*      BMJ=BASE MILITARY JOBS (PEOPLE)
0670*      BMJCR=BASE MILITARY JOBS CHANGE RATE (PEOPLE)
0680*      APCSR=AVERAGE PCS RATE
0690*      PCSC=PCS CYCLE
0700*      MMCR=MILITARY MISSION CHANGE RATE
0710*      BCJ=BASE CIVILIAN JOBS (PEOPLE)
0720*      BCJFR=BASE CIVILIAN JOBS FILLED RATE
0730*      BCA=BASE CIVILIANS AVAILABLE (PEOPLE)
0740*      BCD=BASE CIVILIANS DESIRED (PEOPLE)
0750*      CMCR=CIVILIAN MISSION CHANGE RATE (PEOPLE)
0760*      BCJD=BASE CIVILIAN JOBS DESIRED
0770*      BCJDR=BASE CIVILIAN JOBS DEPARTURE RATE
0780*      AEP=AVERAGE EMPLOYMENT PERIOD
0790*      BCJCR=BASE CIVILIAN JOBS CHANGE RATE
0800*      BJDM=BASE JOBS DESIRABILITY MULTIPLIER
0810N     BMJ=4800
0820N     BCJ=5355
0830N     BCJDR=0
0840N     BCJFR=85
0850C     APCSR=168
0860C     MMCR=0
0870C     CMCR=0
0880C     AEP=60
0890C     BCJD=5450
0900*
```

```
0920*   LABOR FORCE SECTOR
0930*
0940L   LFA.K=LFA.J+DT*LFACR.JK                                LF.1
0950R   LFACR.KL=LFCR.JK-CJFCR.JK                              LF.2
0960R   LFCR.KL=LFF.K*CPCR.JK                                  LF.3
0970A   LFF.K=CLFF-MLRF.K                                      LF.4
0980A   MLRF.K=MLC*(BMJ.K/CP.K)                                LF.5
0990L   LFT.K=LFT.J+DT*LFCR.JK                                 LF.6
1000A   WLA.K=WEDM.K*LFA.K                                     LF.7
1010A   WEDM.K=WJA.K/CJA.K                                     LF.8
1020A   RLA.K=REDM.K*LFA.K                                     LF.9
1030A   REDM.K=RJA.K/CJA.K                                     LF.10
1040A   SLA.K=SEDM.K*LFA.K                                     LF.11
1050A   SEDM.K=SJA.K/CJA.K                                     LF.12
1060A   TLA.K=TEDM.K*LFA.K                                     LF.13
1070A   TEDM.K=TJA.K/CJA.K                                     LF.14
1080A   COLA.K=COEDM.K*LFA.K                                   LF.15
1090A   COEDM.K=COJA.K/CJA.K                                   LF.16
1100*
1110*     LFA=LABOR FORCE AVAILABLE (PEOPLE)
1120*     LFACR=LABOR FORCE AVAILABLE CHANGE RATE (PEOPLE)
1130*     LFCR=LABOR FORCE CHANGE RATE (PEOPLE)
1140*     LFF=LABOR FORCE FRACTION (PEOPLE)
1150*     CLFF=CIVILIAN LABOR FORCE FRACTION
1160*     MLRF=MILITARY LABOR REDUCTION FACTOR
1170*     LFT=LABOR FORCE TOTAL (PEOPLE)
1180*     WLA=WHOLESALE LABOR FORCE AVAILABLE (PEOPLE)
1190*     WEDM=WHOLESALE EMPLOYMENT DESIRABILITY MULT.
1200*     RLA=RETAIL LABOR FORCE AVAILABLE (PEOPLE)
1210*     REDM=RETAIL EMPLOYMENT DESIRABILITY MULT.
1220*     SLA=SERVICES LABOR FORCE AVAILABLE (PEOPLE)
1230*     SEDM=SERVICES EMPLOVMENT DESIRABILITY MULT.
1240*     TLA=TRANSPORTATION LABOR AVAILABLE (PEOPLE)
1250*     TEDM=TRANSPORTATION EMPLOYMENT DESIRABILITY MULT.
1260*     COLA=CONSTRUCTION LABOR FORCE AVAILABLE (PEOPLE)
1270*     COEDM=CONSTRUCTION EMPLOYMENT DESIRABILITY MULT.
1280N    LFA=4200
1290N    LFT=52200
1300C    CLFF=.4
1310C    MLC=.67
```

```
1340*   TOTAL COMMUNITY JOBS SECTOR
1350*
1360L   CJA.K=CJA.J+DT*JCR.JK                               CJ.1
1370R   JCR.KL=TJCR.JK+RJCR.JK+WJCR.JK+
1380X   SJCR.JK+COJCR.JK+CMCR                               CJ.2
1390L   TJA.K=TJA.J+DT*TJCR.JK                              CJ.3
1400R   TJCR.KL=TJA.K*TABXT(TJCRF,DTER.K,LO,HI,INT)         CJ.4
1410T   TJCRF=-.125/0/.25                                   CJ.5
1420L   RJA.K=RJA.J+DT*RJCR.JK                              CJ.6
1430R   RJCR.KL=RJA.K*TABXT(RJCRF,DRER.K,LO,HI,INT)         CJ.7
1440T   RJCRF=-.125/0/.25                                   CJ.8
1450L   WJA.K=WJA.J+DT*WJCR.JK                              CJ.9
1460R   WJCR.KL=WJA.K*TABXT(WJCRF,DWER.K,LO,HI,INT)         CJ.10
1470T   WJCRF=-.125/0/.25                                   CJ.11
1480L   SJA.K=SJA.J+DT*SJCR.JK                              CJ.12
1490R   SJCR.KL=SJA.K*TABXT(SJCRF,DSPR.K,LO,HI,INT)         CJ.13
1500T   SJCRF=-.125/0/.25                                   CJ.14
1510L   COJA.K=COJA.J+DT*COJCR.JK                           CJ.15
1520R   COJCR.KL=COJA.K*TABXT(COJCRF,DCOER.K,
1530X   LO,HI,INT)                                          CJ.16
1540T   COJCRF=-.125/0/.25                                  CJ.17
1550*
1560*     CJA=COMMUNITY JOBS AVAILABLE (# JOBS)
1570*     JCR=JOB CHANGE RATE (# JOBS)
1580*     TJA=TRANSPORTATION JOBS AVAILABLE (# JOBS)
1590*     TJCR=TRANSPORTATION JOBS CHANGE RATE (# JOBS)
1600*     TJCRF=TRANSPORTATION JOBS CHANGE RATE FUNCTION
1610*     RJA=RETAIL JOBS AVAILABLE (# JOBS)
1620*     RJCR=RETAIL JOBS CHANGE RATE (# JOBS)
1630*     RJCRF=RETAIL JOBS CHANGE RATE FUNCTION
1640*     WJA=WHOLESALE JOBS AVAILABLE (# JOBS)
1650*     WJCR=WHOLESALE JOBS CHANGE RATE (# JOBS)
1660*     WJCRF=WHOLESALE JOBS CHANGE RATE FUNCTION
1670*     SJA=SERVICES JOBS AVAILABLE (# JOBS)
1680*     SJCR=SERVICES JOBS CHANGE RATE (# JOBS)
1690*     SJCRF=SERVICES JOBS CHANGE RATE FUNCTION
1700*     COJA=CONSTRUCTION JOBS AVAILABLE (# JOBS)
1710*     COJCR=CONSTRUCTION JOBS CHANGE RATE (# JOBS)
1720*     COJCRF=CONSTRUCTION JOBS CHANGE RATE FUNCTION
1730N    CJA=48000
1740N    TJA=1500
1750N    RJA=16700
1760N    WJA=16000
1770N    SJA=11000
1780N    COJA=2800
1790C    LO=-.25
1800C    HI=.25
1810C    INT=.25
1820*
```

```
1840*   JOBS FILLED SECTOR
1850*
1860L   CJF.K=CJF.J+DT*CJFCR.JK                        JF.1
1870R   CJFCR.KL=BCJCR.K+SJFCR.K+TJFCR.K+
1880X   COJFCR.K+WJFCR.K+RJFCR.K                       JF.2
1890A   SJFCR.K=MIN(SJCR.JK,SLA.K)                     JF.3
1900A   TJFCR.K=MIN(TJCR.JK,TLA.K)                     JF.4
1910A   COJFCR.K=MIN(COJCR.JK,COLA.K)                  JF.5
1920A   WJFCR.K=MIN(WJCR.JK,WLA.K)                     JF.6
1930A   RJFCR.K=MIN(RJCR.JK,RLA.K)                     JF.7
1940*
1950*     CJF=COMMUNITY JOBS FILLED (# JOBS)
1960*     CJFCR=COMMUNITY JOBS FILLED CHANGE RATE (# JOBS)
1970*     SJFCR=SERVICES JOBS FILLED CHANGE RATE (# JOBS)
1980*     TJFCR=TRANSPORTATION JOBS FILLED CHANGE RATE
1990*           (# JOBS)
2000*     COJFCR=CONSTRUCTION JOBS FILLED CHANGE RATE
2010*            (# JOBS)
2020*     WJFCR=WHOLESALE JOBS FILLED CHANGE RATE (# JOBS)
2030*     RJFCR=RETAIL JOBS FILLED CHANGE RATE (# JOBS)
2040N    CJF=48000
2050*
```

```
2070*   COMMUNITY PAYROLL SECTOR
2080*
2090L   TCP.K=TCP.J+DT*PCR.JK                                CPA.1
2100R   PCR.KL=COPCR.K+TPCR.K+SPCR.K+RPCR.K+
2110X   WPCR.K+BCPCR.K+BMPCR.K                               CPA.2
2120A   COPCR.K=COPM*COJFCR.K                                CPA.3
2130A   TPCR.K=TPM*TJFCR.K                                   CPA.4
2140A   SPCR.K=SPM*SJFCR.K                                   CPA.5
2150A   RPCR.K=RPM*RJFCR.K                                   CPA.6
2160A   WPCR.K=WPM*WJFCR.K                                   CPA.7
2170A   BCPCR.K=BCPM*BCJCR.K                                 CPA.8
2180A   BMPCR.K=BMPM*BMJCR.JK*MPRF                           CPA.9
2190A   PAR.K=TCP.K/NCP                                     CPA.10
2200*
2210*     TCP=TOTAL COMMUNITY PAYROLL (DOLLARS)
2220*     PCR=PAYROLL CHANGE RATE (DOLLARS)
2230*     COPCR=CONSTRUCTION PAYROLL CHANGE RATE (DOLLARS)
2240*     COPM=CONSTRUCTION PAY MULTIPLIER
2250*     TPCR=TRANSPORTATION PAYROLL CHANGE RATE (DOLLARS)
2260*     TPM=TRANSPORTATION PAY MULTIPLIER
2270*     SPCR=SERVICES PAYROLL CHANGE RATE (DOLLARS)
2280*     SPM=SERVICES PAY MULTIPLIER
2290*     RPCR=RETAIL PAYROLL CHANGE RATE (DOLLARS)
2300*     RPM=RETAIL PAY MULTIPLIER
2310*     WPCR=WHOLESALE PAYROLL CHANGE RATE (DOLLARS)
2320*     WPM=WHOLESALE PAY MULTIPLIER
2330*     BCPCR=BASE CIVILIAN PAYROLL CHANGE RATE (DOLLARS)
2340*     BCPM=BASE CIVILIAN PAY MULTIPLIER
2350*     BMPCR=BASE MILITARY PAYROLL MULTIPLIER (DOLLARS)
2360*     BMPM=BASE MILITARY PAY MULTIPLIER
2370*     MPRF=MILITARY PAY REDUCTION FACTOR
2380*     NCP=NORMAL COMMUNITY PAYROLL
2390N    TCP=38400000
2400C    TPM=800
2410C    SPM=800
2420C    RPM=800
2430C    WPM=800
2440C    BCPM=800
2450C    BMPM=800
2460C    MPRF=.75
2470C    COPM=800
2480C    NCP=38400000
2490*
```

```
2510*    RETAIL SALES SECTOR
2520*
2530L    RRL.K=RRL.J+DT*(RSR.JK-RER.JK)                     RS.1
2540R    RSR.KL=TCP.K*RPRM+BRPR.K                           RS.2
2550A    BRPR.K=BB*RPMF                                     RS.3
2560R    RER.KL=RER.JK*(1+DRER.K)                           RS.4
2570A    DRER.K=TABHL(DRERF,RPR.K,-.25,.25,.1)              RS.5
2580T    DRERF=-.083/-.075/0/0/.15/.275                     RS.6
2590A    RPR.K=(RSR.JK-RER.JK)/RER.JK                       RS.7
2600*
2610*      RRL=RETAIL REVENUE LEVEL (DOLLARS)
2620*      RSR=RETAIL SALES RATE (DOLLARS)
2630*      BRPR=BASE RETAIL PROCUREMENT RATE (DOLLARS)
2640*      BB=BASE BUDGET
2650*      RPRM=RETAIL PROPORTION MULTIPLIER
2660*      RPMF=RETAIL PROCUREMENT MILITARY FRACTION
2670*      RER=RETAIL EXPENSE RATE (DOLLARS)
2680*      DRER=DELTA RETAIL EXPENSE RATE
2690*      DRERF=DELTA RETAIL EXPENSE RATE FUNCTION
2700*      RPR=RETAIL PROFIT RATE
2710N     RRL=2400000
2720N     RER=38225000
2730C     BB=1000000
2740C     RPRM=1.04
2750C     RPMF=.3
2760*
```

```
2780*    WHOLESALE SALES SECTOR
2790*
2800L    IOL.K=IOL.J+DT*(ROR.JK+COOR.JK-CSR.JK)          WS.1
2810R    CSR.KL=DELAY3(IOR.K,FPCT)                       WS.2
2820A    IOR.K=ROR.JK+COOR.JK                            WS.3
2830R    ROR.KL=ROR.JK*(1+DROR.K)                        WS.4
2840A    DROR.K=TABXT(DRORF,DRER.K,-.2,.2,.2)            WS.5
2850T    DRORF=-.3/0/.2                                  WS.6
2860R    COOR.KL=COOR.JK*(1+DCOOR.K)                     WS.7
2870A    DCOOR.K=TABXT(DCOORF,DCOER.K,-.2,.2,.2)         WS.8
2880T    DCOORF=-.3/0/.2                                 WS.9
2890L    WRL.K=WRL.J+DT*(WSR.JK-WER.JK)                 WS.10
2900R    WSR.KL=CSR.JK+BWPR.K                           WS.11
2910A    BWPR.K=BB*WPRM                                 WS.12
2920R    WER.KL=WER.JK*(1+DWER.K)                       WS.13
2930A    DWER.K=TABHL(DWERF,WPR.K,-.25,.25,.1)          WS.14
2940T    DWERF=-.083/-.075/0/0/.15/.275                 WS.15
2950A    WPR.K=(WSR.JK-WER.JK)/WER.JK                   WS.16
2960*
2970*      IOL=INVENTORY ORDER LEVEL (DOLLARS)
2980*      CSR=COMMERCIAL SALES RATE (DOLLARS)
2990*      FPCT=FINANCIAL PERFORMANCE CYCLE TIME (TIME)
3000*      IOR=INVENTORY ORDER RATE (DOLLARS)
3010*      ROR=RETAIL ORDER RATE (DOLLARS)
3020*      DROR=DELTA RETAIL ORDER RATE (DOLLARS)
3030*      DRORF=DELTA RETAIL ORDER RATE FUNCTION
3040*      COOR=CONSTRUCTION ORDER RATE (DOLLARS)
3050*      DCOOR=DELTA CONSTRUCTION ORDER RATE (DOLLARS)
3060*      DCOORF=DELTA CONSTRUCTION ORDER RATE FUNCTION
3070*      WRL=WHOLESALE REVENUE LEVEL (DOLLARS)
3080*      WSR=WHOLESALE SALES RATE (DOLLARS)
3090*      BWPR=BASE WHOLESALE PROCUREMENT RATE
3100*      WPRM=WHOLESALE PROCUREMENT RATE MULTIPLIER
3110*      WER=WHOLESALE EXPENSE RATE (DOLLARS)
3120*      DWER=DELTA WHOLESALE EXPENSE RATE (DOLLARS)
3130*      DWERF=DELTA WHOLESALE EXPENSE RATE FUNCTION
3140*      WPR=WHOLESALE PROFIT RATE
3150N     IOL=2700000
3160N     ROR=31185000
3170N     COOR=8415000
3180N     WRL=2400000
3190N     WER=38000000
3200C     FPCT=2
3210C     WPRM=.4
3220*
```

```
3240*   CONSTRUCTION SECTOR
3250*
3260L   VEF.K=VEF.J+DT*(COSR.JK-FDR.JK)                    CO.1
3270R   FDR.KL=DELAY3(COSR.JK,FDP)                         CO.2
3280R   COSR.KL=CONDB.K+CONDH.K                            CO.3
3290A   CONDB.K=DELAY3(CONDRB.K,COBD)                      CO.4
3300A   CONDRB.K=BERI.K*CONDBN                             CO.5
3310A   CONDH.K=DELAY3(CONDRH.K,COHD)                      CO.6
3320A   CONDRH.K=PAR.K*CONDHN                              CO.7
3330L   COR.K=COR.J+DT*(COSR.JK-COER.JK)                   CO.8
3340R   COER.KL=COER.JK*(1+DCOER.K)                        CO.9
3350A   DCOER.K=TABHL(DCOERF,COPR.K,-.25,.25,.1)          CO.10
3360T   DCOERF=-.083/-.075/0/0/.15/.275                   CO.11
3370A   COPR.K=(COSR.JK-COER.JK)/COER.JK                  CO.12
3380*
3390*     VEF=VALUE OF EXISTING FACILITIES (DOLLARS)
3400*     FDR=FACILITIES DEVALUATION RATE (DOLLARS)
3410*     FDP=FACILITIES DEVALUATION PERIOD (TIME)
3420*     COSR=CONSTRUCTION SALES RATE (DOLLARS)
3430*     CONDB=CONSTRUCTION DEMAND BY BUSINESS (DOLLARS)
3440*     CONDRB=CONSTRUCTION DEMAND RATE BY BUSINESS
3450*            (DOLLARS)
3460*     CONDBN=NORMAL CONSTRUCTION DEMAND RATE
3470*            BY BUSINESS (DOLLARS)
3480*     COBD=BUSINESS CONSTRUCTION DELAY (TIME)
3490*     CONDH=CONSTRUCTION DEMAND FOR HOUSING (DOLLARS)
3500*     CONDRH=CONSTRUCTION DEMAND RATE FOR HOUSING
3510*            (DOLLARS)
3520*     CONDHN=NORMAL CONSTRUCTION DEMAND RATE FOR
3530*                HOUSING (DOLLARS)
3540*     COHD=HOUSING CONSTRUCTION DELAY (TIME)
3550*     COR=CONSTRUCTION REVENUE (DOLLARS)
3560*     COER=CONSTRUCTION EXPENSE RATE (DOLLARS)
3570*     DCOER=DELTA CONSTRUCTION EXPENSE RATE
3580*     DCOERF=DELTA CONSTRUCTION EXPENSE RATE FUNCTION
3590*     COPR=CONSTRUCTION PROFIT RATE
3600N    VEF=2000000000
3610N    COSR=11000000
3620N    COR=670000
3630N    COER=10450000
3640N    CONDB=CONDBN
3650N    CONDH=CONDHN
3660C    FDP=240
3670C    COD=6
3680C    CONDBN=7443700
3690C    CONDHN=3556300
3700C    COBD=9
3710C    COHD=6
3720*
```

```
3740*   TRANSPORTATION SECTOR
3750*
3760L   TR.K=TR.J+DT*(TSR.JK-TER.JK)                          TR.1
3770R   TSR.KL=PTS.K+GCS.K+HHGS.K                             TR.2
3780A   PTS.K=PTM*CP.K*MPPM                                   TR.3
3790A   MPPM.K=TABHL(MPPMF,BCR.K,0,1,.5)                      TR.4
3800T   MPPMF=1/1.1/1.2                                       TR.5
3810A   GCS.K=GCM*TAR.K+MGCP                                  TR.6
3820A   TAR.K=(RER.JK+WER.JK+COER.JK)/TNR                     TR.7
3830A   MGCP.K=MGCPM*BB                                       TR.8
3840A   HHGS.K=HHGM*CP.K*MHHGM                                TR.9
3850A   MHHGM.K=TABHL(MHHGMF,BCR.K,0,1,.5)                   TR.10
3860T   MHHGMF=1/1.5/2                                       TR.11
3870R   TER.KL=TER.JK*(1+DTER.K)                             TR.12
3880A   DTER.K=TABHL(DTERF,TPR.K,-.25,.25,.1)                TR.13
3890T   DTERF=-.083/-.075/0/0/.15/.275                       TR.14
3900A   TPR.K=(TSR.JK-TER.JK)/TER.JK                         TR.15
3910*
3920*     TR=TRANSPORTATION REVENUE (DOLLARS)
3930*     TSR=TRANSPORTATION SALES RATE (DOLLARS)
3940*     PTS=PASSANGER TRANSPORTATION SEGMENT
3950*     PTM=PASSANGER TRANSPORTATION MULTIPLIER
3960*     MPPM=MILITARY PASSENGER PROCUREMENT MULTIPLIER
3970*     MPPMF=MILITARY PASSENGER PROCUREMENT MULTIPLIER
3980*           FUNCTION
3990*     GCS=GENERAL CARGO SEGMENT
4000*     GCM=GENERAL CARGO MULTIPLIER
4010*     TAR=TRANSPORTATION ACTIVITY RATE
4020*     TNR=TRANSPORTATION NORMAL RATE
4030*     MGCP=MILITARY GENERAL CARGO PROCUREMENT
4040*     MGCPM=MILITARY GENERAL CARGO PROCUREMENT
4050*           MULTIPLIER
4060*     HHGS=HOUSEHOLD GOODS SEGMENT
4070*     HHGM=HOUSEHOLD GOODS MULTIPLIER
4080*     MHHGM=MILITARY HOUSEHOLD GOODS MULTIPLIER
4090*     MHHGMF=MILITARY HOUSEHOLD GOODS MULTIPLIER
4100*            FUNCTION
4110*     TER=TRANSPORTATION EXPENSE RATE (DOLLARS)
4120*     DTER=DELTA TRANSPORTATION EXPENSE RATE
4130*     DTERF=DELTA TRANSPORTATION EXPENSE RATE FUNCTION
4140*     TPR=TRANSPORTATION PROFIT RATE (DOLLARS)
4150N   TR=300000
4160N   TSR=5600000
4170N   TER=5320000
4180C   PTM=5.25
4190C   GCM=4240000
4200C   HHGM=4.85
4210C   TNR=86100000
4220C   MGCPM=.06
4230*
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```
4250*   BUSINESS ACTIVITY SECTOR
4260*
4270L   BAL.K=BAL.J+DT*BAR.JK                                   BA.1
4280R   BAR.KL=BARI.K-1                                         BA.2
4290A   BARI.K=(BAAR.K/BANR)                                    BA.3
4300A   BERI.K=(RER.JK+WER.JK+TER.JK+COER.JK+
4310X   SPR.JK)/BENR                                            BA.4
4320A   BAAR.K=(TSR.JK+COSR.JK+WSR.JK+RSR.JK)/
4330X   BECP.K                                                  BA.5
4340A   BECP.K=MBRF.K*CP.K                                      BA.6
4350A   MBRF.K=TABXT(MBRFF,BCR.K,0,1,.5)                        BA.7
4360T   MBRFF=1/.85/.7                                          BA.8
4370A   BCR.K=(BMJ.K*MFSM)/CP.K                                 BA.9
4380*
4390*     BAL=BUSINESS ACTIVITY LEVEL
4400*     BAR=BUSINESS ACTIVITY RATE
4410*     BARI=BUSINESS ACTIVITY RATE INDICATOR
4420*     BERI=BUSINESS EXPENSE RATE INDICATOR
4430*     BENR=BUSINESS EXPENSE NORMAL RATE
4440*     BAAR=BUSINESS ACTIVITY AGGREGATE RATE
4450*     BANR=BUSINESS ACTIVITY NORMAL RATE
4460*     BECP=BUSINESS EFFECTIVE COMMUNITY POPULATION
4470*     MBRF=MILITARY BUSINESS REDUCTION FACTOR
4480*     MBRFF=MILITARY BUSINESS REDUCTION FACTOR FUNCTION
4490*     BCR=BASE/COMMUNITY RATIO
4500N    BAL=1
4510C    BANR=837
4520C    BENR=98510000
4530*
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4550*    TAXES/SERVICES SECTOR
4560*
4570L    CTF.K=CTF.J+DT*(ATR.JK-SPR.JK)                         TS.1
4580R    ATR.KL=ATRA.K+GMFR.K                                   TS.2
4590A    ATRA.K=PTR.K+RTR.K+WTR.K+TTR.K+COTR.K                  TS.3
4600A    PTR.K=PTXM*TCP.K                                       TS.4
4610A    RTR.K=(RSR.JK-RER.JK)*RTM                              TS.5
4620A    WTR.K=(WSR.JK-WER.JK)*WTM                              TS.6
4630A    TTR.K=(TSR.JK-TER.JK)*TTM                              TS.7
4640A    COTR.K=(COSR.JK-COER.JK)*COTM                          TS.8
4650A    GMFR.K=GMFM*(PTR.K+RTR.K+WTR.K+
4660X    TTR.K+COTR.K)                                          TS.9
4670A    DSPR.K=TABHL(DSPRM,TD.K,-1,1,.5)                      TS.10
4680T    DSPRM=-.375/-.125/0/.5/1                              TS.11
4690R    SPR.KL=SPR.JK*(1+DSPR.K)                              TS.12
4700A    TD.K=(ATR.JK-SPR.JK)/SPR.JK                           TS.13
4710*
4720*      CTF=COMMUNITY TAX FUND (DOLLARS)
4730*      ATR=AGGREGATE TAX RATE (DOLLARS)
4740*      ATRA=AGGREGATE TAX RATE ASSESSMENTS
4750*      PTR=PERSONAL TAX RATE (DOLLARS)
4760*      PTXM=PERSONAL TAX MULTIPLIER
4770*      RTR=RETAIL TAX RATE (DOLLARS)
4780*      RTM=RETAIL TAX MULTIPLIER
4790*      WTR=WHOLESALE TAX RATE (DOLLARS)
4800*      WTM=WHOLESALE TAX MULTIPLIER
4810*      TTR=TRANSPORTATION TAX RATE (DOLLARS)
4820*      TTM=TRANSPORTATION TAX MULTIPLIER
4830*      COTR=CONSTRUCTION TAX RATE (DOLLARS)
4840*      COTM=CONSTRUCTION TAX MULTIPLIER
4850*      GMFR=GOVERNMENT MATCHING FUND RATE (DOLLARS)
4860*      GMFM=GOVERNMENT MATCHING FUND MULTIPLIER
4870*      SPR=SERVICES PROVISION RATE (DOLLARS)
4880*      DSPR=DELTA SERVICES PROVISION RATE
4890*      DSPRM=DELTA SERVICES PROVISION RATE
4900*            MULTIPLIER
4910*      TD=TAX DIFFERENTIAL
4920N     CTF=33000
4930N     SPR=6510000
4940C     PTXM=.03
4950C     RTM=.03
4960C     WTM=.03
4970C     TTM=.03
4980C     COTM=.04
4990C     GMFM=4
5000*
5010*    BASE ECONOMIC MODEL
5020PRINT CP,GG,MFG,PM,BARI,PSPR,PCOSR,UEMP
5030PLOT    CP=P/GG=G/PM=*/BARI=B/PSPR=S/PCOSR=X/UEMP=U/MFG=M
5040SPEC    DT=.25/LENGTH=600/PRTPER=1.0/PLTPER=4.0
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