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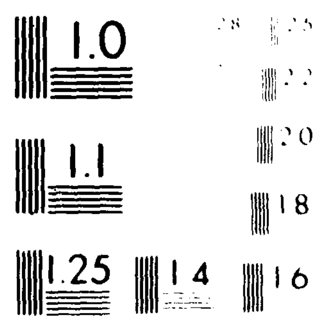
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MANAGING THE U.S. ECONOMY IN A POST-ATTACK ENVIRONMENT: A SYSTEM DYNAMICS MODEL OF VIABILITY

FINAL REPORT - VOLUME 2

Gary A. Hill
Peter C. Gardiner

Contract No. DCPA01-78-C-0324
FEMA WORK UNIT NO. 4341-E

Approved for Public Release
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This report is Volume II of the final report under this contract. Volume I is "Civil Preparedness and Post-Attack U.S. Economic Recovery: A State-of-the-Art Assessment and Selected Annotated Bibliography" by A. Feinberg. Volume III is "Options for Accelerating Economic Recovery After Nuclear Attack" by G. Quester.

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The primary objective of this study is to determine if post-attack viability (or collapse) is automatic for a given system, or if management actions can influence the outcome. In investigating this problem, the approach focuses on exploring the structure of a post-attack system for instabilities, identifying the processes that could lead to collapse, and then evaluating if and how alternative post-attack management policies can mitigate the effects of those instabilities.

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At the conceptual level, the approach characterized a system's viability in terms of an inventories "race." Since the immediate post-attack period would be marked by a reliance on stockpiles and inventories to sustain the surviving population, the critical question was whether inventories would be depleted before the economy could replenish supplies by reorganizing initial production facilities. Additionally, the study attempted to determine how various types of systemic instabilities can affect this inventories race and how management actions can effectively overcome any debilitating effects that these instabilities might have on the ability of the nation to recover. These instabilities may appear due to the delays and uncertainties affecting such basic economic support systems as communication and transportation networks, organizational structures and resource allocation mechanisms.

A system dynamics model is constructed of a post-attack economy to study the management problems affecting these support systems in the immediate post-attack period. Through repeated simulations, the model is able to demonstrate the effects of potential instabilities on the performance of the economy and how alternative management policies could mitigate those effects. While the results should be qualified as being preliminary in the sense that this effort is a first pass at the problem, there is sufficient evidence to proceed with a more extended analysis. The evidence suggests that the issue of viability is greatly dependent on effective emergency preparedness policies and resource management actions. The simulation results from the model clearly indicate that viability is not automatic even if adequate productive capacities survive; the same system can produce both viability and collapse depending on the choice of policies and management strategies. If ineffective pre-attack and post-attack policies are followed, the potential for debilitating instabilities arising greatly increases and so, too, does the potential for system collapse.

PREFACE

This report has been written as part of Analytical Assessments Corporation's study of the management of the post-attack U.S. economy. Two other reports have been written covering other aspects of AAC's research on the management of the post-attack U.S. economy. They are:

A. Feinberg, "Civil Preparedness and Post-Attack U.S. Economic Recovery: A State-of-the-Art Assessment and Selected Annotated Bibliography," AAC-TR-9204/79, October 1979; and

G. Quester, "Options for Accelerating Economic Recovery After Nuclear Attack," AAC-TR-9203/79, July 1979.

Feinberg's report contains an assessment of the state-of-the-art of modeling and analysis for civil preparedness and management of the post-attack U.S. economy. This evaluation was derived considerably from a large volume of related literature. A selected, annotated bibliography of over 100 entries follows the state-of-the-art assessment.

Literature areas reviewed included historical disasters, industry studies, post-attack viability, survival and economic recovery, and civil defense, both U.S. and Soviet. Some literature on modeling methods was researched. Modeling methods covered were input/output, econometrics, optimization, and system dynamics.

Analysis of the literature and current state-of-the-art revealed several key management aspects of the post-attack economy. These aspects were resource allocation and distribution, energy, information, communication, command and control (C^3), finance, social and behavioral response, and government authority. Most of these managerial aspects were found to have been neither thoroughly analyzed nor specifically modeled.

Assessing modeling needs, available modeling methods, and deficiencies in the state-of-the-art led to a recommendation for further development of system dynamics models for management of U.S. post-attack economic recovery. System dynamics is suggested because of its flexibility, potential scope and capabilities for handling non-linearities, dynamic effects, and soft items such as social and behavioral responses.

The results of Feinberg's review led to the development of a system dynamics model of the management of the U.S. economy reported on in the present report. The primary focus of this study is to determine if post-attack viability (or collapse) is automatic for a given system, or if management actions can influence the outcome. In investigating this problem, the approach focuses on exploring the structure of a post-attack system for instabilities, identifying the processes that could lead to collapse, and then evaluating if and how alternative post-attack management policies can mitigate the effects of those instabilities.

At the conceptual level, the approach that is taken characterizes a system's viability in terms of an inventories "race." Since the immediate post-attack period would be marked by a reliance on stockpiles and inventories to sustain the surviving population, the critical question is whether inventories will be depleted before the economy can replenish supplies by reorganizing initial production facilities. Additionally, the study attempts to determine how various types of systemic instabilities can affect this inventories race and how management actions can effectively overcome any debilitating effects that these instabilities might have on the ability of the nation to recover. These instabilities may appear due to the delays and uncertainties affecting such basic economic support systems as communication and transportation networks, organizational structures and resource allocation mechanisms.

A system dynamics model is constructed of a post-attack economy to study the management problems affecting these support systems in the immediate post-attack period. Through repeated simulations, the model is able to demonstrate the effects of potential instabilities on the performance of the economy and how alternative management policies could mitigate those effects. While the results should be qualified as being preliminary in the sense that this effort is a first pass at the problem, there is sufficient evidence that it would be profitable to proceed with a more extended analysis. The evidence suggests that the issue of viability is greatly dependent on effective emergency preparedness policies and resource management actions. The simulation results from the model clearly indicate that viability is not automatic even if adequate productive capacities survive; the same system can produce both viability and collapse depending on the choice of policies and management strategies. If ineffective pre-attack and post-attack policies are followed, the potential for debilitating instabilities arising greatly increases and so, too, does the potential for system collapse.

Quester's report is a companion piece to these two studies. It starts with the conclusion of these two studies, as well as many other studies of the post-attack recovery, that we are likely to fail to exploit to the fullest our potential for economic recovery following a nuclear attack because of failures in post-attack management in both the political and economic sectors. It also presumes that large-scale changes in peacetime arrangements will not win acceptance, so that the best hope for improvement is to look for more marginal adjustments in our continually evolving peacetime management systems, adjustments which might contribute substantially to post-attack recovery at little peacetime cost.

In addition, Quester's report reviews general technological trends in key areas with regard to whether they will tend to make the government reorganization problems easier or harder. Inferences are drawn about relatively inexpensive pre-attack actions, based on exploiting favorable technological trends, which could be taken to make the post-attack management problems more tractable. The report is optimistic, in that it believes that a number of such djustments deserves to be explored. The post-attack considerations addressed include making government more effective in bringing about economic recovery *and*, very importantly, making sure that government continues as government, i.e., that we do not sink into anarchy.

This analysis in Quester's report is intended to put upon the table a number of new ideas worthy of further consideration. It is not within the scope of this analysis to evaluate these ideas. Consequently, it may turn out that some of these ideas do not stand up to the scrutiny of further exploration. Nevertheless, this report should serve the important purpose of providing a rich menu of management policies which should be evaluated further.

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I. OVERVIEW

Several studies have examined the problems of national recovery after a nuclear attack. Overwhelmingly, these studies conclude that if the nation remains *viable*, recovery is certain to follow. Viability, as the term is used here, is essentially a race between the drawdown of inventory and inventory replenishment in the post-attack period. If the rate of the drawdown of food, medicine, heating oil, and so on exceeds the rate of replenishment over a sufficiently long time horizon, the post-attack economy will collapse. However, if the drawdown rate is eventually balanced or exceeded by the replenishment rate, the system is said to be viable and recovery will follow.

What then influences viability? The answer is relatively simple: Pre- and post-attack *management* and the *inherent characteristics* of the social system being managed. Questions about viability can be reduced to questions about how management and system characteristics singularly and jointly affect viability. Implicit in this viewpoint is the assumption that management, properly exercised, can mean the difference between system viability and system collapse, for if a system's inherent characteristics effectively guaranteed *a priori* either viability or collapse, *regardless of the management action taken*, there would be little point in studying pre- and post-attack management. If, on the other hand, viability or collapse can be demonstrated to be a function of management actions coupled with system characteristics, the case could be made for studying pre- and post-attack management as a means of insuring viability. Viewed in this light, the research question can now be stated: "Given some system, is viability (or collapse) automatic for that system, or can management by its actions influence the eventual outcome?"

This approach permits us to determine in a preliminary fashion if viability is independent of management actions. If viability cannot be shown to be influenced by management actions, there would be little need to focus resources on further developments in this area. A system would simply be viable or collapse regardless of what managers do. If, on the other hand, viability does depend on which set of management policies are actually in effect at the time of and immediately following an attack, subsequent research can then proceed to develop a better understanding of the impacts of pre- and post-attack management to insure national viability.

The basic philosophy of this modeling effort is to construct a model that represents a social system to determine if it contains fundamental instabilities in terms of its inherent characteristics that lead to either viability or collapse, and further, to see if management actions can be introduced that influence these results. For this reason, we are not trying to determine what is likely to happen. Rather, we are attempting simply to discover if and where instabilities might occur and what effect management actions might have on these instabilities.

The results of the research demonstrate that neither viability nor collapse is inherently automatic in a system. When tested under conditions of variable management parameters and policies, the same system produced instabilities leading to either collapse or viability. Thus viability, at least in terms of this model, is not certain but, rather, is directly a function of management actions and interventions both before and immediately after an attack. The remainder of this report discusses in detail the model construction, the background conceptualization of the model, and the policies and parameters that lead to both collapse and viability.

II. BACKGROUND

Several recent studies of the post-attack period underscore the importance of understanding how resource management problems could affect the economic recovery of the nation should a nuclear exchange occur.[1] Bolstered by findings from historical cases of post-war and disaster recovery efforts, these studies conclude that the most critical recovery problems do not involve either the production capabilities of a nation or the availability of raw materials. Rather, the critical problems have concerned management of the surviving resources.

In the situations examined, food and medical supplies, raw materials and finished goods, machinery and equipment have been found to survive in sufficient quantity to provide the economic capabilities for recovery, but locating and matching the surviving resources to the points of need have hampered the recovery operations. The most plausible explanation for this concerns the extent to which economic recovery requires effective resource management; and to be effective, management requires the support of communication and transportation networks, organizational structures, and resource allocation mechanisms. Not unexpectedly, these supporting systems have not been as efficient or as reliable as they are in a normally functioning economy.

Such resource management problems would be more acute during the period immediately following a nuclear exchange. Cognizant emergency preparedness agencies would require accurate information as to what resources are needed where, where those resources are located, and how those resources can be allocated equitably and transported to the points of need. Again, to

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[1]See for example, C. R. Neu, *Economic Models and Strategic Targeting* (U), The Rand Corporation, R-1864-ARPA, June 1976, SECRET; H. M. Berger, *A Critical Review of Studies of Survival and Recovery After a Large-Scale Nuclear Attack*, R&D Associates, RDA-TR-107006-009, December 1978; and A. Feinberg, *Civil Preparedness and Management of the Post-Attack Economy: A State-of-the-Art Review*, Analytical Assessments Corp., AAC-TR-9204/79, September 1979.

accomplish this would require efficiently functioning support systems. The problem, however, is that the immediate post-attack period is likely to be characterized by such problems as communication systems that provide incomplete and/or contradictory information, transportation systems that can not function due to failures to match vehicles with drivers and fuel supply points, and organizational structures with competing lines of authority that create delays and confusion in resource allocation decisions. As summarized by one writer, the major problems will be in developing the transportation, communications, and organizational capabilities required to bring these resources to bear at the points where they are needed.[2]

Given these circumstances, it appears highly probable that at the point when the nation is in greatest jeopardy, there is also the greatest potential for instabilities arising that would lead to the collapse of the system. Obviously, careful pre-attack planning of post-attack management policies is needed to help mitigate the effects of these potential instabilities and thus improve the nation's chance for timely recovery to its pre-attack status as a major world power.

It is somewhat ironic that while effective resource management policies are recognized as being critical for economic recovery, little attention has been paid to the problem of properly measuring the impact of various post-attack management policies on the performance of the economy. For example, what effects do inventories of key supplies and equipment and their pre-positioning have on the performance of the post-attack economy? what are the critical delays that will degrade economic recovery? where are those delays found in the communication and transportation networks? in the organizational structures? what effects do alternative allocation mechanisms have on productivity?

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[2] S. G. Winter, Jr., *Economic Viability After Thermonuclear War: The Limits of Feasible Production*, The Rand Corporation, RM-3436-PR, September 1963.

A major reason for the inattention is that those studies that investigate post-attack economic recovery typically assume that since sufficient production capabilities and resources will exist after a nuclear exchange, it is only a matter of time before the growth of the economy begins anew. In other words, it is only a question of when. But, if it is possible to show that with the same initial conditions after an attack, the economy of the nation can remain viable or collapse depending on which post-attack management policies (and in some cases, pre-attack policies) are selected, the need for exploring the problem of economic viability would be undeniable.

The present study reports on research investigating this problem. The central task was to explore the structure of the post-attack economic system for instabilities, identify the processes that would lead to its collapse, and then evaluate if and how alternative pre-attack preparations and post-attack management policies could mitigate the effects of those instabilities.

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III. APPROACH

The critical first step in any modeling effort is to develop a conceptual model of the "real" world system that is being studied. This conceptual model then forms the basis for the simulation model that will be constructed. Since there are many different ways to conceptualize any "real" system (different levels of aggregation, different structural components chosen for particular emphasis, and so on), considerable thought should be given to the question of what you want the model to be capable of demonstrating.

The present case is no different; several caveats have guided the selection of both the general modeling approach and the specific elements included in the model. At the conceptual level, the most important initial consideration has been our characterization of the system serving as the "real" world referent: post-attack economic viability. We framed the model in terms of an inventories "race." The analogy is useful in that immediately after any nuclear exchange, there would be a period during which the surviving population would be sustained by pre-attack stockpiles and inventories. Shortly thereafter, efforts would begin to reorganize the economy to start up production of critical supplies and materials.

Winter, who first presented the conceptual notion of an inventories race to depict the problem of post-attack viability, succinctly characterized the challenge of post-attack management:

> Unless production of the necessities of life can be resumed, whatever success there has been in protecting the population from the immediate consequences of the war will dissipate as supplies of food, medicines, and heating oil disappear; the surviving thermal generating plants exhaust their supplies of coal and fuel oil, and starvation, disease, and exposure take their toll.[1]

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[1] S. G. Winter, Jr., *Economic Viability after Thermonuclear War: The Limits of Feasible Production*, p. 10, The Rand Corporation, RM-3436-PR, September 1963.

In other words, it is during this period that the race will be won or lost. If the rate of drawdown on inventories exceeds the rate of replenishment over a sufficiently long period, the scenario depicted by Winter would emerge and the post-attack economy would collapse. If, however, the drawdown rate is eventually balanced or exceeded by the replenishment rate, the system would become viable and recovery would follow. Conceptualized in this manner, the first requirement is to construct a model with the capability of testing for systemic instabilities likely to influence the outcome of the race.

A second general requirement of the model concerns its ultimate use. Although the general focus of the model concerns the instabilities affecting the inventories race, the model must be capable of evaluating the effects of alternative post-attack management policies on those instabilities identified in the system. Without this capability, it would be impossible to answer the basic question of whether or not it is possible to demonstrate how the same system can collapse or remain viable depending upon the emergency preparedness policies adopted in the post-attack period.

The third requirement for the model is more specific. It concerns the inputs and constraints that would operate in the model. Since it is highly likely that post-attack demand would be radically different from pre-attack demand, the model should not utilize pre-attack coefficients in the equations depicting post-attack economic relationships. For example, where productivity may be primarily a function of capital investment in the pre-attack economy, productivity in the post-attack economy may depend heavily on the availability of food and heating oil and only to a lesser extent on the capital available. It is not likely that this relationship between subsistence level and productivity would emerge in an econometric model, for instance, where economic behavior is depicted by equations derived from the modeler's understanding of a normally functioning economy.

A fourth, and related requirement for the model pertains to the nature of the relationship between economic inputs and outputs. Characteristically, input/output relationships are represented as being linear, a specified amount of input "x" results in a specified amount of output "y" with increments of "x" resulting in linear increments of "y." In the post-attack economy, the situation would be quite different due to the level of damage and destruction. For example, if a significant portion of an industry's capacity has been destroyed, linear incremental inputs will not result in corresponding linear increments of output. Thus, the model must be capable of operating with non-linear production factors.

Delays will be inevitable in the post-attack economy. Thus, a fifth requirement of the model is that it be capable of simulating the various delays that would affect the start-up of production. Examples would be delays affecting transportation, retraining labor, information flows, decision times, repair and replacement times, and the lead times affecting production processes. These delays would not be uniform nor would they be isolated in their effects. Two or more delays may create either synergistic or unwelcomed higher order effects in the system. Since these delays and their effects are an essential feature of the instabilities we are searching for, their inclusion is critical to the overall effort.

A sixth requirement of the model is that it not operate under steady-state or static conditions. The immediate post-attack period is indelibly marked by dynamic time dependencies that cannot be ignored in evaluating the viability race. These include resource allocation decisions, time lags in production and distribution cycles as well as inventory depletion and capital accumulation for investment. A model operating with steady-state assumptions would miss several of the fundamental sources of instabilities that could lead to the system's potential collapse.

Uncertainty is also a major factor to be considered in analyzing post-attack viability. Uncertainties abound, particularly in the period immediately following an attack when recovery operations are beginning and the information critical to their success is at best incomplete and at worst unreliable. Thus, a seventh requirement of the model is that it be capable of operating with variable uncertainties about the delays that will affect recovery.

An eighth consideration for the model is that it be able to optimize management policies. Such optimizations may be applied either as a procedure integrated into the model or as a "front-end" to a compatible simulation model. Basically, what is required is that procedures be used to run through the model's variables to determine the 'best' outcome.

A ninth requirement of the modeling approach is that it be able to operate at different levels of aggregation. Structurally, the model will consist of several sectors that represent various subsystems of the post-attack economy. To minimize the amount of time required for detailed data collection, the approach should follow a "top-down" procedure for constructing the model. In this manner, the aggregate representations of the post-attack economy would be used to capture its essential features during this viability phase, and then those sectors which are the most likely to produce potential instabilities would be expanded and further disaggregated to explore those instabilities further.

A tenth and final requirement of the model also concerns the use of "hard" data. Actually, data are less a requirement for a modeling capability than a general strategy for approaching the modeling problem. Given the approach noted above concerning the use of aggregate levels to represent the model's subcomponents, it should be apparent that the modeling approach we espouse is one in which patterns of outcomes cast in terms of rough approximations are favored over precise point estimate results. For one thing, the data requirements for precision are enormous and even then point-estimate precision remains elusive except for the most immediate temporal points. Moreover, the modeler typically becomes rapidly bogged down in Herculean data gathering efforts only to discover in the long run that those data efforts were not required for each subcomponent at the level of detail needed to investigate the phenomena of interest.

Also, since the primary research interest is in discovering whether post-attack management could make the difference between viability or collapse, the model only has to be able to produce both outcomes (viability and collapse) through general policy and parameter adjustments. Extensive resources would not have to be focused on precisely calibrating the model with detailed data sets. In effect, what this modeling strategy means is that we have chosen to explore the general behavior of the system in an attempt to identify the potential regions of instability, given the general parameters and policies that may exist. While a more precise determination of these parameters would be required for specific recommendations, the general approach followed in the present effort is more than adequate to answer the proposed research question.

Given the array of requirements and capabilities presented in the preceding discussion, the most appropriate modeling approach was found to be system dynamics. System dynamics is essentially a simulation modeling paradigm (that incidentally utilizes a specialized, tailor-made, and highly efficient programming language, DYNAMO) that aids modelers in conceptualizing, formulating, and operating models of "real" world systems. System dynamics was developed initially by Jay Forrester and his colleagues at Massachusetts Institute of Technology to aid in understanding the dynamic behavior of complex systems. Fundamentally, system dynamics views systems as being comprised of components that are connected in circular, interlocking, and time-delayed manners and that the structures and processes that comprise these systems are equally important as the behavior characteristics of the system components themselves.[2]

System dynamics has several recommending attributes. First, and perhaps foremost, is the fact that this approach views systems as a series of interlocking feedback loops and it is the feedback that produces the behavior of the system over time. As stated earlier, system instabilities represent the focus of the present research effort. It is therefore entirely appropriate that a technique be used that analyzes system behavior in terms of positive and negative feedback loops since these two types of feedback loops and their combinations can produce the instabilities of interest.

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[2] See Jay W. Forrester, *Industrial Dynamics*, Cambridge: MIT Press, 1961; and *Principles of Systems*, Cambridge: Wright-Allen Press, 1968.

A second recommending feature, related to its feedback loop aspect, is that system dynamics has been demonstrated as an effective analytical technique for evaluating the effects of alternative policies on system behavior. Several notable studies have been conducted in such diverse fields as urban and regional studies, industrial production and marketing, criminal justice, energy policy, economics, and international systems. In each case, the models developed to study these systems have examined the systemic behavior under a variety of assumptions concerning policies that may influence the ultimate fate of the system under question. Perhaps, the report to the Club of Rome (*The Limits to Growth*) provides the strongest evidence of the policy orientation of the system dynamics approach.

At a more specific level, system dynamics is useful because of its versatility. For example, non-linear relationships are readily accommodated. In fact, system dynamics can operate with many types of non-linear relationships that help produce exponential, sigmoidal, or even oscillating system behavior. Similarly, the technique focuses on both negative and positive feedback loops and in the context of these loops, effects produced by delay mechanisms can easily be examined. And finally, the data requirements of system dynamics are such that highly aggregated representations can be used to model any system initially. More importantly, once the sensitivity of each structural component and its appropriate feedback loops are identified, those that are the most sensitive can easily be disaggregated and more precise bounds can be determined. The modeler is not required to disaggregate every structural component to provide a consistent level of analysis.

In summary, given the requirements of the research task and characteristics of the system dynamics approach, the application of this particular dynamic simulation technique seemed an obvious way to proceed.

IV. MODEL DESCRIPTION

Winter's early study of the limits of feasible production in a post-attack economy is one of the earliest quantitative treatments of the problems posed by limited resources and technological capabilities in the post-attack period.[1] While Winter did not address the organizational problems involved in the post-attack economy (although he discusses them qualitatively in a later paper), he did offer a definition of what constitutes viability and presented a simple model of the technological requirements for achieving economic viability. According to Winter:

> An economy is viable if it is functioning and capable of producing, without external aid, an output sufficiently large and appropriate in composition to:
>
> (a) provide its workers and their families with a level of consumption high enough to maintain their productivity and to give them the incentive to continue to contribute their services to the economy in a socially productive way;
>
> (b) meet any fixed claims on its output that may exist;
>
> (c) maintain the stock of real capital (including inventories) required to accomplish (a) and (b).[2]

Using this definition, Winter goes on to note that since it is unlikely that the economy would be capable of meeting these requirements in the immediate post-attack period, the problem is to reorganize the surviving resources to provide for a viable economy. Again, although Winter disregards "effects of the war on social arrangements by which economic activity is guided," Winter argues that explanations for non-viability would be narrowed to the fact that critical segments of capital stock

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[1] S. G. Winter, Jr., *Economic Viability after Thermonuclear War: The Limits of Feasible Production,* The Rand Corporation, RM-3436-PR, September 1963.

[2] Winter, 1963, p. 17.

(including labor skills) would be lost. Thus, economic viability could be achieved, from the technological perspective, if the remaining capital stock (inventories and skills included) is both adequate in size and composition to:

(a) restore the capital stock to a level and composition consistent with viability;

(b) meet any fixed requirement that may exist;

(c) support the members of the labor force and their families at a level sufficiently high to prevent a significant reduction in the labor supply available for the reorganization effort.[3]

The diagram in Figure 1 depicts graphically the essential elements of Winter's model. Time is the critical element in the "inventories race" of which there are two basic outcomes. Either the production capacity (K_o) of the economy will be sufficient to achieve the viability threshold ($\bar{K}$) and meet the requirements noted above (represented by the solid line K_o) or, that capacity will not be achieved, inventories (S_o) will be depleted, and the economy will collapse (represented by the dashed line).

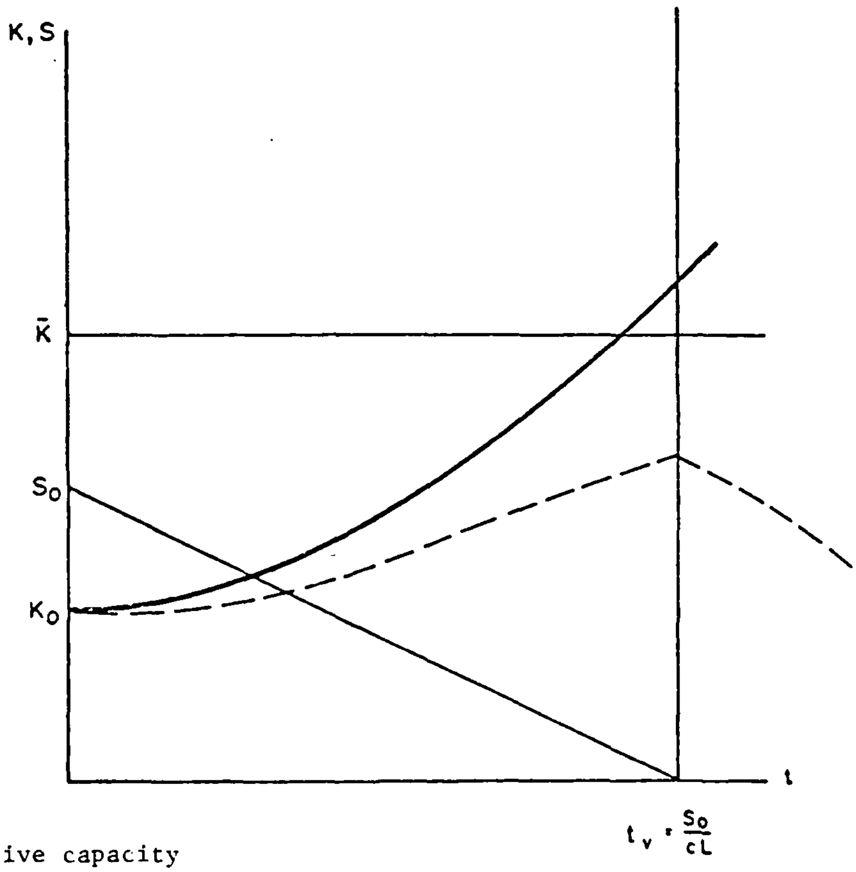
Winter's framework for analysis is extremely useful in that it focuses attention on and underscores the importance of understanding the fundamental problem in achieving viability: restoring productive capacity before inventories are depleted. Although highly aggregated and admittedly preliminary, Winter's approach and framework provide a useful point of departure for the present modeling efforts.

While Winter was interested in determining the technological constraints on achieving economic viability, the present effort expanded the analytic domain to include the organizational aspects that would affect the outcome

[3] Winter, 1963, p. 18.

FIGURE 1

SUCCESS AND FAILURE IN ACHIEVING VIABILITY



K = Productive capacity
S = Inventory of food
L = Labor
$\bar{K}$ = Productive capacity required for viability
S_o = Food inventory at end of survival period
K_o = Productive capacity at end of survival period
t_v = Time of depletion of food inventory
S_o/cL = Ratio of food stock to food requirements per period

From Winter, 1963, p. 22.

of Winter's inventory "race." By expanding the analytic framework to include these organizational aspects, many of the critical resource management problems could be examined. It was noted at the outset of this report that historical case studies reveal how post-war economic recovery has been hampered due to inefficient communication and transportation networks, organizational structures, and resource allocation mechanisms--the basic support systems for effective resource management.

The pilot model we developed for studying these resource management problems in the immediate post-attack period focuses on these support systems since they represent the sources of instabilities that ultimately determine the viability of the nation. The central question is what conditions lead to these instabilities and how can alternative emergency preparedness policies mitigate their effects?

To answer these questions, a system dynamics model was constructed of a post-attack economy using Winter's model as a point of departure. The behavior of this model reveals the sources of instabilities in the post-attack economy and identifies their characteristic effects on the performance of the economy. Through repeated simulations, insights are gained as to how alternative emergency preparedness policies can mitigate the effects of these instabilities and insure viability and the eventual recovery of the nation.

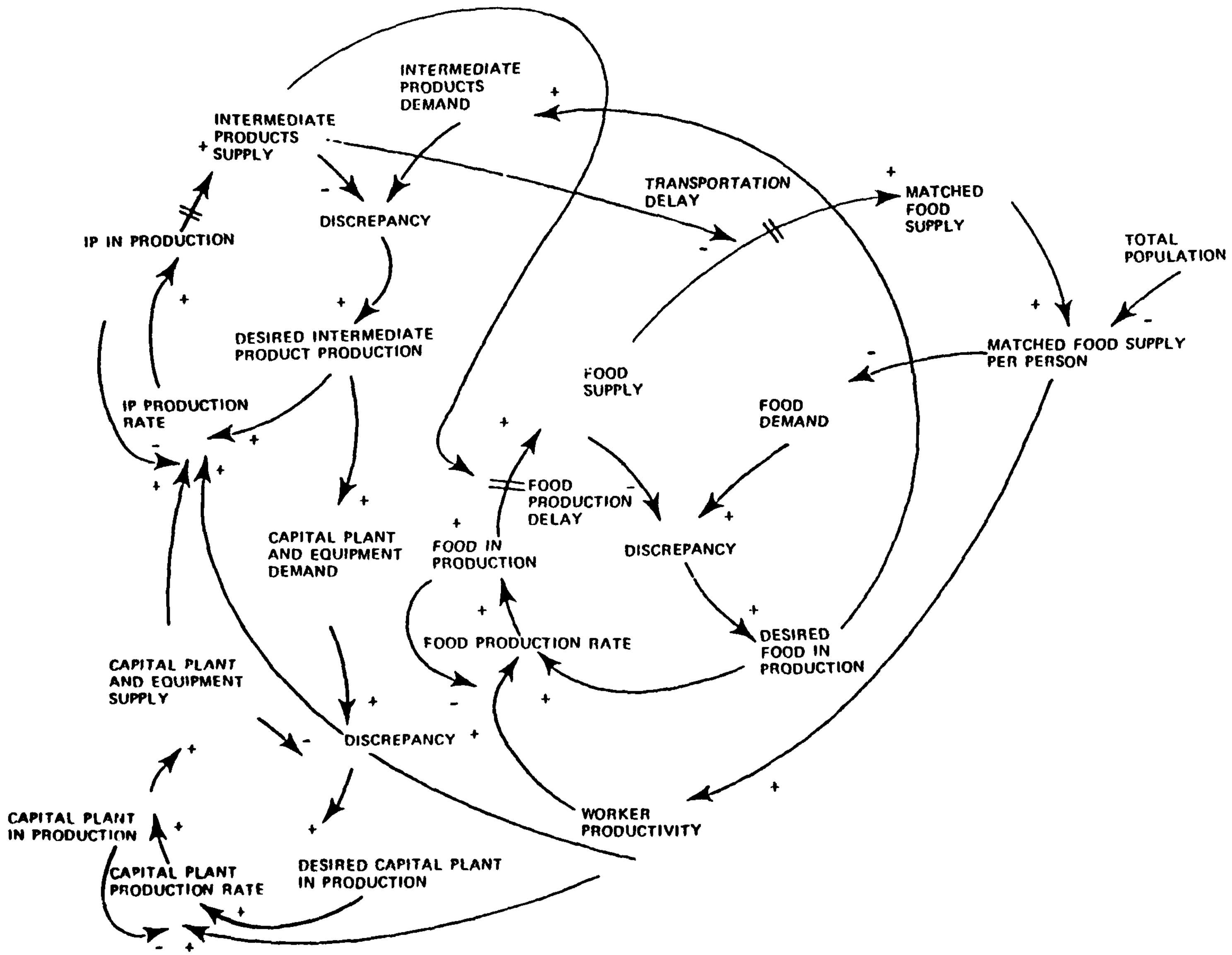
The model was developed in several stages with each stage representing an enhancement and refinement over the previous stage. The current version, PAM4 (Post-Attack Model No. 4), operates with four basic sectors that represent the structural components of the post-attack economic system. These four are capital plant and equipment, intermediate products, labor, and food supplies. The food supply sector is further disaggregated into production, transportation, and distribution (called matched food supply) subcomponents.

These sectors and subsectors are interrelated through interlocking feedback loops that depict the interaction of these sectors in terms of information and material flows. Figure 2 presents this feedback loop structure. It is a causal loop diagram of the post-attack system that defines

FIGURE 2

CAUSAL LOOP DIAGRAM

SUPPLY DRAWDOWN VERSUS SUPPLY REPLENISHMENT



the basic causal relationships between the system variables. The causal relationships cluster into the feedback loops structure shown in Figure 2.

Several feedback loops are presented in Figure 2. The arrows indicate the direction of the causation between variables while the (+) and (-) signs indicate the direction of causal influences. For example, the amount of the matched food supply available per person affects the worker productivity in the same direction, a positive manner in this example, i.e., the greater the food supply per person the higher the worker productivity. Worker productivity influences the food production rate which in turn affects the amount of food in production that determines the size of the food supply. Depending on the transportation delay, the food supply affects the matched food supply that then determines the matched food supply per person; thus completing the feedback loop.

Obviously other factors also operate in this feedback loop such as the availability of workers and transportation and the effect of information inputs to determine how much and what types of food need to be produced and where it should be distributed. Appendix A contains a complete listing of the model's equations which can be consulted to obtain a more complete understanding of the system's structure and operating relationships.

Figures 3 through 6 display the causal loop relationships operating in PAM4 (see Figure 2). Basically, each diagram depicts the interrelationships between food shortage, worker productivity a..d demand, and inventory drawdown and replacement rates in the respective sectors of the model. The cross-hatches appearing on selected arrows indicate that a delay operates between the two points. For example, retraining delays affect the reassignment of workers from a general labor pool to individual sectors, transportation delays affect the distribution of food, and production delays reflect the time required to grow food or produce intermediate products.

FIGURE 3

CAPITAL SECTOR

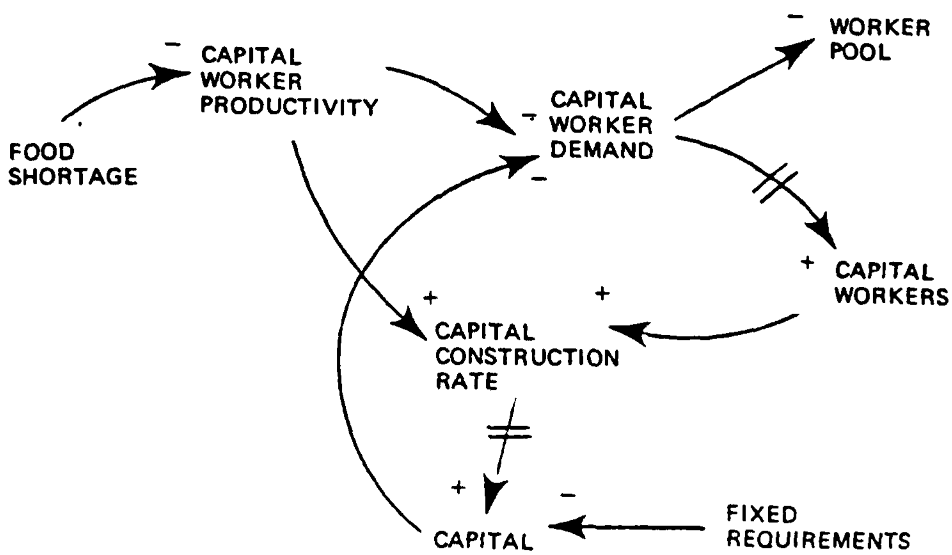


FIGURE 4

INTERMEDIATE PRODUCTS SECTOR

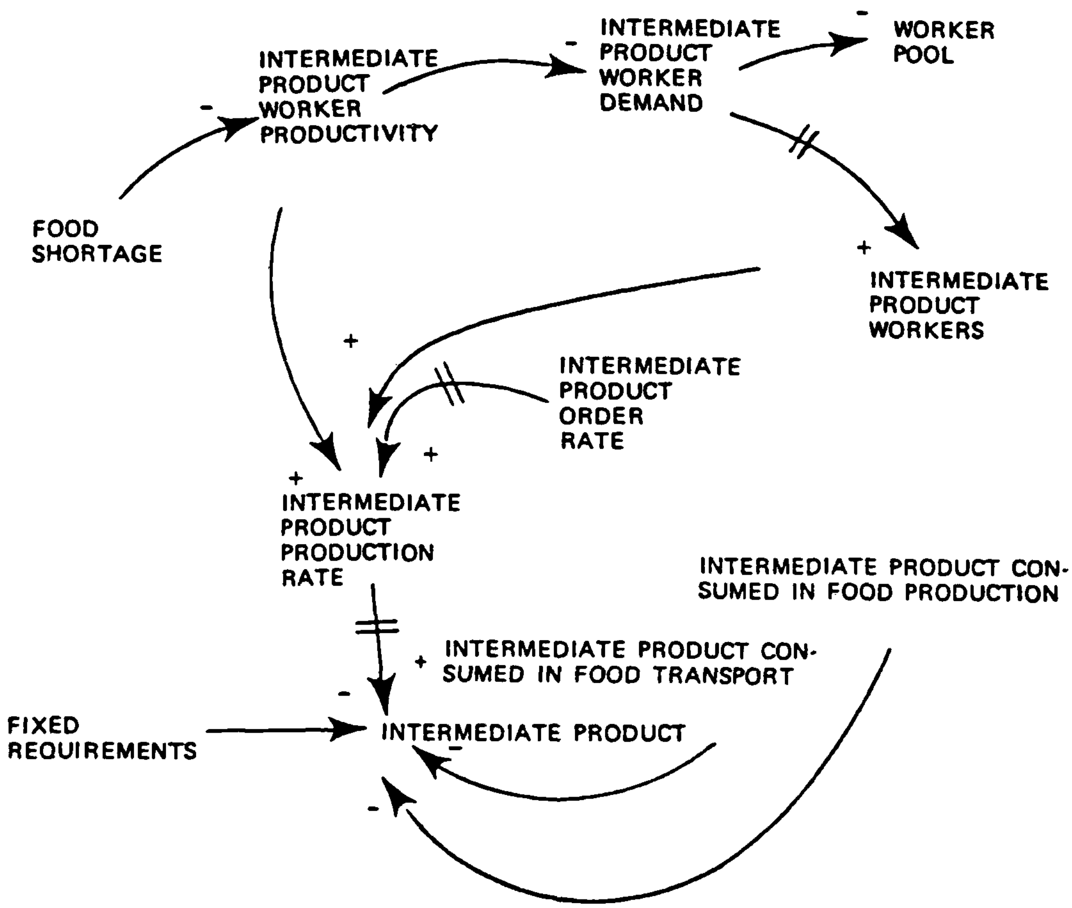


FIGURE 5

FOOD SECTOR

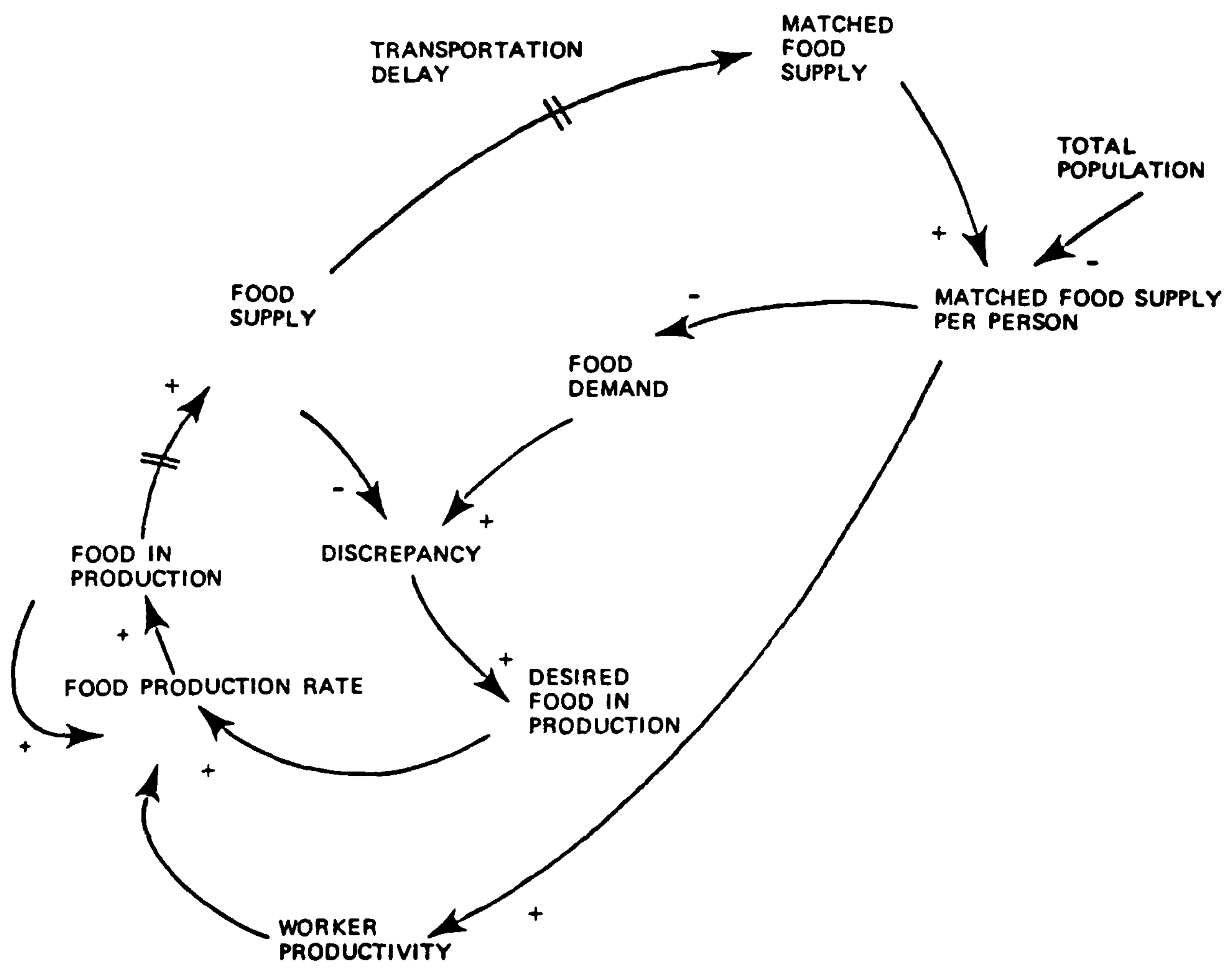
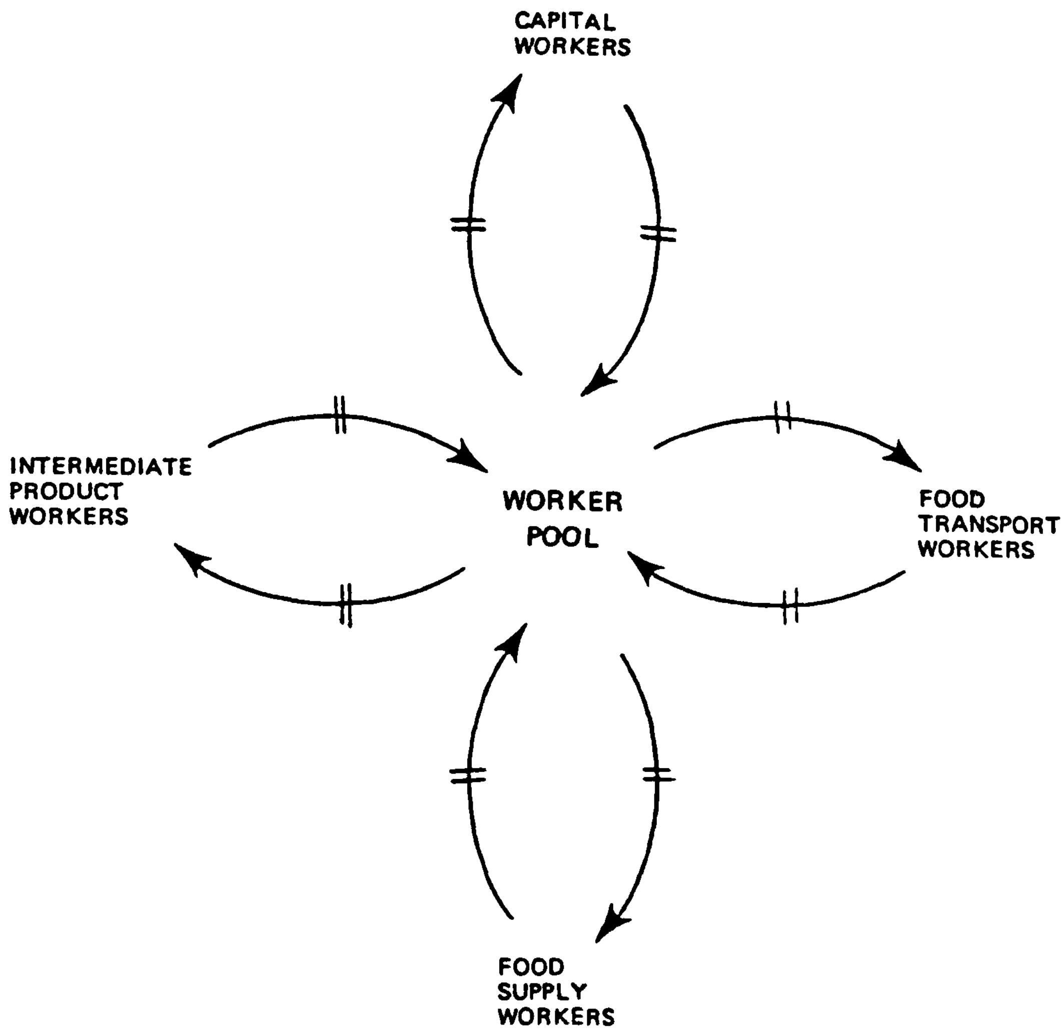


FIGURE 6

WORKER POOL



V. MODEL PARAMETERS

PAM4 served as the basis for examining the potential instabilities affecting post-attack economic viability. (Recall that the strategy was to develop cases in which the same model structure would produce collapse or viability as a function of the management policy variables selected to represent the model's operating parameters.) Since the current research interest centered around discovering whether viability is in fact an issue in post-attack management, the effort focused on whether or not the same model could produce both outcomes--collapse and viability--by adjusting these policy parameters rather than on trying to establish with any great accuracy the specific parameters characterizing the existing system. The rationale for this approach is simply that if viability cannot be shown to be a potential problem, there is little need to focus extensive resources on developing exact sets of numbers and policies for precise calibration of the model. If, on the other hand, viability cannot be demonstrated as a certainty, and it in fact depends on which sets of numbers and policies are actually in effect at the time of an attack, subsequent research efforts can then focus on improving the model's precision.

The search for instabilities focused on the key operating parameters in PAM4. These parameters represent areas in which alternative management policies can be implemented to influence and direct the system. They include:

- the effect of initial conditions on the model, i.e., the amount of product on hand and in the pipeline for each sector;
- the effect of food shortages on labor productivity;
- the effect of communication delays in ordering food supplies for distribution;
- the effect of various combinations of external fixed requirements that draw on each sector's inventories;
- the effect of rising expectations concerning food supplies as time progresses in the post-attack period;

- the effect of labor allocation rules on overall economic performance; and
- the effect of time delays associated with locating and retraining labor as workers are transferred between sectors.

Each of these parameters has a range of values associated with it that were used in repeated simulations of PAM4. Since each parameter contains more than one value, the model could be tested under a variety of conditions by varying any combination of parameter values. For example, the tests for instabilities could be conducted under conditions of high or low fixed external requirements, short or long communication and labor allocation delays, high or low levels of stockpiles, and so on. The following section presents the results of these simulation tests.

VI. RESULTS

The results of the simulation tests of PAM4 offer a number of useful insights regarding the nature of the instabilities affecting post-attack viability and lead to several conclusions concerning the effects alternative post-attack management policies have on those instabilities. Thus, the following discussion presents the results in terms of changes in the behavior of the system brought about through changes in its operating parameters and policies. In presenting these results, several choices exist for characterizing the behavior of the modeled system. Another way to state this is to say that various objective functions can be used to describe how the system's behavior changes under alternative operating conditions. The level of capital or intermediate product stocks, worker productivity, or food supplies represent, singularly or in combination, potential objective functions. In the present case, we have selected the amount of matched food available per person (MFAPP) as the primary criterion for assessing the system's performance. Since viability has been characterized as a 'race' between inventory drawdown and replenishment and since food represents a fundamental factor in worker survival and productivity, selecting this variable as the objective function seemed an obvious choice.

Simulations of the PAM4 model were run over a 24-month period, a time span that is generally regarded as the upper bound for the nation to regain viability. Since PAM4 is intended as a viability model, it does not include any capability for assessing economic damage in the trans-attack period. In other words, the model's calculations assume that an attack is over and that the initial conditions characterizing the system reflect the economic damage that occurred.

The results of the simulation test runs are presented in a framework similar to that used by Winter and presented previously in Figure 1. Like Winter, the results presented here examine the behavior of the system over time (the x-axis) but unlike Winter's conceptualization, our results employ the variable MFAPP as a surrogate for the productive capacity (K) and inventory of food (S). (Three times subsistence level is considered to be the normal level of food consumption, as indicated on the y-axis of the graphs depicting the simulation results.) Similarly, where Winter denoted $\bar{K}$ as the productive capacity necessary to achieve viability, we have selected a subsistence level of matched food supplies (F_s) to represent the viability threshold. Thus, in interpreting results, if the simulation tests reveal the system to be operating below this subsistence level (F_s) for an extensive period of time, the conclusion would be one that points to a pervasive system instability rendering the economy non-viable given the operating policies and parameters of that particular simulation test.

The results from the first set of simulation tests from PAM4 are displayed in Figure 7. These curves depict system viability versus non-viability as a function of the initial conditions of the nation's food supply stockpile when a subsistence level food rationing policy has been initiated immediately following a nuclear attack. The first curve (presented in Figure 7 on the left) represents initial conditions under which the population has a matched food supply (on-hand) of one month at a (40 pound/month per capita) subsistence level, and another month of food supplies inventories at remote production and distribution points. Clearly, the system portrayed by PAM4 and the pre-attack conditions (food stockpiles) and post-attack management policies (subsistence level rationing) do not constitute a viable system.

Figure 7 also displays the results of PAM4 simulations when food supply inventories (not co-located with consumers) were set at six- and twelve-month levels. Given an initial condition of a six-month stockpile, the subsistence level is maintained for five months then drops below this level for approximately four months. As seen in Figure 7, a turn-around occurs at month 15 when the matched food supply begins to decrease, leading to the eventual collapse of the system. When simulated using an initial condition of a 12-month food supply stockpile, this downturn does not occur. The amount of food available per capita remains above the subsistence level after the brief drop between the fifth and tenth month.

Figure 8 presents the results of a second series of simulations. In these simulations, the same parameters and policies as those in Figure 7

FIGURE 7

VIABILITY AND FOOD SUPPLY
(1 MONTH MATCHED FOOD SUPPLY ON HAND)

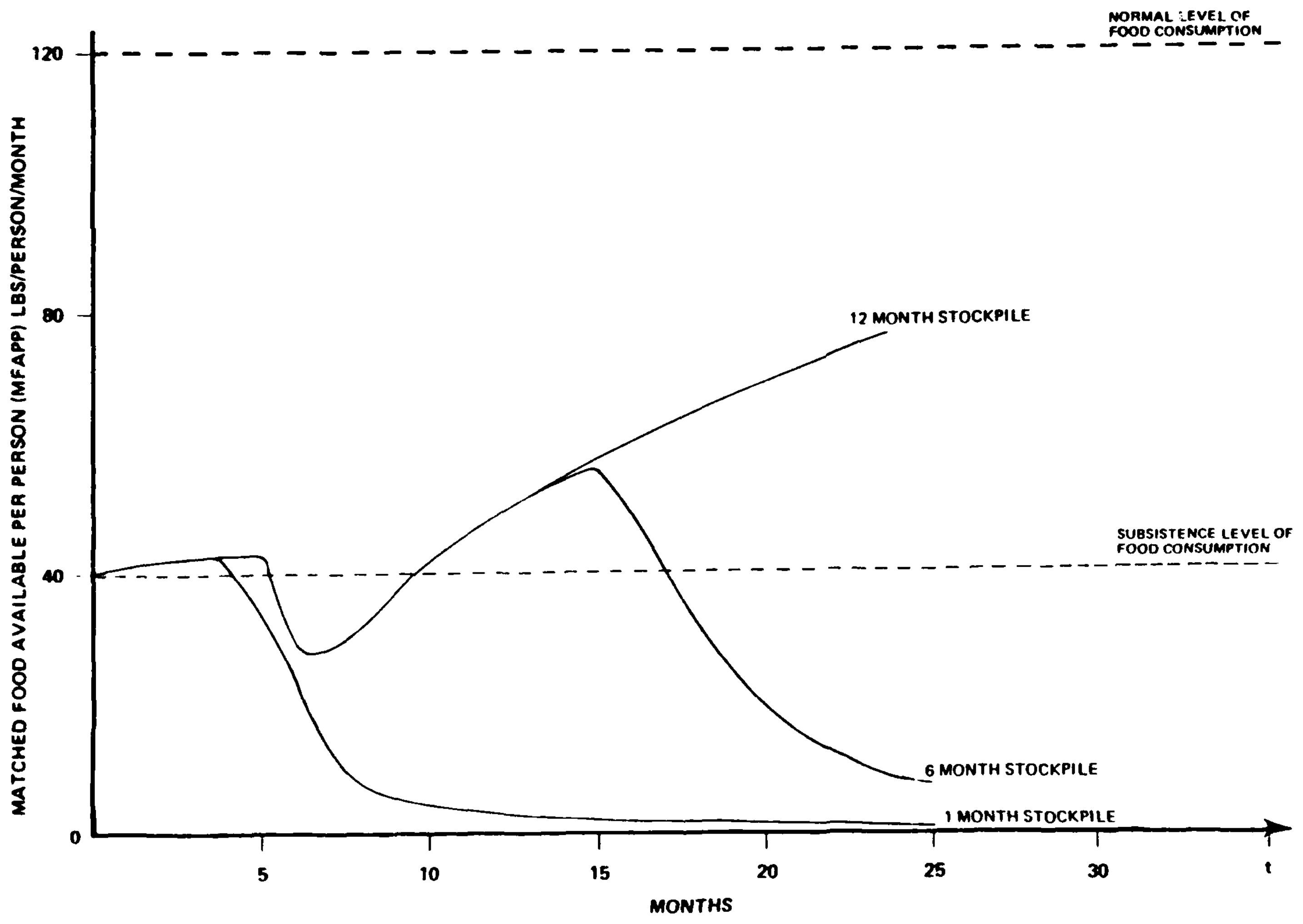
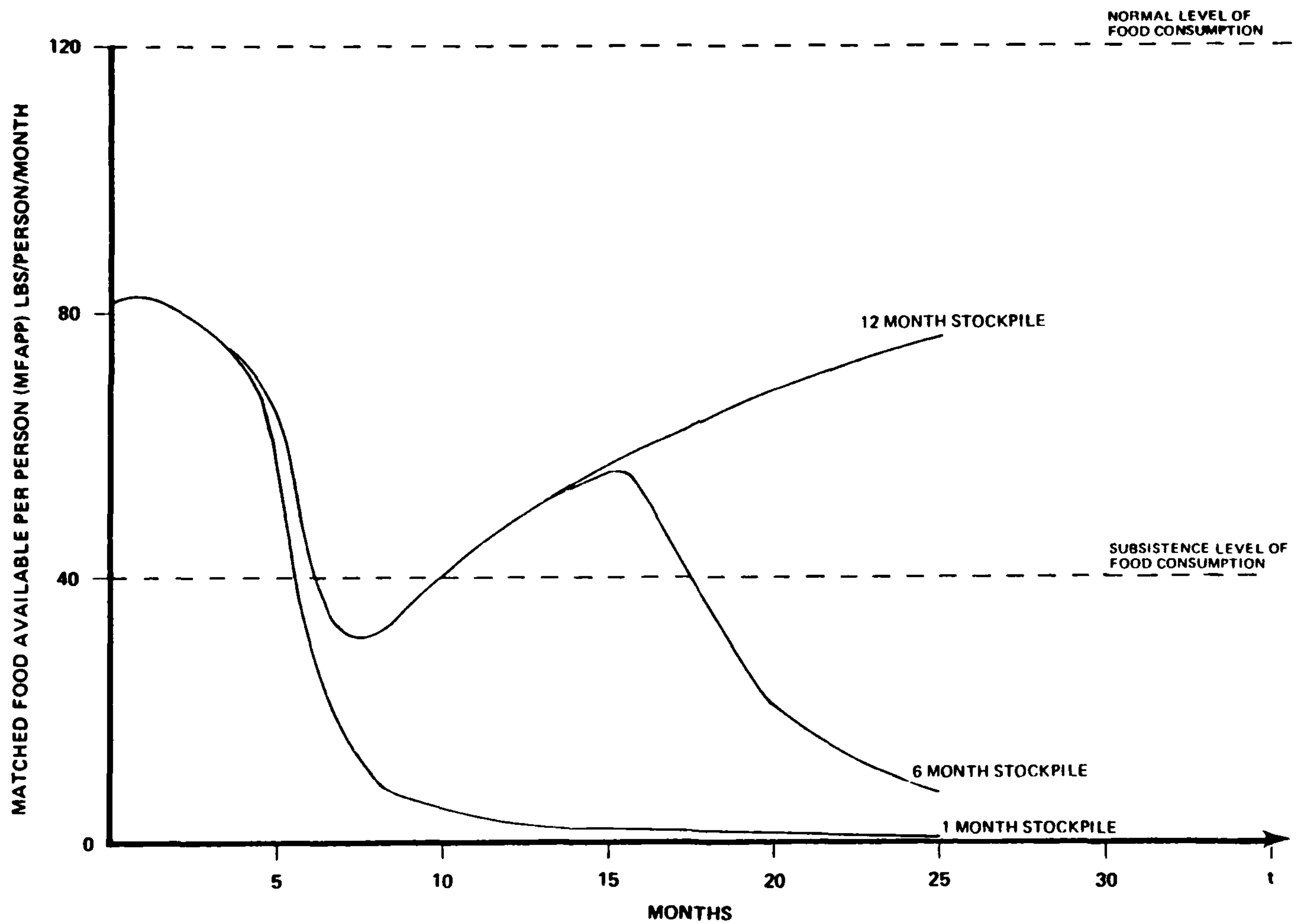


FIGURE 8

VIABILITY AND FOOD SUPPLY

(2 MONTH MATCHED FOOD SUPPLY ON HAND)



were used except that the initial amount of food available per person (co-located with consumers) was set at twice the subsistence level. The results for the three cases (1-, 6-, and 12-month stockpiles) examined previously reveal once again that viability conditions are met in only one case--the 12-month food supply stockpile.

Figure 9 extends the analysis by presenting the simulation results using initial conditions in which the matched food supply was set at three times the subsistence level. Again, only the 12-month stockpile case met the viability condition.

The results displayed in Figures 7 through 9 reflect post-attack management policies and procedures that are operating under favorable conditions. For example, the communication and transportation delays that affect management activities have been set at one month in these simulations of PAM4. In this sense, the system has been simulated using favorable conditions. More realistically, however, the post-attack period will probably be characterized by longer transportation and communication delays than have been used in the example runs thus far.

Figures 10 through 12 present the results of PAM4 simulations when longer transportation delays are introduced into the system. These simulations were run using the assumptions of a 12-month food supply stockpile and three different initial conditions regarding the availability of matched food supplied (those supplies on hand that do not have to be transported and distributed). Figure 10 is based on a matched food supply at subsistence levels, Figure 11 at twice subsistence levels, and Figure 12 at three times subsistence levels. The solid line reflects the undelayed system while the dashed line portrays the effects of an initial three-month delay in transporting and distributing the food supplies to the points of need.

As seen in these figures, the introduction of these transportation delays significantly degrades the performance of the post-attack economy as measured by the level of the matched food supply available per person. Although the simulation results for each case show food availability, returning above the threshold level, the nature of the recovery raises an interesting question; namely, how long can food availability remain below subsistence levels before the system collapses? In both Figures 10 and 11,

FIGURE 9

VIABILITY AND FOOD SUPPLY

(3 MONTH MATCHED FOOD SUPPLY ON HAND)

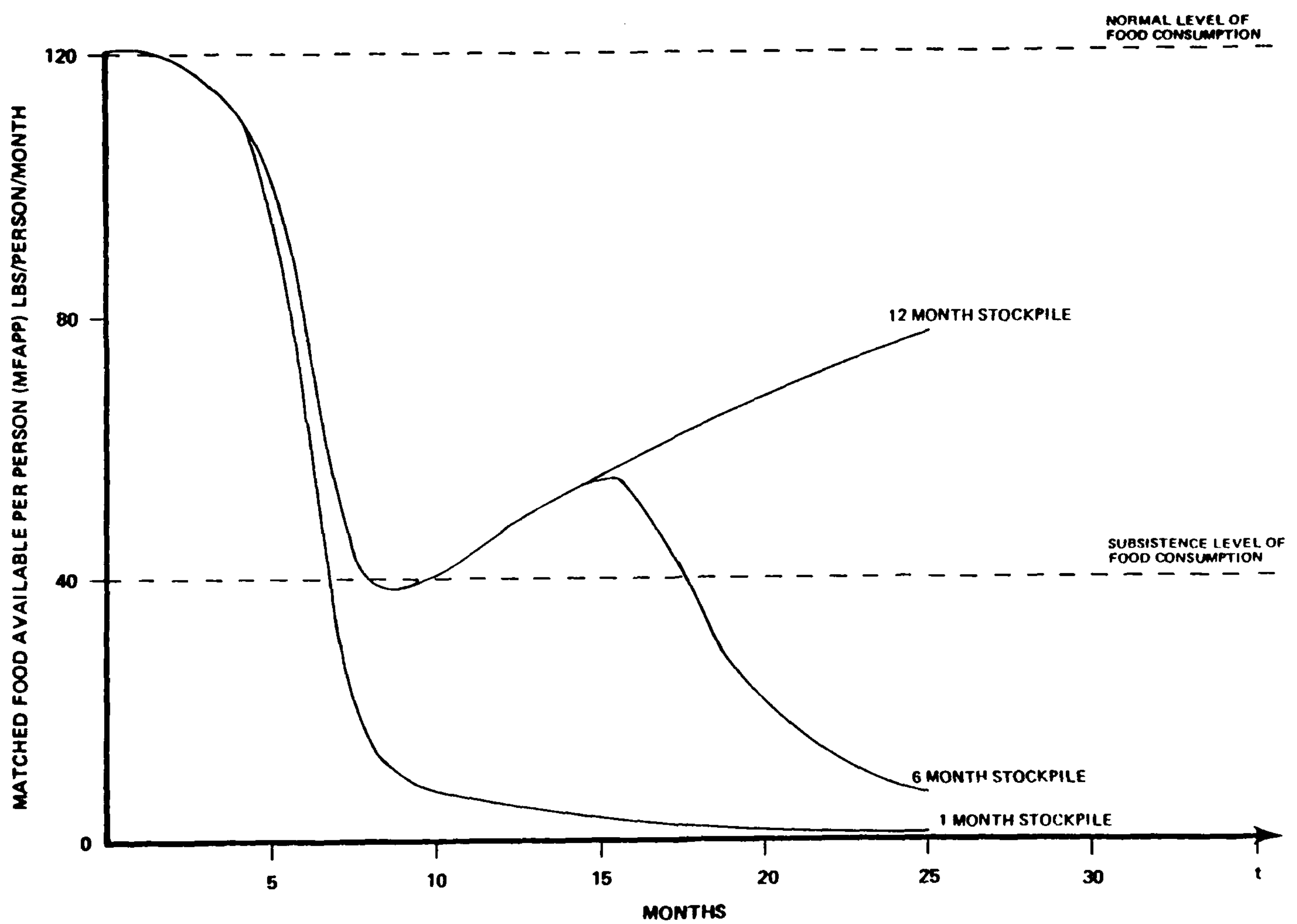


FIGURE 10

VIABILITY AND FOOD SUPPLY WITH TRANSPORTATION DELAY

(1 MONTH MATCHED FOOD SUPPLY ON HAND)

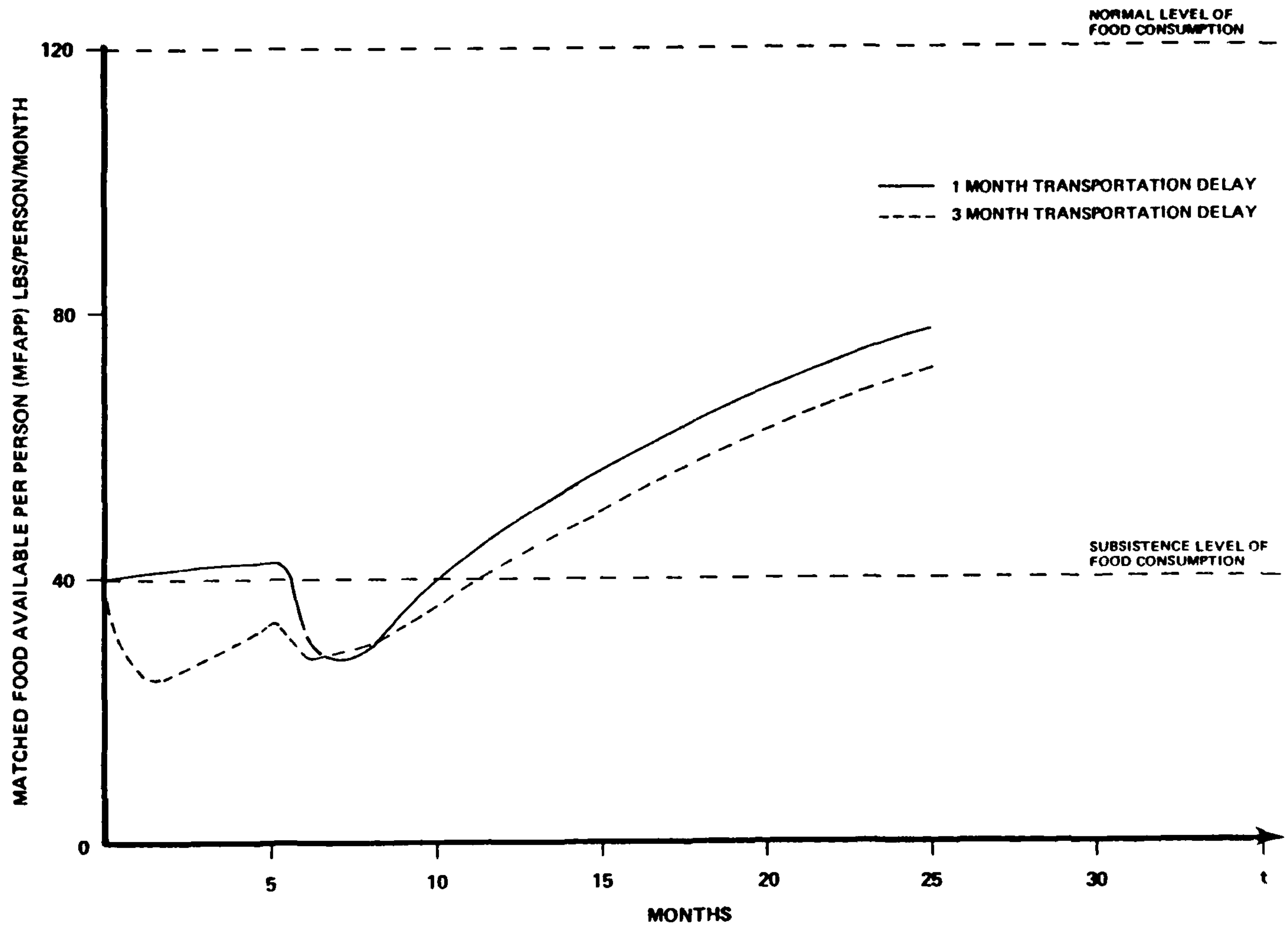


FIGURE 11

VIABILITY AND FOOD SUPPLY WITH TRANSPORTATION DELAY

(2 MONTH MATCHED FOOD SUPPLY ON HAND)

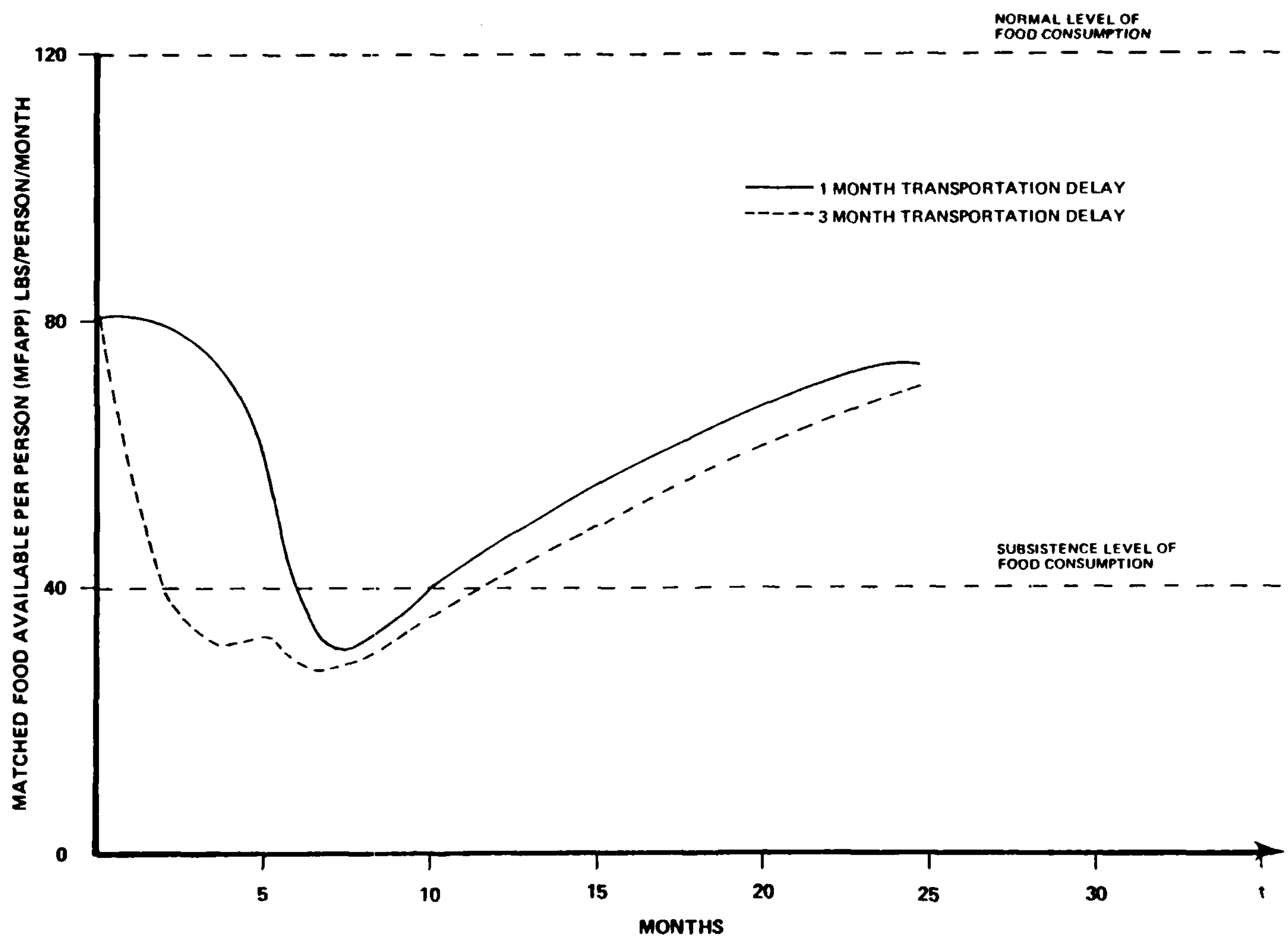
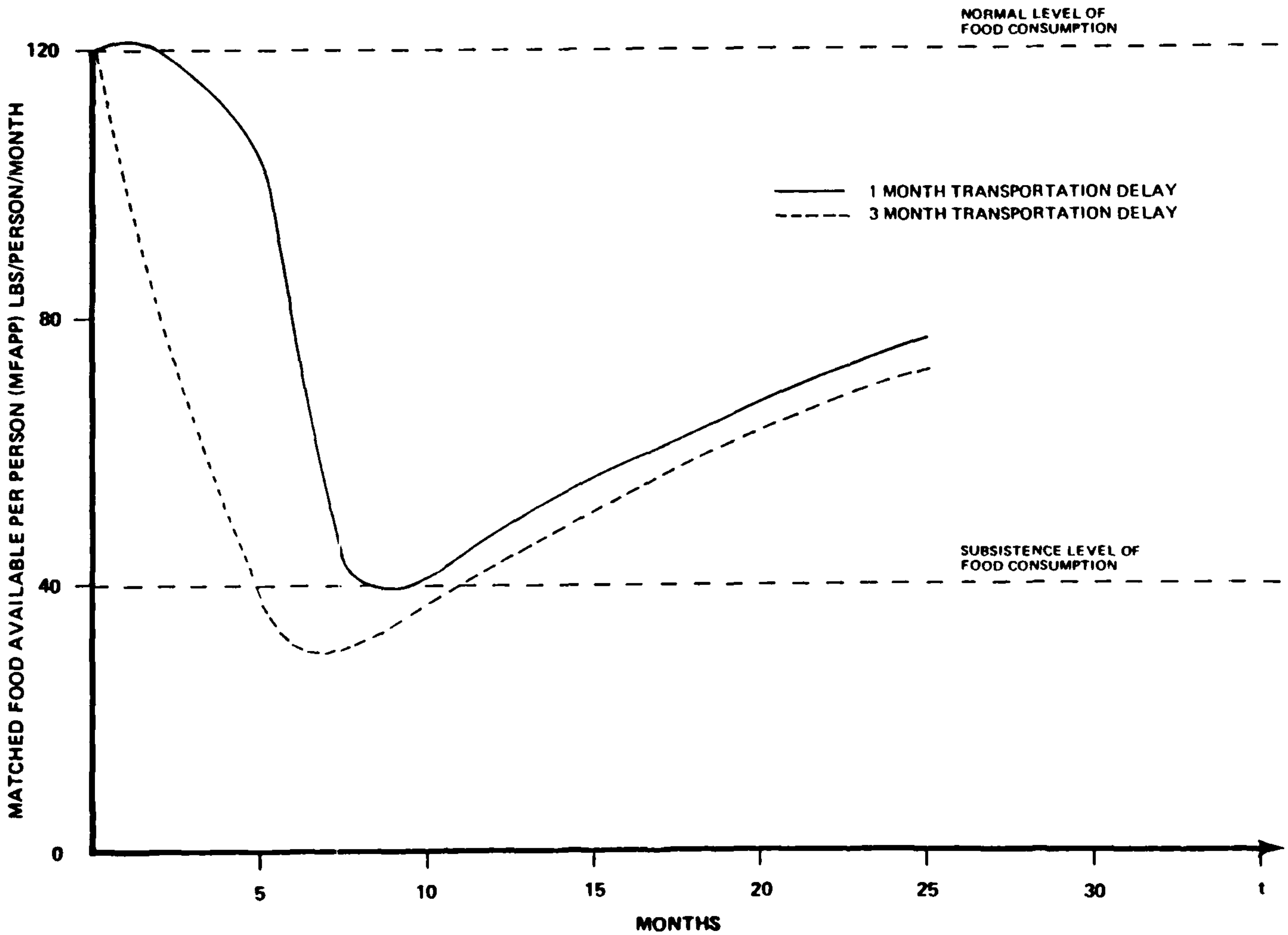


FIGURE 12

VIABILITY AND FOOD SUPPLY WITH TRANSPORTATION DELAY

(3 MONTH MATCHED FOOD SUPPLY ON HAND)



food availability is below the viability threshold level for approximately ten months while the results displayed in Figure 12 show food availability below the threshold for five months. Should one assume imminent collapse in all three cases even though the trajectories reveal eventual recovery? Clearly, the results in Figure 12 are more encouraging in terms of the survivability of the system. The critical point, however, is that the transportation delay is an important source of instability that threatens viability. Moreover, instability is subject to control through effective management policies and actions but only if managers are aware of its potential effects. In this sense, the PAM4 simulations offer an important contribution.

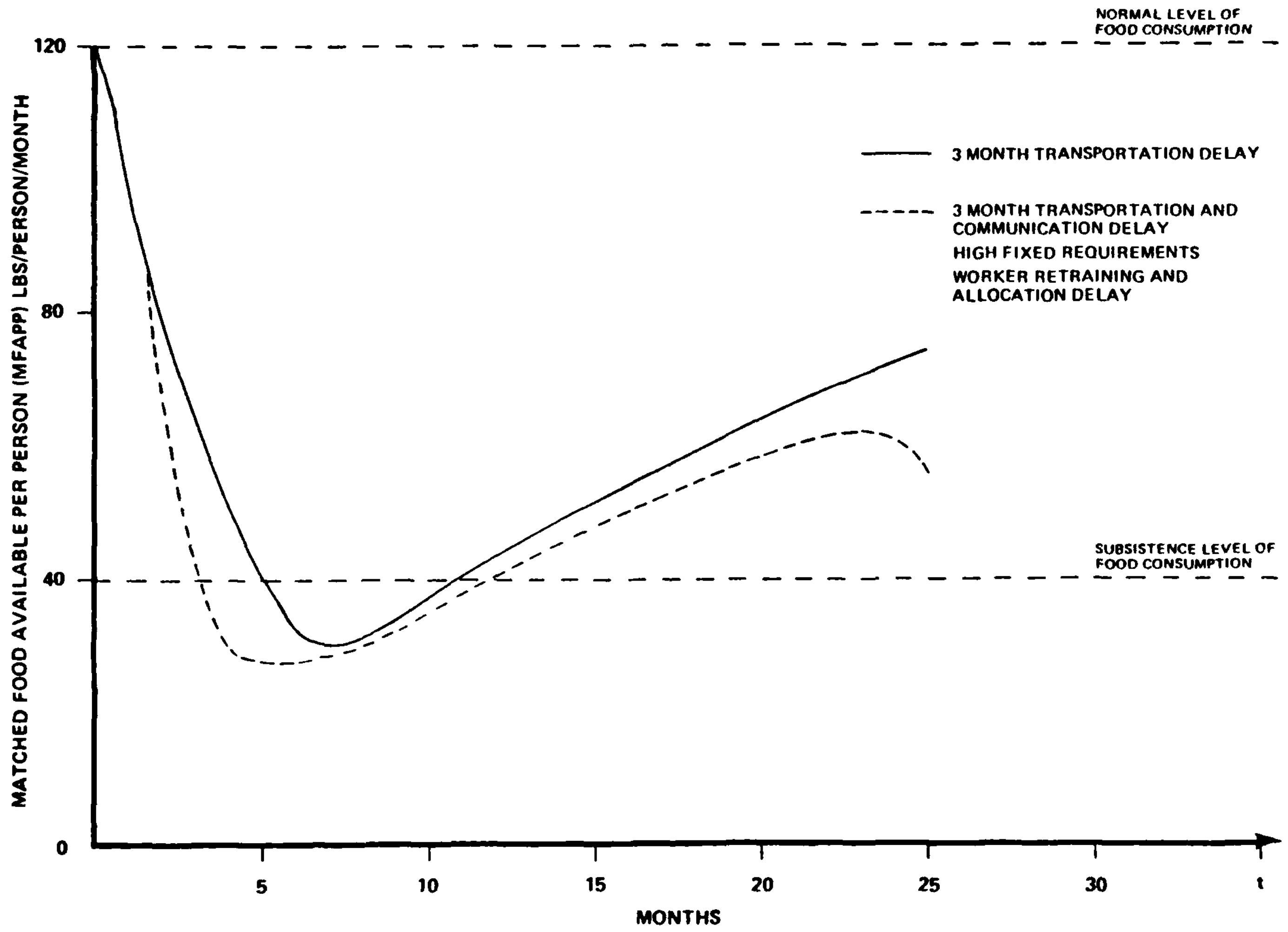
Transportation delays represent only one of the potential sources of instability in the system. Communication delays and delays in retraining and transferring workers between sectors are two additional delay factors that could affect the performance of the economy. Moreover, the economy would be burdened with fixed requirements to support military and official recovery operations. Again, the simulation results for PAM4 presented thus far have not incorporated these factors as operating assumptions.

Figure 13 displays the results of a PAM4 simulation where these assumptions have been adopted. This simulation is based on the following initial conditions: a three-month matched food supply, a 12-month food supply inventory (not co-located with consumers), longer transportation and communication delays, increased worker retraining and allocation delays, and higher fixed requirements on the economy. The solid curve depicts the economy's performance with only the longer transportation delay assumed (from Figure 12). The dashed curve displays the effects of the changes in the assumed initial conditions. It is particularly interesting to note the downturn that occurs later in the simulation period. Not only is the economy's performance degraded initially, the recovery seen in other simulations is never fully achieved. Again, the importance of effective management policies to mitigate the effects of these delays is apparent.

FIGURE 13

VIABILITY AND FOOD SUPPLY WITH MULTIPLE DELAYS

(3 MONTH MATCHED FOOD SUPPLY ON HAND)



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VII. CONCLUSIONS

We noted at the outset of this study that our primary objective was to determine if post-attack viability (or collapse) is automatic for a given system, or if management actions could influence the outcome. In investigating this problem our approach focused on exploring the structure of a post-attack system for instabilities, identifying the processes that could lead to collapse, and then evaluating if and how alternative post-attack management policies could mitigate the effects of those instabilities.

At the conceptual level, our approach was to characterize a system's post-attack viability in terms of an inventories "race." Since the immmediate post-attack period would be marked by a reliance on stockpiles and inventories to sustain the surviving population, the critical question was whether inventories would be depleted before the economy could replenish supplies by reorganizing initial production facilities. Moreover, we wanted to determine how various types of systemic instabilities would affect this inventories race and how management actions could effectively overcome any debilitating effects that these instabilities might have on the ability of the nation to recover. These instabilities may appear due to the delays and uncertainties affecting such basic economic support systems as communication and transportation networks, organizational structures and resource allocation mechanisms.

A system dynamics model was constructed of a post-attack economy to study the management problems affecting these support systems in the immediate post-attack period. Through repeated simulations, the model was able to demonstrate the effects of potential instabilities on the performance of the economy and how alternative management policies could mitigate those effects. While the results should be qualified as being preliminary in the sense that this effort is a first pass at the problem, there is sufficient evidence to proceed with a more extended analysis The evidence suggests that the issue of viability is greatly dependent on effective emergency preparedness policies and resource management actions. The simulation results from the PAM4 model clearly indicate that viability is not automatic even if adequate productive

productive capacities survive; the same system can produce both viability and collapse depending on the choice of policies and management strategies. If ineffective pre-attack and post-attack policies are followed, the potential for debilitating instabilities arising greatly increases and so, too, does the potential for system collapse.

VIII. BIBLIOGRAPHY

Ansoff, H. I.; and Slevin, Dennis P. "An Appreciation of Industrial Dynamics." *Management Science* (March 1968).

Berger, Howard M. *A Critical Review of Studies of Survival and Recovery After a Large-Scale Nuclear Attack.* Marina del Rey: R & D Associates, December 1978.

Buffa, Elwood S.; and Dyer, James S. "Managerial Use of Dynamic Structural Models." *Decision Sciences,* Vol. 8, No. 1 (January 1977).

Coyle, R. G. *Management System Dynamics.* New York: John Wiley and Sons, 1977.

________. "On the Scope and Purpose of Industrial Dynamics." *International Journal of Systems Sciences,* Vol. 4, No. 8 (1973).

Dresch, Francis W. *Information Needs for Post-Attack Recovery Management.* Menlo Park: Stanford Research Institute, April 1968.

________.; and Ellis, H. B. *Criteria for Early Post-Attack Economic Viability of Local Areas.* Menlo Park: Stanford Research Institute, June 1974.

Feinberg, Abe. *Civil Preparedness and Post-Attack U.S. Economic Recovery: A State-of-the-Art Assessment and Selected Annotated Bibliography.* Marina del Rey: Analytical Assessments Corporation, October 1979.

Forrester, Jay W. "Changing Economic Patterns." *Technology Review* (August-September 1978).

________. *Industrial Dynamics.* Cambridge: MIT Press, 1961.

________. *Urban Dynamics.* Cambridge: MIT Press, 1969.

________. *World Dynamics.* Cambridge: Wright-Allen Press, 1971.

________.; and Senge, Peter M. *Tests for Building Confidence in System Dynamics Models.* Cambridge: Massachusetts Institute of Technology, System Dynamics Group, December 1978.

Greenberger, M.; Crenson, M. A.; and Crissey, B. L. *Models in the Policy Process.* New York: Russell Sage Foundation, 1976.

Mass, Nathaniel J. *Destabilizing Impacts of Price and Quantity Adjustments to Relative Supply and Demand.* Cambridge: Massachusetts Institute of Technology, System Dynamics Group, June 2, 1978.

________. *Economic Fluctuation: A Framework for Analysis and Policy Design.* Cambridge: Massachusetts Institute of Technology, System Dynamics Group, 1977.

Neu, C. R. *Economic Models and Strategic Targeting (U).* Santa Monica: Rand Corporation, June 1976 (Secret).

Randers, Jørgen; and Ervik, Leif K., Editors. *The Systems Dynamics Method. The Proceedings of the 1976 International Conference on System Dynamics.* Geilo, Norway: August 8-15, 1976.

Senge, Peter M. *The System Dynamics National Model Investment Function: A Comparison to the Neoclassical Investment Function.* Ph.D. Dissera-tion, Massachusetts Institute of Technology, January 1978.

________. *Tests for Building Confidence in System Dynamics Models.* Cambridge: Massachusetts Institute of Technology, System Dynamics Group, 1978.

System Dynamics Group. *The System Dynamics National Project Annual Report.* Cambridge: Massachusetts Institute of Technology, 1976.

Winter, Sidney G. *Economic Viability After Thermonuclear War: The Limits of Feasible Production.* Santa Monica: Rand Corporation, September 1963.

________. *The Federal Role in Post-Attack Economic Organization.* Santa Monica: Rand Corporation, 1967.

APPENDIX A

PAM4 COMPUTER PROGRAM

```
****************************************************
 INTERMEDIATE PRODUCTS SECTOR
****************************************************

IP.K=IP.J+(DT)(IPRR.JK-IPCR.JK-IPFRCR.JK)            1, L
IP=IPI                                               1.1, N
IPI=1000 UNITS                                       1.2, C
     IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
                TRACTORS, ETC.)
     IPRR   - INTERMEDIATE PRODUCTS REPLENISHMENT
                (PRODUCTION) RATE
     IPCR   - INTERMEDIATE PRODUCTS CONSUMPTION RATE
     IPFRCR - FIXED REQUIREMENTS CONSUMPTION (OUT
                SHIPMENT) RATE
     IPI    - NUMBER OF IP UNITS IN SYSTEM INITIALLY

IPFRCR.KL=MIN(IPFROR.JK,IP.K)                        2, R
     IPFRCR - FIXED REQUIREMENTS CONSUMPTION (OUT
                SHIPMENT) RATE
     IPFROR - FIXED EXTERNAL REQUIREMENT ORDERS LEVIED ON
                IP PRODUCT SUPPLIES
     IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
                TRACTORS, ETC.)

IPCR.KL=MAX(0,MIN(IP.K-IPFRCR.JK,IPB.K-IPFROR.JK))   3, R
     IPCR   - INTERMEDIATE PRODUCTS CONSUMPTION RATE
     IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
                TRACTORS, ETC.)
     IPFRCR - FIXED REQUIREMENTS CONSUMPTION (OUT
                SHIPMENT) RATE
     IPB    - THE BACKORDERS (BACKLOG) FOR INTERMEDIATE
                PRODUCTS
     IPFROR - FIXED EXTERNAL REQUIREMENT ORDERS LEVIED ON
                IP PRODUCT SUPPLIES

IPRR.KL=IPP.K/PRODD.K                                4, R
     IPRR   - INTERMEDIATE PRODUCTS REPLENISHMENT
                (PRODUCTION) RATE
     IPP    - INTERMEDIATE PRODUCTS IN THE PRODUCTION
                PIPELINE NOT YET RECEIVED
     PRODD  - PRODUCTION DELAY FOR INTERMEDIATE PRODUCTS

PRODD.K=PRODLY+CPDM.K                                5, A
PRODLY=2 MONTHS                                      5.1, C
     PRODD  - PRODUCTION DELAY FOR INTERMEDIATE PRODUCTS
     PRODLY - THE MINIMUM IP PRODUCTION DELAY DUE TO
                PURELY PHYSICAL LIMITS
     CPDM   - THE DELAY IN IP PRODUCTION DUE TO SHORTAGE
                OF CAPITAL PLANT

CPDM.K=TABHL(CPDMT,DC.K/C.K,0,1,.2)                  6, A
CPDMT=0/1/2/5/10/20                                  6.1, T
     CPDM   - THE DELAY IN IP PRODUCTION DUE TO SHORTAGE
                OF CAPITAL PLANT
     CPDMT  - TABLE FOR IP PRODUCTION DELAY VALUES
     C      - CAPITAL (PLANT AND EQUIPMENT)
```

```
IPB.K=IPB.J+(DT)(IPORR.JK+IPFROR.JK-IPFRCR.JK-          7, L
  IPCR.JK)
IPB=IPBI                                                7.1, N
IPBI=1000 UNITS                                         7.2, C
    IPB    - THE BACKORDERS (BACKLOG) FOR INTERMEDIATE
               PRODUCTS
    IPORR  - THE ORDER RECEIVING RATE FOR INTERMEDIATE
               PRODUCTS (DEMAND)
    IPFROR - FIXED EXTERNAL REQUIREMENT ORDERS LEVIED ON
               IP PRODUCT SUPPLIES
    IPFRCR - FIXED REQUIREMENTS CONSUMPTION (OUT
               SHIPMENT) RATE
    IPCR   - INTERMEDIATE PRODUCTS CONSUMPTION RATE
    IPBI   - NUMBER OF IP BACKORDERS INITIALLY

IPFROR.KL=FRIP*IP.K                                     8, R
FRIP=.10 PERCENT                                        8.1, C
    IPFROR - FIXED EXTERNAL REQUIREMENT ORDERS LEVIED ON
               IP PRODUCT SUPPLIES
    FRIP   - PERCENT OF IP SUPPLIES THAT ARE
               REQUISITIONED FROM OUTSIDE
    IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
               TRACTORS, ETC.)

IPORR.KL=IPCINF.K+IPCINT.K                              9, R
    IPORR  - THE ORDER RECEIVING RATE FOR INTERMEDIATE
               PRODUCTS (DEMAND)
    IPCINF - INTERMEDIATE PRODUCTS CONSUMED IN FOOD
               PRODUCTION
    IPCINT - INTERMEDIATE PRODUCTS CONSUMED IN FOOD
               TRANSPORTATION

NETIPS.K=MAX(0,IPB.K-IP.K)                              10, A
    NETIPS - THE NET IP SUPPLIES ON HAND ( BACKORDERS
               COMPARED WITH SUPPLY)
    IPB    - THE BACKORDERS (BACKLOG) FOR INTERMEDIATE
               PRODUCTS
    IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
               TRACTORS, ETC.)

IPP.K=IPP.J+(DT)(IPOR.JK-IPRR.JK)                       11, L
IPP=IPPI                                                11.1, N
IPPI=800 UNITS                                          11.2, C
    IPP    - INTERMEDIATE PRODUCTS IN THE PRODUCTION
               PIPELINE NOT YET RECEIVED
    IPOR   - RATE AT WHICH INTERMEDIATE PRODUCTS ARE
               ORDERED INTO PRODUCTION
    IPRR   - INTERMEDIATE PRODUCTS REPLENISHMENT
               (PRODUCTION) RATE
```

```
DIPP.K=(MAX(0,NETIPS.K-IPP.K))*C200                    12, A
C200=1.0                                               12.1, C
    DIPP    - DESIRED INTERMEDIATE PRODUCTION RATE (NET
                SUPPLIES - PIPELINE)
    NETIPS - THE NET IP SUPPLIES ON HAND ( BACKORDERS
                COMPARED WITH SUPPLY)
    IPP     - INTERMEDIATE PRODUCTS IN THE PRODUCTION
                PIPELINE NOT YET RECEIVED
    C200    - PERCENT OF IP SUPPLY DISCREPANCY BETWEEN
                ORDERED AND DESIRED

IPWD.K=DIPP.K/IPPPW.K                                  13, A
    IPWD    - DEMAND FOR IP PRODUCTION WORKERS
    DIPP    - DESIRED INTERMEDIATE PRODUCTION RATE (NET
                SUPPLIES - PIPELINE)
    IPPPW   - PRODUCTIVITY PER INTERMEDIATE PRODUCTS
                WORKER

IPPPW.K=IPPWN*IPPM.K                                   14, A
    IPPPW   - PRODUCTIVITY PER INTERMEDIATE PRODUCTS
                WORKER
    IPPWN   - NORMAL PRODUCTIVITY PER IP WORKER
    IPPM    - IP WORKER PRODUCTIVITY MULTIPLIER (HEALTH
                AND FOOD SHORTAGES)

IPPM.K=TABHL(IPPMT,FSHORT.K,0,1,.2)                    15, A
IPPMT=1/.9/.6/.4/.2/0                                  15.1, T
IPPWN=1                                                15.2, C
    IPPM    - IP WORKER PRODUCTIVITY MULTIPLIER (HEALTH
                AND FOOD SHORTAGES)
    IPPMT   - TABLE FOR IP WORKER PRODUCTIVITY VALUES
    IPPWN   - NORMAL PRODUCTIVITY PER IP WORKER

IPW.K=IPW.J+(DT)(IPWINR.JK-IPWOUT.JK)                  16, L
IPW=IPWI                                               16.1, N
IPWI=1000 WORKERS                                      16.2, C
    IPW     - THE INTERMEDIATE PRODUCTS WORKERS
    IPWINR - RATE OF WORKERS ENTERING IP SECTOR
    IPWOUT - RATE AT WHICH WORKERS LEAVE IP SECTOR
    IPWI    - NUMBER OF IP WORKERS IN SYSTEM INITIALLY

IPOR.KL=MIN(DIPP.K,IPW.K*IPPPW.K)                      17, R
    IPOR    - RATE AT WHICH INTERMEDIATE PRODUCTS ARE
                ORDERED INTO PRODUCTION
    DIPP    - DESIRED INTERMEDIATE PRODUCTION RATE (NET
                SUPPLIES - PIPELINE)
    IPW     - THE INTERMEDIATE PRODUCTS WORKERS
    IPPPW   - PRODUCTIVITY PER INTERMEDIATE PRODUCTS
                WORKER

IPWINR.KL=CLIP(IPWINA.K,0,DISIPW.K,0)                  18, R
    IPWINR - RATE OF WORKERS ENTERING IP SECTOR
    IPWINA - CALCULATION FOR WORKERS ENTERING IP SECTOR
    DISIPW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
                NUMBER OF IP WORKERS
```

```
IPWINA.K=MAX(0,WP.K*PDIPW.K*IPWDF)                          19, A
IPWDF=.8                                                    19.1, C
    IPWINA - CALCULATION FOR WORKERS ENTERING IP SECTOR
    WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED
    PDIPW  - PERCENT OF IP WORKERS DESIRED
    IPWDF  - DELAY FACTOR FOR TRANSFERRING WORKERS TO IP
               SECTOR

DISIPW.K=DIPW.K-IPW.K                                       20, A
    DISIPW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
               NUMBER OF IP WORKERS
    DIPW   - DESIRED NUMBER OF IP WORKERS
    IPW    - THE INTERMEDIATE PRODUCTS WORKERS

DIPW.K=PDIPW.K*WA.K                                         21, A
    DIPW   - DESIRED NUMBER OF IP WORKERS
    PDIPW  - PERCENT OF IP WORKERS DESIRED
    WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
               SYSTEM

PDIPW.K=IPWD.K/(IPWD.K+CWD.K+FTWD.K+FSWD.K)                 22, A
    PDIPW  - PERCENT OF IP WORKERS DESIRED
    IPWD   - DEMAND FOR IP PRODUCTION WORKERS
    CWD    - DEMAND FOR CAPITAL WORKERS
    FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
    FSWD   - DEMAND FOR FOOD SUPPLY WORKERS

WA.K=IPW.K+CW.K+FTW.K+FSW.K+WP.K                            23, A
    WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
               SYSTEM
    IPW    - THE INTERMEDIATE PRODUCTS WORKERS
    CW     - THE CAPITAL SECTOR WORKERS
    FTW    - THE FOOD TRANSPORT WORKERS
    FSW    - THE FOOD SUPPLY WORKERS
    WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED

IPWOUT.KL=CLIP(0,IPWOUA.K,DISIPW.K,0)                       24, R
    IPWOUT - RATE AT WHICH WORKERS LEAVE IP SECTOR
    IPWOUA - CALCULATION FOR WORKERS LEAVING IP SECTOR
    DISIPW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
               NUMBER OF IP WORKERS

IPWOUA.K=-DISIPW.K*IPWDF                                    25, A
    IPWOUA - CALCULATION FOR WORKERS LEAVING IP SECTOR
    DISIPW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
               NUMBER OF IP WORKERS
    IPWDF  - DELAY FACTOR FOR TRANSFERRING WORKERS TO IP
               SECTOR
```

```
*****************************************************************
      CAPITAL SECTOR  (PLANT AND EQUIPMENT)
*****************************************************************

C.K=C.J+(DT)(CCRD.JK-COR.JK-CFR.JK)                         26, L
C=CI                                                        26.1, N
CI=200 UNITS                                                26.2, C
    C       - CAPITAL (PLANT AND EQUIPMENT)
    CCRD    - RATE OF CAPITAL CONSTRUCTION (DELAYED)
    COR     - RATE AT WHICH CAPITAL BECOMES OBSOLESCENT
    CFR     - FIXED REQUIREMENTS CONSUMPTION (OUT
                SHIPMENT) RATE
    CI      - NUMBER OF CAPITAL UNITS IN THE SYSTEM
                INITIALLY

CFR.KL=MAX(0,MIN(C.K,CFIX))*SWITCH.K                        27, R
CFIX=20 UNITS                                               27.1, C
    CFR     - FIXED REQUIREMENTS CONSUMPTION (OUT
                SHIPMENT) RATE
    C       - CAPITAL (PLANT AND EQUIPMENT)
    CFIX    - AMOUNT OF CAPITAL REQUISITIONED FROM
                OUTSIDE
    SWITCH - TIME DELAY AFFECTING FIXED REQUIREMENTS FOR
                CAPITAL

CIP.K=CIP.J+(DT)(CCR.JK-CCRD.JK)                            28, L
CIP=CIPI                                                    28.1, N
CIPI=0                                                      28.2, C
    CIP     - AMOUNT OF CAPITAL IN CONSTRUCTION
    CCR     - CAPITAL CONSTRUCTION RATE
    CCRD    - RATE OF CAPITAL CONSTRUCTION (DELAYED)
    CIPI    - AMOUNT OF CAPITAL CONSTRUCTION IN THE
                SYSTEM INITIALLY

EFFCAP.K=C.K+CIP.K                                          29, A
    EFFCAP - EFFECTIVE AMOUNT OF CAPITAL (PIPELINE +
                ACTUAL)
    C       - CAPITAL (PLANT AND EQUIPMENT)
    CIP     - AMOUNT OF CAPITAL IN CONSTRUCTION

SWITCH.K=STEP(1,TIM)                                        30, A
TIM=10                                                      30.1, C
    SWITCH - TIME DELAY AFFECTING FIXED REQUIREMENTS FOR
                CAPITAL
    TIM     - TIME WHEN FIXED REQUIREMENTS FOR CAPITAL
                ENTER SYSTEM

COR.KL=CORF*C.K                                             31, R
CORF=.06 PERCENT                                            31.1, C
    COR     - RATE AT WHICH CAPITAL BECOMES OBSOLESCENT
    CORF    - PERCENT CAPITAL OBSOLESCENT FACTOR
    C       - CAPITAL (PLANT AND EQUIPMENT)
```

```
CCRD.KL=CIP.K/CCRDF                                          32, R
CCRDF=6 MONTHS                                               32.1, C
    CCRD    - RATE OF CAPITAL CONSTRUCTION (DELAYED)
    CIP     - AMOUNT OF CAPITAL IN CONSTRUCTION
    CCRDF   - DELAY FACTOR IN CAPITAL CONSTRUCTION RATE

CCR.KL=MIN(DCC.K,CW.K*PRODC.K)                               33, R
    CCR     - CAPITAL CONSTRUCTION RATE
    DCC     - DESIRED RATE FOR CAPITAL CONSTRUCTION
    CW      - THE CAPITAL SECTOR WORKERS
    PRODC   - PRODUCTIVITY OF CAPITAL WORKERS

DCC.K=MAX(0,CD.K)                                            34, A
    DCC     - DESIRED RATE FOR CAPITAL CONSTRUCTION
    CD      - DISCREPANCY IN CAPITAL PLANT AND EQUIPMENT
                (DESIRED - EFFECTIVE)

CD.K=(DC.K-EFFCAP.K)*POLICY                                  35, A
    CD      - DISCREPANCY IN CAPITAL PLANT AND EQUIPMENT
                (DESIRED - EFFECTIVE)
    EFFCAP  - EFFECTIVE AMOUNT OF CAPITAL (PIPELINE +
                ACTUAL)
    POLICY  - PRODUCTION LEVEL DESIRED BY POLICYMAKER

DC.K=IPOR.JK*CRPUIP                                          36, A
CRPUIP=1                                                     36.1, C
POLICY=1.0                                                   36.2, C
    IPOR    - RATE AT WHICH INTERMEDIATE PRODUCTS ARE
                ORDERED INTO PRODUCTION
    CRPUIP  - CAPITAL TO INTERMEDIATE PRODUCT  PRODUCTION
                RATIO REQUIRED
    POLICY  - PRODUCTION LEVEL DESIRED BY POLICYMAKER

PRODC.K=CCPWN*CWPM.K                                         37, A
CCPWN=.06 PRODUCTIVITY                                       37.1, C
    PRODC   - PRODUCTIVITY OF CAPITAL WORKERS
    CCPWN   - NORMAL PRODUCTIVTY FACTOR
    CWPM    - CAPITAL WORKER PRODUCTIVITY MULTIPLIER
                (HEALTH AND FOOD SHORTAGES)

CWPM.K=TABHL(CWPMT,FSHORT.K,0,1,.2)                          38, A
CWPMT=1/.9/.6/.4/.2/0                                        38.1, T
    CWPM    - CAPITAL WORKER PRODUCTIVITY MULTIPLIER
                (HEALTH AND FOOD SHORTAGES)
    CWPMT   - TABLE FOR CAPITAL WORKER PRODUCTIVITY
                VALUES

CW.K=CW.JK(DT)(CWINR.JK-CWOUTR.JK)                           39, L
CW=CWI                                                       39.1, N
CWI=1000 OF                                                  39.2, C
    CW      - THE CAPITAL SECTOR WORKERS
    CWINR   - RATE OF WORKERS ENTERING CAPITAL SECTOR
    CWOUTR  - RATE AT WHICH WORKERS LEAVE CAPITAL SECTOR
    CWI     - NUMBER OF WORKERS IN CAPITAL SECTOR
                INITIALLY
```

```
CWINR.KL=CLIP(CWINA.K,O,DISCCW.K,O)                           40, R
    CWINR  - RATE OF WORKERS ENTERING CAPITAL SECTOR
    CWINA  - CALCULATION FOR WORKERS ENTERING CAPITAL
                SECTOR
    DISCCW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
                NUMBER OF CAPITAL WORKERS

CWINA.K=MAX(O,WP.K*PDCW.K*CWDF)                               41, A
CWDF=.8                                                       41.1, C
    CWINA  - CALCULATION FOR WORKERS ENTERING CAPITAL
                SECTOR
    WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED
    PDCW   - PERCENT OF CAPITAL WORKERS DESIRED
    CWDF   - DELAY FACTOR FOR TRANSFERRING WORKERS TO
                CAPITAL SECTOR

DISCCW.K=DCW.K-CW.K                                           42, A
    DISCCW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
                NUMBER OF CAPITAL WORKERS
    DCW    - DESIRED NUMBER OF CAPITAL WORKERS
    CW     - THE CAPITAL SECTOR WORKERS

DCW.K=PDCW.K*WA.K                                             43, A
    DCW    - DESIRED NUMBER OF CAPITAL WORKERS
    PDCW   - PERCENT OF CAPITAL WORKERS DESIRED
    WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
                SYSTEM

PDCW.K=CWD.K/(IPWD.K+CWD.K+FTWD.K+FSWD.K)                     44, A
    PDCW   - PERCENT OF CAPITAL WORKERS DESIRED
    CWD    - DEMAND FOR CAPITAL WORKERS
    IPWD   - DEMAND FOR IP PRODUCTION WORKERS
    FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
    FSWD   - DEMAND FOR FOOD SUPPLY WORKERS

CWOUTR.KL=CLIP(O,CWOUT.K,DISCCW.K,O)                          45, R
    CWOUTR - RATE AT WHICH WORKERS LEAVE CAPITAL SECTOR
    CWOUT  - CALCULATION FOR WORKERS LEAVING CAPITAL
                SECTOR
    DISCCW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
                NUMBER OF CAPITAL WORKERS

CWOUT.K=-DISCCW.K*CWDF                                        46, A
    CWOUT  - CALCULATION FOR WORKERS LEAVING CAPITAL
                SECTOR
    DISCCW - DISCREPANCY BETWEEN DESIRED AND ACTUAL
                NUMBER OF CAPITAL WORKERS
    CWDF   - DELAY FACTOR FOR TRANSFERRING WORKERS TO
                CAPITAL SECTOR

CWD.K=DCC.K/PRODC.K                                           47, A
    CWD    - DEMAND FOR CAPITAL WORKERS
    DCC    - DESIRED RATE FOR CAPITAL CONSTRUCTION
    PRODC  - PRODUCTIVITY OF CAPITAL WORKERS
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*******************************************************
      FOOD SUPPLY SECTOR
*******************************************************

FS.K=FS.J+(DT)(FRR.JK-FFRSR.JK-FSR.JK)                 48, L
FS=FSI                                                 48.1, N
FSI=440E3                                              48.2, C
    FS       - FOOD SUPPLY AT THE PRODUCTION SITES
    FRR      - RATE AT WHICH FOOD IS RECEIVED FROM
                 PRODUCTION SOURCES
    FFRSR    - RATE AT WHICH FOOD IS SHIPPED TO MEET FIXED
                 REQUIREMENTS
    FSR      - RATE AT WHICH FOOD IS SHIPPED
    FSI      - AMOUNT OF FOOD SUPPLY AT PRODUCTION SITES
                 INITIALLY

FFRSR.KL=MIN(FFROR.JK,FS.K)                            49, R
    FFRSR    - RATE AT WHICH FOOD IS SHIPPED TO MEET FIXED
                 REQUIREMENTS
    FFROR    - RATE OF FOOD SUPPLY REQUISITIONED FROM
                 OUTSIDE
    FS       - FOOD SUPPLY AT THE PRODUCTION SITES

FFROR.KL=FSFIX                                         50, R
FSFIX=44E3 LBS                                         50.1, C
    FFROR    - RATE OF FOOD SUPPLY REQUISITIONED FROM
                 OUTSIDE
    FSFIX    - AMOUNT OF FOOD SUPPLY REQUISITIONED FROM
                 OUTSIDE

FRR.KL=FOODIP.K/FPD.K                                  51, R
    FRR      - RATE AT WHICH FOOD IS RECEIVED FROM
                 PRODUCTION SOURCES
    FOODIP   - FOOD IN PRODUCTION AT THE FOOD SUPPLY SITES
    FPD      - TOTAL DELAY FOR FOOD PRODUCTION

FPD.K=PD+IPFPD.K                                       52, A
PD=3 MONTH                                             52.1, C
    FPD      - TOTAL DELAY FOR FOOD PRODUCTION
    PD       - DELAY IN PRODUCING FOOD
    IPFPD    - THE DELAYS IN FOOD PRODUCTION DUE TO IP
                 SUPPLIES

IPFPD.K=CLIP(0,4,IP.K-IPB.K,0)                         53, A
    IPFPD    - THE DELAYS IN FOOD PRODUCTION DUE TO IP
                 SUPPLIES
    IP       - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
                 TRACTORS, ETC.)
    IPB      - THE BACKORDERS (BACKLOG) FOR INTERMEDIATE
                 PRODUCTS

FSR.KL=MIN(DFSR.K,FSXPW.K*FTW.K)                       54, R
    FSR      - RATE AT WHICH FOOD IS SHIPPED
    DFSR     - DESIRED RATE OF FOOD SHIPMENT
    FSXPW    - AMOUNT OF FOOD TRANSPORTED PER WORKER
    FTW      - THE FOOD TRANSPORT WORKERS
```

```
DFSR.K=MAX(0,MIN(FSB.K-FFROR.JK,FS.K-FFRSR.JK))          55, A
    DFSR    - DESIRED RATE OF FOOD SHIPMENT
    FSB     - BACKORDERS FOR FOOD AT THE FOOD SUPPLY
                SITES
    FFROR   - RATE OF FOOD SUPPLY REQUISITIONED FROM
                OUTSIDE
    FS      - FOOD SUPPLY AT THE PRODUCTION SITES
    FFRSR   - RATE AT WHICH FOOD IS SHIPPED TO MEET FIXED
                REQUIREMENTS

FSXPW.K=FSXPWN*FSXPM.K                                   56, A
FSXPWN=1220 LBS                                          56.1, C
    FSXPW   - AMOUNT OF FOOD TRANSPORTED PER WORKER
    FSXPWN  - AMOUNT OF FOOD TRANSPORTED PER WORKER
                (NORMALLY)
    FSXPM   - FOOD TRANSPORTATION MULTIPLIER (HEALTH &
                FOOD SHORTAGES)

FSXPM.K=TABHL(FSXPMT,FSHORT.K,0,1,.2)                    57, A
FSXPMT=1/.9/.6/.4/.2/0                                   57.1, T
    FSXPM   - FOOD TRANSPORTATION MULTIPLIER (HEALTH &
                FOOD SHORTAGES)
    FSXPMT  - TABLE FOR FOOD TRANSPORTATION MULTIPLIER
                VALUES

FTW.K=FTW.J+(DT)(FTWINR.JK-FTWOUT.JK)                    58, L
FTW=FTWI                                                 58.1, N
FTWI=1000 FOOD                                           58.2, C
    FTW     - THE FOOD TRANSPORT WORKERS
    FTWINR  - RATE OF WORKERS ENTERING FOOD
                TRANSPORTATION SECTOR
    FTWOUT  - RATE AT WHICH WORKERS LEAVE FOOD
                TRANSPORTATION SECTOR
    FTWI    - NUMBER OF WORKERS IN FOOD TRANSPORTATION
                INITIALLY

FTWINR.KL=CLIP(FTWINA.K,0,DISFTW.K,0)                    59, R
    FTWINR  - RATE OF WORKERS ENTERING FOOD
                TRANSPORTATION SECTOR
    FTWINA  - CALCULATION FOR WORKERS ENTERING FOOD
                TRANSPORTATION SECTOR
    DISFTW  - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
                TRANSPORTATION WORKERS

FTWINA.K=MAX(0,WP.K*PDFTW.K*FTWDF)                       60, A
FTWDF=.8                                                 60.1, C
    FTWINA  - CALCULATION FOR WORKERS ENTERING FOOD
                TRANSPORTATION SECTOR
    WP      - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED
    FTWDF   - DELAY FACTOR TO TRANSFER WORKERS TO FOOD
                TRANSPORTATION SECTOR
```

```
DISFTW.K=DFTW.K-FTW.K                                          61, A
     DISFTW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
                TRANSPORTATION WORKERS
     DFTW   - DESIRED NUMBER OF FOOD TRANSPORTATION
                WORKERS
     FTW    - THE FOOD TRANSPORT WORKERS

DFTW.K=PDFTW.K*WA.K                                            62, A
     DFTW   - DESIRED NUMBER OF FOOD TRANSPORTATION
                WORKERS
     WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
                SYSTEM

PDFTW.K=FTWD.K/(IPWD.K+CWD.K+FTWD.K+FSWD.K)                    63, A
     FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
     IPWD   - DEMAND FOR IP PRODUCTION WORKERS
     CWD    - DEMAND FOR CAPITAL WORKERS
     FSWD   - DEMAND FOR FOOD SUPPLY WORKERS

FTWOUT.KL=CLIP(0,FTWOUA.K,DISFTW.K,0)                          64, R
     FTWOUT - RATE AT WHICH WORKERS LEAVE FOOD
                TRANSPORTATION SECTOR
     FTWOUA - CALCULATION FOR WORKERS LEAVING FOOD
                TRANSPORTATION SECTOR
     DISFTW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
                TRANSPORTATION WORKERS

FTWOUA.K=-DISFTW.K*FTWDF                                       65, A
     FTWOUA - CALCULATION FOR WORKERS LEAVING FOOD
                TRANSPORTATION SECTOR
     DISFTW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
                TRANSPORTATION WORKERS
     FTWDF  - DELAY FACTOR TO TRANSFER WORKERS TO FOOD
                TRANSPORTATION SECTOR

FTWD.K=DFSR.K/FSXPW.K                                          66, A
     FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
     DFSR   - DESIRED RATE OF FOOD SHIPMENT
     FSXPW  - AMOUNT OF FOOD TRANSPORTED PER WORKER

FSB.K=FSB.J+(DT)(FSORR.JK+FFROR.JK-FFRSR.JK-FSR.JK)  67, L
     FSB    - BACKORDERS FOR FOOD AT THE FOOD SUPPLY
                SITES
     FSORR  - RATE AT WHICH FOOD SUPPLY ORDERS ARE
                RECEIVED
     FFROR  - RATE OF FOOD SUPPLY REQUISITIONED FROM
                OUTSIDE
     FFRSR  - RATE AT WHICH FOOD IS SHIPPED TO MEET FIXED
                REQUIREMENTS
     FSR    - RATE AT WHICH FOOD IS SHIPPED
```

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FSORR.KL=DELAY3(MFSOR.JK,COMMD)                                68, R
COMMD=1 MONTH                                                  68.1, C
FSB=FSBI                                                       68.2, N
FSBI=440E3 LBS                                                 68.3, C
    FSORR  - RATE AT WHICH FOOD SUPPLY ORDERS ARE
               RECEIVED
    MFSOR  - MATCHED FOOD SUPPLY ORDER RATE
    COMMD  - COMMUNICATION DELAY AFFECTING FOOD ORDERS
    FSB    - BACKORDERS FOR FOOD AT THE FOOD SUPPLY
               SITES
    FSBI   - BACKORDERS FOR FOOD AT FOOD SUPPLY SITES
               INITIALLY

NETFS.K=MAX(0,FSB.K-FS.K)                                      69, A
    NETFS  - NET FOOD SUPPLY (BACKORDERS COMPARED TO
               SUPPLY)
    FSB    - BACKORDERS FOR FOOD AT THE FOOD SUPPLY
               SITES
    FS     - FOOD SUPPLY AT THE PRODUCTION SITES

FOODIP.K=FOODIP.J+(DT)(FPR.JK-FRR.JK)                          70, L
FOODIP=FIPI                                                    70.1, N
FIPI=1260E3                                                    70.2, C
    FOODIP - FOOD IN PRODUCTION AT THE FOOD SUPPLY SITES
    FPR    - RATE AT WHICH FOOD IS PRODUCED
    FRR    - RATE AT WHICH FOOD IS RECEIVED FROM
               PRODUCTION SOURCES
    FIPI   - FOOD IN PRODUCTION AT SUPPLY SITES
               INITIALLY

FPR.KL=MIN(DFP.K,FSW.K*PPFSWN*FSWPM.K)                         71, R
FSPPW.K=PPFSWN*FSWPM.K                                         71.1, A
    FPR    - RATE AT WHICH FOOD IS PRODUCED
    DFP    - DESIRED LEVEL OF FOOD PRODUCTION
    FSW    - THE FOOD SUPPLY WORKERS
    PPFSWN - AMOUNT OF FOOD PRODUCED PER FOOD SUPPLY
               WORKER NORMALLY
    FSWPM  - FOOD SUPPLY WORKER PRODUCTIVITY  (HEALTH
               AND FOOD SHORTAGES)
    FSPPW  - AMOUNT OF FOOD SUPPLY PRODUCED PER WORKER

DFP.K=MAX(0,NETFS.K-FOODIP.K)*C201                             72, A
C201=1.0                                                       72.1, C
PPFSWN=1680 LBS                                                72.2, C
    DFP    - DESIRED LEVEL OF FOOD PRODUCTION
    NETFS  - NET FOOD SUPPLY (BACKORDERS COMPARED TO
               SUPPLY)
    FOODIP - FOOD IN PRODUCTION AT THE FOOD SUPPLY SITES
    C201   - PERCENT OF FOOD IN PRODUCTION DESIRED
    PPFSWN - AMOUNT OF FOOD PRODUCED PER FOOD SUPPLY
               WORKER NORMALLY
```

```
FSWPM.K=TABHL(FSWPMT,FSHORT.K,0,1,.2)                    73, A
FSWPMT=1/.9/.6/.4/.2/0                                   73.1, T
    FSWPM  - FOOD SUPPLY WORKER PRODUCTIVITY  (HEALTH
               AND FOOD SHORTAGES)
    FSWPMT - TABLE FOR FOOD SUPPLY WORKER PRODUCTIVITY
               MULTIPLIER VALUES

FSW.K=FSW.J+(DT)(FSWINR.JK-FSWOUT.JK)                    74, L
FSW=FSWI                                                 74.1, N
FSWI=1000 INITIAL                                        74.2, C
    FSW    - THE FOOD SUPPLY WORKERS
    FSWINR - RATE AT WHICH WORKERS ENTER FOOD PRODUCTION
               SECTOR
    FSWOUT - RATE AT WHICH WORKERS LEAVE FOOD SUPPLY
               SECTOR
    FSWI   - NUMBER OF WORKERS IN FOOD PRODUCTION
               INITIALLY

FSWINR.KL=CLIP(FSWINA.K,0,DISFSW.K,0)                    75, R
    FSWINR - RATE AT WHICH WORKERS ENTER FOOD PRODUCTION
               SECTOR
    FSWINA - CALCULATION FOR WORKERS ENTERING FOOD
               PRODUCTION SECTOR
    DISFSW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
               TRANSPORT WORKERS

FSWINA.K=MAX(0,WP.K*PDFSW.K*FSWDF)                       76, A
FSWDF=.8 DELAY                                           76.1, C
    FSWINA - CALCULATION FOR WORKERS ENTERING FOOD
               PRODUCTION SECTOR
    WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED
    PDFSW  - PERCENT OF FOOD SUPPLY WORKERS DESIRED
    FSWDF  - DELAY FACTOR FOR TRANSFERRING WORKERS TO
               FOOD PRODUCTION SECTOR

DISFSW.K=DFSW.K-FSW.K                                    77, A
    DISFSW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
               TRANSPORT WORKERS
    DFSW   - DESIRED NUMBER OF FOOD SUPPLY WORKERS
    FSW    - THE FOOD SUPPLY WORKERS

DFSW.K=PDFSW.K*WA.K                                      78, A
    DFSW   - DESIRED NUMBER OF FOOD SUPPLY WORKERS
    PDFSW  - PERCENT OF FOOD SUPPLY WORKERS DESIRED
    WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
               SYSTEM

PDFSW.K=FSWD.K/(IPWD.K+CWD.K+FTWD.K+FSWD.K)              79, A
    PDFSW  - PERCENT OF FOOD SUPPLY WORKERS DESIRED
    FSWD   - DEMAND FOR FOOD SUPPLY WORKERS
    IPWD   - DEMAND FOR IP PRODUCTION WORKERS
    CWD    - DEMAND FOR CAPITAL WORKERS
    FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
```

```
FSWOUT.KL=CLIP(0,FSWOUA.K,DISFSW.K,0)                         80, R
    FSWOUT - RATE AT WHICH WORKERS LEAVE FOOD SUPPLY
               SECTOR
    FSWOUA - CALCULATION FOR WORKERS LEAVING FOOD SUPPLY
               SECTOR
    DISFSW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
               TRANSPORT WORKERS

FSWOUA.K=-DISFSW.K*FSWDF                                       81, A
    FSWOUA - CALCULATION FOR WORKERS LEAVING FOOD SUPPLY
               SECTOR
    DISFSW - DISCREPANCY BETWEEN DESIRED & ACTUAL FOOD
               TRANSPORT WORKERS
    FSWDF  - DELAY FACTOR FOR TRANSFERRING WORKERS TO
               FOOD PRODUCTION SECTOR

FSWD.K=DFP.K/(PPFSWN*FSWPM.K)                                  82, A
    FSWD   - DEMAND FOR FOOD SUPPLY WORKERS
    DFP    - DESIRED LEVEL OF FOOD PRODUCTION
    PPFSWN - AMOUNT OF FOOD PRODUCED PER FOOD SUPPLY
               WORKER NORMALLY
    FSWPM  - FOOD SUPPLY WORKER PRODUCTIVITY  (HEALTH
               AND FOOD SHORTAGES)

IPCINF.K=IPCPUF*FPR.JK                                         83, A
IPCPUF=.00025 UNITS                                            83.1, C
    IPCINF - INTERMEDIATE PRODUCTS CONSUMED IN FOOD
               PRODUCTION
    IPCPUF - INTERMEDIATE PRODUCTS CONSUMED PER UNIT
               FOOD PRODUCED
    FPR    - RATE AT WHICH FOOD IS PRODUCED

IPCINT.K=IPCPUT*FSR.JK                                         84, A
IPCPUT=.00025 UNITS                                            84.1, C
    IPCINT - INTERMEDIATE PRODUCTS CONSUMED IN FOOD
               TRANSPORTATION
    IPCPUT - INTERMEDIATE PRODUCTS CONSUMED PER UNIT
               FOOD TRANSPORTED
    FSR    - RATE AT WHICH FOOD IS SHIPPED

 ********************************************************
       MATCHED FOOD SUPPLY SECTOR
 ********************************************************

MFS.K=MFS.J+(DT)(FAR.JK-FCR.JK)                                85, L
MFS=MFSI                                                       85.1, N
MFSI=400E3 LBS                                                 85.2, C
    MFS    - THE QUANTITY OF FOOD THAT IS MATCHED WITH
               DEMAND
    FAR    - RATE AT WHICH FOOD ARRIVES TO CONSUMERS
    FCR    - RATE AT WHICH MATCHED FOOD IS BEING
               CONSUMED
    MFSI   - AMOUNT OF MATCHED FOOD FOOD SUPPLY (IN
               CONSUMER HANDS) INITIALLY
```

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FAR.KL=FIT.K/TRANSD.K                                        86, R
    FAR    - RATE AT WHICH FOOD ARRIVES TO CONSUMERS
    FIT    - FOOD ORDERED FROM FOOD SUPPLY SECTOR IN
               TRANSIT TO MATCHED
    TRANSD - TOTAL FOOD TRANSPORTATION DELAY

FIT.K=FIT.J+(DT)(FSR.JK-FAR.JK)                              87, L
FIT=FITI                                                     87.1, N
FITI=440E3                                                   87.2, C
    FIT    - FOOD ORDERED FROM FOOD SUPPLY SECTOR IN
               TRANSIT TO MATCHED
    FSR    - RATE AT WHICH FOOD IS SHIPPED
    FAR    - RATE AT WHICH FOOD ARRIVES TO CONSUMERS
    FITI   - FOOD IN TRANSIT PIPELINE TO CONSUMERS
               INITIALLY

TRANSD.K=TRAND+IPFTD.K                                       88, A
    TRANSD - TOTAL FOOD TRANSPORTATION DELAY
    TRAND  - PHYSICAL DELAY IN TRANSPORTING FOOD TO
               CONSUMERS
    IPFTD  - FOOD TRANSPORTATION DELAY DUE TO
               INTERMEDIATE PRODUCT SHORTAGE

IPFTD.K=CLIP(0,2,IP.K-IPB.K,0)                               89, A
TRAND=1 MONTH                                                89.1, C
    IPFTD  - FOOD TRANSPORTATION DELAY DUE TO
               INTERMEDIATE PRODUCT SHORTAGE
    IP     - INTERMEDIATE PRODUCTS (FUEL, TRUCKS,
               TRACTORS, ETC.)
    IPB    - THE BACKORDERS (BACKLOG) FOR INTERMEDIATE
               PRODUCTS
    TRAND  - PHYSICAL DELAY IN TRANSPORTING FOOD TO
               CONSUMERS

FCR.KL=MAX(0,MIN(MFS.K,FCPP.K*PTOTAL.K))                     90, R
    FCR    - RATE AT WHICH MATCHED FOOD IS BEING
               CONSUMED
    MFS    - THE QUANTITY OF FOOD THAT IS MATCHED WITH
               DEMAND
    FCPP   - AMOUNT OF FOOD CONSUMED PER PERSON
    PTOTAL - TOTAL POPULATION OF SYSTEM

PTOTAL.K=CW.K+FSW.K+IPW.K+FTW.K+OTHER.K+WP.K                 91, A
    PTOTAL - TOTAL POPULATION OF SYSTEM
    CW     - THE CAPITAL SECTOR WORKERS
    FSW    - THE FOOD SUPPLY WORKERS
    IPW    - THE INTERMEDIATE PRODUCTS WORKERS
    FTW    - THE FOOD TRANSPORT WORKERS
    OTHER  - NON-WORKER POPULATION
    WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED

OTHER.K=OTHER.J+(DT)(ONCR.JK)                                92, L
OTHER=OTHERI                                                 92.1, N
OTHERI=6000 PEOPLE                                           92.2, C
    OTHER  - NON-WORKER POPULATION
    ONCR   - OTHER NET CHANGE RATE
    OTHERI - NON-WORKER POPULATION INITIALLY
```

```
ONCR.KL=NCR*OTHER.K                                          93, R
NCR=0.0                                                      93.1, C
     ONCR    - OTHER NET CHANGE RATE
     NCR     - NET CHANGE RATE
     OTHER   - NON-WORKER POPULATION

FCPP.K=MIN(130,CLIP(SFCPP.K-DFRPP,MFAPP.K-DFRPP,             94, A
  MFAPP.K,SFCPP.K))
     FCPP    - AMOUNT OF FOOD CONSUMED PER PERSON
     SFCPP   - NSL
     DFRPP   - DESIRED FOOD CONSUMPTION RATE PER PERSON
     MFAPP   - AMOUNT OF MATCHED (ON HAND) FOOD AVAILABLE
                 PER PERSON

MFAPP.K=MFS.K/PTOTAL.K                                       95, A
DFRPP=0                                                      95.1, C
     MFAPP   - AMOUNT OF MATCHED (ON HAND) FOOD AVAILABLE
                 PER PERSON
     MFS     - THE QUANTITY OF FOOD THAT IS MATCHED WITH
                 DEMAND
     PTOTAL  - TOTAL POPULATION OF SYSTEM
     DFRPP   - DESIRED FOOD CONSUMPTION RATE PER PERSON

SFCPP.K=NSL*SUBM.K                                           96, A
NSL=40 LBS                                                   96.1, C
     SFCPP   - NSL
     SUBM    - SUBSISTENCE EXPECTATIONS MULTIPLIER

SUBM.K=TABHL(SUBMT,TIME.K,0.LENGTH,LENGTH)                   97, A
     SUBM    - SUBSISTENCE EXPECTATIONS MULTIPLIER

FSHORT.K=MAX(0,(NFCPP-FCPP.K)/NFCPP)                         98, A
NFCPP=122 LBS                                                98.1, C
SUBMT=1/3                                                    98.2, T
     FCPP    - AMOUNT OF FOOD CONSUMED PER PERSON

MFSB.K=MAX(0,MFSORR.JK-FCR.JK)                               99, A
     MFSB    - THE SHORTAGE OF MATCHED FOOD IN MATCHED
                 FOOD SUPPLY
     MFSORR  - MATCHED FOOD SUPPLY ORDER RECEIVING RATE
                 (DEMAND FOR FOOD)
     FCR     - RATE AT WHICH MATCHED FOOD IS BEING
                 CONSUMED

MFSORR.KL=SFCPP.K*PTOTAL.K                                   100, R
     MFSORR  - MATCHED FOOD SUPPLY ORDER RECEIVING RATE
                 (DEMAND FOR FOOD)
     SFCPP   - NSL
     PTOTAL  - TOTAL POPULATION OF SYSTEM

MFSOR.KL=DMFS.K*C205                                         101, R
C205=1                                                       101.1, C
     MFSOR   - MATCHED FOOD SUPPLY ORDER RATE
     DMFS    - DEMAND FOR MATCHED FOOD SUPPLY
     C205    - MULTIPLIER FOR ORDERING MATCHED FOOD SUPPLY
```

```
DMFS.K=MFSORR.JK                                        102, A
     DMFS   - DEMAND FOR MATCHED FOOD SUPPLY
     MFSORR - MATCHED FOOD SUPPLY ORDER RECEIVING RATE
                (DEMAND FOR FOOD)

 ***************************************************************
 WORKER POOL SECTOR
 ***************************************************************

WP.K=WP.J+(DT)(IPWOUT.JK+CWOUTR.JK+FSWOUT.JK+           103, L
  FTWOUT.JK-IPWINR.JK-CWINR.JK-FSWINR.JK-FTWINR.JK+
  WPSR.JK)
WP=WPI                                                  103.2, N
WPI=0                                                   103.3, C
     WP     - POOL OF WORKERS IN THE SYSTEM NOT EMPLOYED
     IPWOUT - RATE AT WHICH WORKERS LEAVE IP SECTOR
     CWOUTR - RATE AT WHICH WORKERS LEAVE CAPITAL SECTOR
     FSWOUT - RATE AT WHICH WORKERS LEAVE FOOD SUPPLY
                SECTOR
     FTWOUT - RATE AT WHICH WORKERS LEAVE FOOD
                TRANSPORTATION SECTOR
     IPWINR - RATE OF WORKERS ENTERING IP SECTOR
     CWINR  - RATE OF WORKERS ENTERING CAPITAL SECTOR
     FSWINR - RATE AT WHICH WORKERS ENTER FOOD PRODUCTION
                SECTOR
     FTWINR - RATE OF WORKERS ENTERING FOOD
                TRANSPORTATION SECTOR
     WPSR   - WORKER TRANSFER RATE BETWEEN REGIONS IN THE
                SYSTEM
     WPI    - INITIAL NUMBER OF WORKERS IN WORKER POOL

WPSR.KL=WPDF*DISCWP.K                                   104, R
WPDF=0 PERCENT                                          104.1, C
     WPSR   - WORKER TRANSFER RATE BETWEEN REGIONS IN THE
                SYSTEM
     WPDF   - DELAY FACTOR FOR TRANSFERRING WORKERS
                BETWEEN REGIONS
     DISCWP - DISCREPANCY BETWEEN WORKERS AVAILABLE &
                DEMAND

DISCWP.K=TWD.K-WA.K                                     105, A
     DISCWP - DISCREPANCY BETWEEN WORKERS AVAILABLE &
                DEMAND
     TWD    - TOTAL NUMBER OF WORKERS DEMANDED
     WA     - TOTAL NUMBER OF WORKERS AVAILABLE IN THE
                SYSTEM

TWD.K=CWD.K+IPWD.K+FSWD.K+FTWD.K                        106, A
     TWD    - TOTAL NUMBER OF WORKERS DEMANDED
     CWD    - DEMAND FOR CAPITAL WORKERS
     IPWD   - DEMAND FOR IP PRODUCTION WORKERS
     FSWD   - DEMAND FOR FOOD SUPPLY WORKERS
     FTWD   - DEMAND FOR FOOD TRANSPORTATION WORKERS
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