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Title SIMULATION AND SYSTEMS ANALYSIS OF THE UNITED STATES SOFTWOOD PLYWOOD INDUSTRY

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The United States softwood plywood industry is analyzed as a feedback system and simulated on a large scale digital computer. Introductory chapters present the motivation for an interdisciplinary study linking engineering with economics and compare the methodology of the study with the more common econometric approach found in economic literature.

Discussion of system simulation begins with a description of the General System Model which defines seven interacting sectors that approximately represent the hundreds of firms interacting in the industry. Sectors are defined as to make possible the aggregation of firms tending to behave homogeneously in response to changes in final demand and market price. The seven sectors include two producing sectors representing, in the aggregate, independent mills of the industry and mills integrated in their organization with wholesale warehouses. Three wholesale sectors represent aggregations

of independent jobbers, jobbers integrated organizationally with producers and office wholesalers who hold no physical inventory. Two retail sectors represent, in the aggregate, retailers and users who buy in box-car-load lots and those who buy in less than box-car-load lots. A detailed description of each of the sectors of the general model is presented along with a development of the sector simulation model programmed in DYNAMO. Results of simulation model tests are presented and compared with industry data. Model tests assume as independent (exogenous) variable end user demand with a strong seasonal component (due to seasonal fluctuations in new construction). Given model structure and end user demand, major industry variables are generated by the simulation model as functions of time. Included among these are: mill market price, mill production, mill unfilled orders, mill profit, wholesale inventory and wholesale unfilled orders. Simulation model behavior resembles past industry data in a number of significant respects though further model refinements are deemed necessary before applications can be made to industry problems.

The use of exponential lags in the simulation of aggregated processes (such as the plywood industry model) is discussed. It is shown that if n system elements each with transfer function Ke^{-ts}/n relating output $O_i(s)$ to input $I(s)$, t being a random variable distributed as the Erlang distribution with density function given by

$f(t) = a(at)^{(k-1)} e^{-at} / (k-1)!$, have the common input $I(s)$, then the transfer function relating aggregated output, $O(s) = \sum_{i=1}^{n} O_i(s)$, to input $I(s)$ approaches the kth order exponential lag $K/(as+1)^k$ as n becomes very large.

Conclusions of the study are presented which relate to the simulation art, the plywood industry and to educational patterns in the interdisciplinary area spanning engineering and social science.

SIMULATION AND SYSTEMS ANALYSIS OF THE UNITED STATES SOFTWOOD PLYWOOD INDUSTRY

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CHAPTER I

INTRODUCTION

At the outset, it would perhaps be well to present some of the thinking that has motivated a study bridging the fields of engineering and a social science such as economics. One reason for this interdisciplinary interest is the generality of certain bodies of theory that have been successfully applied in the natural sciences. For many years engineers familiar with feedback phenomena in the physical realm have been intrigued by the fact that this same mechanism is at work, sometimes with disastrous consequences as in the case of national economic depressions, in systems involving human beings. In his book "The Mechanism of Economic Systems" Tustin (47), an engineer, approaches the problem of economic stabilization from the point of view of feedback control system engineering. In the years during and since the second world war, feedback theory has developed into a sophisticated body of knowledge with widespread application to the control and optimization of systems in the physical realm. A number of engineers such as Forrester (15) and Smith (42, 43, 44) have sought to apply this theory to systems involving human beings and their interactions. The relatively newer field of information theory also appears to have applications to problems in the social sciences.

A second bridge linking modern engineering with the social sciences is computer simulation--the use of large scale computers to model systems involving a multitude of interrelated variables. The phrase "computer simulation" means many things to many people depending upon the nature of the system being simulated. The engineer's experience with simulation has primarily, though not exclusively, been with respect to a class of systems that can be described by linear or nonlinear differential or difference equations. Since many economic and other social systems can also be described by these equations, much of the engineers background in simulation is also applicable to a class of social systems.

Two early attempts to apply simulation to economic systems are those of Strotz, Calvert, and Morehouse (45) in 1951 and Smith and Erdley (42) (the latter both engineers) in 1952. In these two cases, the simulations were carried out on relatively small analogue computers and the models simulated were, due to the lack of adequate computers, necessarily oversimplifications of economic reality. During the fifties, advances were made in computer technology which can hardly be termed less than revolutionary. In particular, the large scale digital computer came into being and for the first time it became possible to approach realism in the simulation of complex economic and social systems. The work of Forrester (15), also an engineer, is noteworthy here. Under his direction, a group at M. I. T. developed DYNAMO, a compiler written for a large digital computer, for simulating large systems describable by differential or difference equations. Forrester was also instrumental in merging large scale simulation with feedback theory and decision theory in a unified approach to the study of problems in industrial management. This approach, termed "Industrial Dynamics", is described in his book of the same name published in 1961 (15). Since DYNAMO was developed, a host of large scale digital simulation compilers have been written to simulate a variety of system types, the analogue computer has greatly advanced as a simulation tool, and hybrid analogue-digital simulation techniques have proven themselves superior to pure analogue and digital simulations in certain applications.

A third, more subtle, motivation for study linking engineering with the social sciences exists because of a gap that exists today in the educational structure underlying the social sciences. The "gap" referred to here can be loosely defined as follows: engineering is to the natural sciences as "gap" is to the social sciences. That is, few people are being formally trained to <u>apply</u> social science in the sense that engineers are trained to apply natural science. In order to make this distinction sharper, it would be well to consider just what characterizes engineering education. Engineering education has at least the following attributes:

1) A "problem" orientation that places emphasis upon application of theory to real life problems as well as on the theory itself.
2) Nurture in the creative process that can lead one from fundamental principles to the solution of new problems.
3) Training in the use of abstract models of reality.
4) Grounding in the theory underlying the area of application.

Of these attributes, the first two, and in some cases the third, are not normally a part of existing educational patterns in the social sciences. The vast complexity of social phenomena and the attendant difficulty involved in applying theory is undoubtedly one reason for this lack. The point being made here is that a need is developing for people who can apply social science as engineers have been applying natural science. It would seem that the engineer by virtue of his heritage as an "applier" of knowledge can make a contribution to the application of social science. This is not to say that all problems in the social sciences are amenable to the engineering approach nor that engineers with a grounding in natural science can effectively contribute to the solution of problems in the social sciences without a grounding in social science.

The work that follows is basically an engineering systems analysis of a system that is economic in nature. Feedback theory and computer simulation, together with economic theory, provide the tools for analysis. The second chapter is devoted to a discussion of the method of approach used in the study and how this approach differs from that found in much of economic literature. Chapter three provides background information concerning the plywood industry and develops the general system model. In chapter four is presented a lengthy and detailed description of the industry simulation model which may be omitted by the reader with more general interests. Chapter five presents the results of tests of the simulation model, chapter six theory relating to the simulation of aggregative processes, and chapter seven the conclusions drawn as a result of the work as a whole. The appendices contain suggested improvements for a "second generation" simulation model and the simulation programs developed for the plywood industry.

CHAPTER II

COMPARATIVE METHODOLOGY

As has been indicated, the methodology employed in this study is considerably different from that found in much of economic literature. The purpose of this chapter is to briefly describe the more conventional approach and to then show specifically how the chosen approach differs from this.

1) The Econometric Approach

The "conventional" approach to the quantitative study of economic phenomena alluded to above is that of Econometrics. Loosely speaking, the econometrician works with data taken from past behavior of the independent and dependent variables relevant to the economic system under study and, using statistical estimation techniques, seeks to derive a mathematical model that will explain this observed past behavior of the dependent variables of the system and to some extent predict future behavior of these same dependent variables. In economic and econometric literature these dependent system variables are called "endogenous" variables and independent variables are termed "exogenous" variables.

In general, econometric models have the form of Equation (2-1) (49):

$$BY+GZ=U \tag{2-1}$$

Where:

Y is the gxl vector of endogenous variables
B is a gxg coefficient matrix
Z is the hxl vector of exogenous variables
G is a gxh coefficient matrix
U is a gxl vector of random errors
g is the number of endogenous variables
h is the number of exogenous variables

The inclusion of the random error term in Equation (2-1) is necessary because of an inherent randomness in human behavior, incomplete or inexact model specification and measurement errors in data. Once a reasonable model has been specified, the econometrician seeks statistical estimates of the coefficient matrices B and G that will minimize some function of the residual error between the hypothesized model and actual data. Obtaining unbiased, consistent estimates of these coefficients is no small undertaking in a real world situation and econometricians have developed many elaborate techniques for arriving at useful estimates. In some cases it is impossible to estimate all the coefficients that make up the B and G matrices and the econometrician settles for estimates of the coefficient matrix P in Equation (2-2).

$$Y=PZ+V \tag{2-2}$$

Where:

Y is as defined in Equation (2-1)
Z is as defined in Equation (2-1)
P is a gxh coefficient matrix
V is a new gxl random error vector

This latter equation is called the "reduced form" equation and is derivable from Equation (2-1).

2) Salient Features of Econometric Models

Comments here on a few salient features of these models will help to better understand the econometricians approach. First it should be pointed out that such models may be either dynamic or static in time depending upon whether or not the Z vector includes endogenous variables lagged by one or more time periods. If Z does include lagged endogenous variables, Equations (2-1) and (2-2) represent a system of difference equations which will generate the time path of the system endogenous variables given the exogenous variables, past values of the endogenous variables, and estimates of the coefficient matrices.

A second point worthy of note has to do with the reduced form Equation (2-2). If, due to estimation problems, the econometrician is forced to estimate reduced form equations instead of certain of the Equations (2-1) he loses knowledge concerning how some structural coefficients in the B and G matrices affect system behavior. That is, he is left with a model that may reproduce and predict behavior of endogenous variables but have gaps in its ability to relate economic cause to economic effect.

Thirdly, it should be pointed out that the econometric model is highly dependent upon data describing past behavior of system variables for its construction. This fact places a number of restrictions upon the scope and usefulness of econometric models. Data gathering can be an onerous task and there is an incentive to keep the number of variables in the model to a minimum. Unfortunately this can adversely affect the usefulness of a particular model. In some cases, particular variables may be significant in determining system behavior and yet it may be difficult or impossible to obtain data reflecting past behavior of these variables. In such an instance, the econometric approach is clearly at a disadvantage. Another situation in which the data dependence of econometric models can be disadvantageous arises when the time interval between data points is too coarse for the particular system being considered. Data are frequently recorded at monthly, quarterly or yearly intervals and are difficult to obtain on a more frequent than recorded basis. In some cases, relevant system time lags may be less than the time interval between data points. In such cases, an econometric model can fail to represent important dynamic characteristics of the system under study.

The object here has not been to discredit the econometric approach. This approach is contributing to understanding of economic phenomena. The object, rather, is to provide a basis for comparison with what will be termed the "simulation" approach to economic system analysis. As will be seen, the two approaches can be considered as complementary; that is jointly providing a more powerful approach to the study of complex economic systems than either taken alone.

3) The Simulation Approach

What is termed the "simulation" approach to systems analysis is that which has been the conventional approach in engineering and in particular electrical engineering for many years. The engineer considers a system to be composed of system components or sub-systems which individually obey certain laws and which interact according to certain interaction rules. Taken together, the system sub-systems and interaction rules define the system structure. Given the sub-systems, interaction rules, and external disturbances, the behavior of the system is deduced.

To an electronic engineer a "sub-system" is a transistor, resistor, capacitor, etc. and the "interaction rules" are embodied in the circuit that ties these components or sub-systems together. To an aeronautical engineer, a "sub-system" may be an airframe, a power plant, a pilot, or a control surface and the "interaction rules" embodied in a block diagram that specifies the interrelationships among these system components. The simulation approach applied to the economics of an industry, such as the plywood industry, would take as "sub-systems" plywood mills, distribution warehouses, and retail distributors, and as "interaction rules" the human decisions that govern the flows of money, material, and information among sub-systems. In these three diverse system types, the "simulation approach" would uniformly start with a detailed identification of system structure and from the structure deduce system behavior.

A question naturally arises as to how one obtains a detailed identification of the structure of an industry. This is a question to which J. W. Forrester addressed himself, and much of his book "Industrial Dynamics" (15) is his answer to this question. To very briefly outline Forrester's thinking, such identification begins with a broad understanding of system interrelationships, physical constraints imposed by technology and other factors, and the policies underlying the key decisions being made in the system. With this framework, a mathematical model is constructed and simulated using parameter values that are "reasonable" in the light of current knowledge of the system. The simulated model is tested to determine parameters and decision rules which have significant influences upon system behavior, and this information is used to guide further data collection and investigation of decision rules. Re-simulation and testing of refined models proceeds until the investigator is satisfied that his model represents the aspects of real world behavior that he desires to study. The final model, then, relates the details of system structure to system behavior and is used as a means of determining feasible structural changes which will result in more desirable system behavior.

A problem that arises in connection with both econometric and simulation approaches should be noted here. Models of complex systems are at present, very difficult to validate. Validation usually must rest upon the judgment of the investigator and those who must accept the consequences that result from application of the model.

4) Summary

The econometric and simulation approaches can be considered alternative attacks on the problem of obtaining an abstract model which relates causes and effects in complex systems. The econometric approach works from the "outside in" and seeks to deduce system structure from observed behavior of system variables. This has been called the "black box" approach in engineering literature. On the other hand, the simulation approach works from the "inside out" in that it seeks, by careful study of sub-systems and interaction rules, to identify the details of system structure that cause the overall system to behave as it does. Since the goal in either case is the same, to determine relationships between causes and effects, it would seem that judicious use of both methods would be preferable to either taken alone. This complimentarity is at least implicit in Forrester's thinking. He would use a simulation model to isolate parameters which require additional data taken from past system behavior. Econometric methods would then provide parameter estimates to be used in refining the simulation model.

CHAPTER III

DEVELOPMENT OF THE GENERAL SYSTEM MODEL

In this chapter a general description of the industry will be presented, the boundaries of the system established, and sectors, which form the basis for the simulation model, defined.

1) General Industry Description

As industries go, the softwood plywood[1] industry, having its beginning in 1905, is young. The art of plywood making is known to date back to the ancient Egyptians but only since the turn of the century has plywood found widespread application as a building material. Since its inception, the industry has shown steady growth up to the time of the Second World War and since the war industry growth has been nothing short of remarkable.

From 1947 to 1964 the number of plywood mills increased from 43 to 165 and the output from 1.7 billion square feet to 10 billion square feet.[2] This growth cannot be explained on the basis of a

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[1] The term "plywood" will henceforth be taken to mean "softwood plywood". Hardwood plywood and plywood with a thin veneer of hardwood will be excluded.

[2] "Square feet" refers to the standard industry measure of one square foot of 3/8" thick, three-ply plywood. All quantities referred to in this thesis are in terms of this standard measure.

secular increase of construction alone. In many applications, plywood has proven itself to be superior to competitive materials (chiefly lumber) in terms of cost-put-in-place and has replaced competitive products.

Though the markets for plywood are numerous, one particular market emerges as being of major importance to the industry; namely construction. In 1962 the American Plywood Association (then called the Douglas Fir Plywood Association or "DFPA") estimated that 64 percent of production was consumed in residential and non-residential construction. Since construction has a strong seasonal variation over a year, the influence of this market will later be investigated as a source of the observed seasonal variations in system variables such as price, output, and inventory levels. According to estimates for the year 1962 by the American Plywood Association, other markets for plywood are: industrial users--22 percent, agricultural users--2 percent, and miscellaneous, including do it yourself trade, 12 percent.

On the production side, the plywood industry is heavily concentrated in Washington, Oregon, and northern California. In 1961, 65 percent of production was centered in Oregon, 19 percent in Washington, 14 percent in California, and 2 percent in Idaho and Montana. While production of plywood is concentrated in the Pacific Northwest, plywood is truly a national industry with nearly 1,000 wholesale warehouses and many times that number of retail distributors located throughout the United States.

In spite of the fact that growth in the industry has been rapid, prices since the Second World War have trended steadily downward and many people in the industry claim that the less-efficient mill with little financial backing is barely able to continue operation. This is characteristic of a competitive industry and indeed the market in which mills and wholesalers meet fulfills the requirements for pure competition in the classical economic sense (20, p. 88):

1. Price at the mill is determined in a market in which many buyers and many sellers meet; none of which, individually, has a great deal of influence upon the market.

2. Plywood is essentially a homogeneous product.

3. Information regarding current prices and bids is rapidly propagated throughout the industry by means of a national telephone network.

4. Entry into and exit from the industry is relatively easy for for buyers and sellers.

While above the plywood "market" has been referred to, there are, in reality, two distinct plywood markets both competitive according to the four criteria cited. What will be termed "sanded" plywood is a smooth surface product used mainly for interior construction where surfaces are visible and "unsanded" plywood a rough surface product used mainly in construction where the panels are not visible. Since a high degree of correlation does not necessarily exist between final user demand for the two products, the two markets may behave quite differently. Mills tend to fall into three categories depending upon whether they produce sanded, unsanded, or mixed plywood while distribution warehouses and retailers almost invariably stock both types.

2) System Boundaries

In general it is probably true that everything in the world is dependent upon everything else, hence a major problem in the analysis of large scale systems is the definition of system boundaries--that is, defining what variables are to be taken as dependent, determined by the system, and what variables are to be taken as independent. If the analyst is too all-inclusive in his system definition, he may obscure fundamental interrelationships with trivia and create a system model so large that it can't be handled with allotted resources. On the other hand, if the system definition is too narrow, interrelationships may be omitted which are essential to the study of those aspects of system behavior of interest.

At this point a fundamental principle applies which greatly facilitates this establishing of system boundaries. The objectives of the study must be defined as clearly as possible. This is necessary because different objectives lead to different system models with different sets of dependent (endogenous) and independent (exogenous) variables. In this particular study, the objective has been to construct a model of the industry which will relate the behavior of mill price and output to relevant industry structure. Particular variables are included in the model on the basis of whether or not they have a significant effect on mill price and mill output.

With the above goals as guidelines the following system boundaries were tentatively established; recognizing that they might later have to be altered as the systems analysis progressed or as industry structure or environment changed:

1. The U. S. plywood market will be assumed independent of plywood produced by foreign firms. Due to existing tariffs on imported plywood, U. S. plywood imports constitute a negligible fraction of domestic production (48).

2. The U. S. plywood market will be taken as independent of the price of competitive products such as lumber and particle board. This assumption is based on the concensus of opinion that exists among knowledgeable industry officials. It is industry experience that plywood, in most applications, is priced considerably lower than competitive so that end user demand for plywood is virtually independent of the prices of competitive products.

3. The plywood market will be assumed to have a negligible effect upon the price of logs--the primary raw material in the manufacturing of plywood. Log prices are dependent upon the markets for plywood, lumber, paper, other wood products, and U. S. Government policies, in a rather complicated manner. Since the plywood market is only one of several determining factors of log prices, log price will be taken as an independent variable as far as the plywood market is concerned.

4. The production and distribution of sanded plywood will be assumed independent of the production and distribution of unsanded plywood. This assumption, based upon interviews

with industry officials, makes it possible to study the market behavior of sanded and unsanded plywood independently.

5. End user demand for plywood will be taken as an independent variable, determined by the level of national economic activity, and independent of the plywood market itself. This assumption is also based on industry experience.

3) <u>General System Model</u>

The purpose of this section is to define industry sub-divisions or sectors into which firms can be placed for purposes of aggregation. Some form of aggregation is necessary because of the prohibitive complexity involved in simulating, individually, hundreds of firms. A fundamental principle applying here is the aggregation of firms which have common input variables, common output variables, and similar rules of behavior relating outputs to inputs. The "general system model" then consists of a number of interacting sectors which, when simulated, approximately represent the hundreds of interacting firms. It should be stressed that no one general model can correctly aggregate every firm in the industry. Due to the wide diversity of organizational patterns that were found to exist, some firms, of necessity, did not fall into the sectors defined. Since aggregation, for the present at least, is essential from the practical standpoint, the problem is one of defining the sectors of the general model such that as many firms as possible are correctly aggregated and, at the same time, the general model is tractable.

The general model of Figure (3-1) was arrived at on the basis of published information relating to the industry (7, 8, 32, 33, 41) and interviews with industry personnel. Included in the general model are two producing sectors, three wholesaling sectors, and two sectors at the retail level. It should be pointed out that two of these models, illustrated in Figure (3-1), are required to represent the entire industry--one each for the sanded and unsanded markets. Descriptions of the individual sectors that make up the general model follow.

3.1) Producing sectors. The two producing sectors are designated as the "M" and "P" sectors in Figure (3-1). Firms included in the "M" sector are independent producers in the sense that they are not tied organizationally to wholesaling organizations--they are in business primarily to produce plywood. On the other hand, the producers of "P" sector are tied organizationally to the plywood distributors of "C-D" sector and are hence termed "integrated producers". The integrated producers are typically the giants of the industry--Georgia Pacific, U. S. Plywood, Weyerhaeuser, Evans Products, and small independent producers bound to these larger firms by contractual agreements. In 1962 independent mills were responsible for 60 percent of industry production with the remainder produced by integrated mills.

This sectoral breakdown of plywood producers was necessary

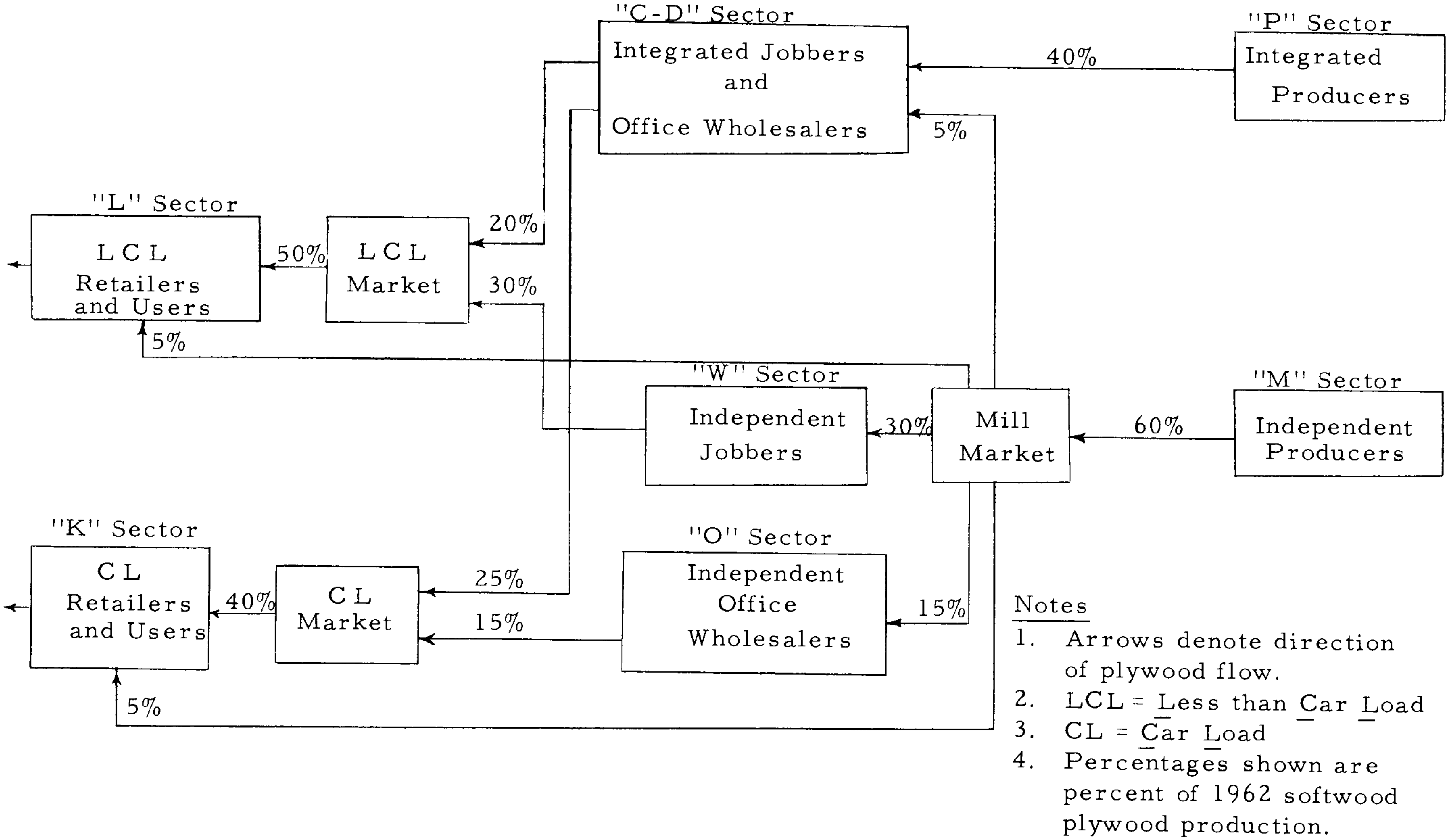

Figure (3-1) GENERAL SYSTEM MODEL

for two reasons. First, as seen in Figure (3-1) the output of the independent producers of "M" sector is offered for sale in a competitive market designated the "mill market" in Figure (3-1) while that of the integrated producers of "P" sector, for the most part, by-passes the mill market and is transferred intra-firm to the distribution outlets of "C-D" sector. Second, due to the organizational difference cited, the independent and integrated producers have markedly different price and production policies. As will be discussed in detail in the following chapter, independent mills are subject to the vagaries of the competitive market which strongly influences their price and production decisions. Integrated mills, on the other hand, are buffered from these market forces by the large distribution warehouses to which they are organizationally tied.

3.2) Retailer-user sectors. A description of the retail-user sectors ("L" and "K" in Figure (3-1)) will next be presented. These sectors include not only plywood retailers but also users of plywood who buy from the same sources as do the retailers. Included among such users are building contractors and industrial users who, due to the volume of their utilization, can purchase from wholesale outlets.

In Figure (3-1) "L" sector represents the aggregation of retailers and users who buy plywood in less than boxcar load lots from distribution warehouses. They are called "LCL Retailers and Users" where "LCL" stands for Less-than CarLoad. On the other hand, "K" sector represents users and retailers who buy plywood in boxcar load lots. They are hence called "CL Retailers and Users" where "CL" is a mnemonic representation for "CarLoad".

The distinction between the two types of retailers and users is a significant one. While less-than-carload purchases usually are made out of distribution warehouses, boxcar sized lots are normally shipped directly from the mill to save unloading, warehousing, and reloading costs at the wholesale level. There are therefore the two distinct wholesale markets for plywood shown in Figure (3-1). Prices in the LCL market are higher than the prices that prevail in the CL market because of increased costs in selling out of warehouse. In 1962 it was estimated that 50 percent of production was sold through the LCL market, 40 percent through the CL market, and 10 percent bypassed wholesale markets as seen in Figure (3-1).

3.3) Wholesale sectors. As shown in Figure (3-1), three sectors have been defined at the wholesale level. As will be seen, the three sectors represent firms that are distinctly different in terms of policies and behavior. The first of these to be discussed, the "C-D" sector, has been mentioned in connection with the integrated producers of "P" sector. The "C-D" sector is an aggregation of jobbers[1] and office wholesalers[2] who are organizationally integrated with firms in "P" sector. As seen in Figure (3-1), this sector obtains the major portion of its plywood on intra-firm transfer from integrated producers. In the aggregate, however; the "C-D" sector is able to sell more plywood than "P" sector can produce. The "C-D" sector is therefore a net buyer in the mill market and, in 1962, obtained about 10 percent of its input by buying from independent mills in the mill market as shown in the figure. On the selling side, the "C-D" sector sells out of warehouse into the LCL wholesale market and also arranges for direct shipments from mills to customers through the CL wholesale market. The sector therefore represents the aggregation of firms which perform both jobbing and office wholesaling functions. This dual role is the reason for the dual nomenclature in the sector designation "C-D". As will be seen in the following chapter, "C" refers to variables related to the jobbing function while "D" refers to office wholesaling related variables. Large integrated firms, spanning the "P"--"C-D" sectors, make profit by producing as well as by selling plywood and over-all profit is of primary concern to top level decision makers.

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[1] The term "jobber" here will be taken to mean a middleman who physically stocks plywood and sells out of his inventory.

[2] An "office wholesaler" will be defined as a middleman who buys and sells plywood without taking physical possession of the product. (In practice this is done by arranging for direct shipment from mill to customer).

Production as well as selling policies are therefore influenced by the integrated nature of firm organization.

In Figure (3-1), "O" sector represents an aggregation of distributors who act as independent office wholesalers. The firms of "O" sector buy plywood in carload lots from mills (mainly independent ones) and sell with a markup of approximately 3 percent to the retailers and users of "K" sector. Though these firms legally own the plywood for a time, the physical flow of plywood is from mill to customer. Some firms of this sector take advantage of the seasonal variation in plywood price and sell short and engage in position buying to increase their normal 3 percent markup. In 1962 it was estimated that 15 percent of the industry production was handled through independent office wholesalers.

The last of the three sectors at the wholesale level is "W" sector--an aggregation of independent jobbers. These firms are not integrated with producers and make their profit by selling plywood and other building materials out of inventory. As shown in Figure (3-1) these firms buy from independent mills and sell out of inventory in less-than-carload lots to retailers and users of "L" sector. Independent jobbers also perform an office wholesaling function but since this part of their operation is essentially the same as that of the office wholesalers of "C" sector it has been lumped together with the firms of "O" sector. Independent jobbers also take advantage of seasonal plywood price variation. They tend, as a group, to increase buying when prices are low and decrease buying when prices are high and are largely responsible for the negatively sloped demand curve which has been measured by econometric methods (41). As seen in the figure, independent jobbers handled 30 percent of 1962 production.

CHAPTER IV

CONSTRUCTION OF THE SIMULATION MODEL

In this chapter the selection of a simulation language will be discussed along with a description of salient features of the chosen language--DYNAMO. Next, conventions used in the simulation equations and diagrams will be discussed in order to provide a basis for presentation of the detailed simulation model. Finally, the simulation model for the industry will be developed in detail by constructing models for each of the seven sectors in the general model of Figure (3-1) and by specifying the interaction rules that interrelate the industry sectors.

1) Simulation Languages

At the present time, a number of simulation languages are available specifically for system simulation. The choice of a simulation language is largely dictated by the nature of the system being simulated. A number of simulation languages have become available for representing systems in which discrete events are of interest; for example--arrivals and departures in systems involving queues. The better known of these are SIMSCRIPT (29), SIMPAC (28) and GPSS (19).

As discussed in the foregoing chapter, the variables in the general model of the industry are aggregate variables. It is well known that aggregation of discrete events can lead to variables which are essentially continuous in nature. In chapter six it is shown that under certain assumptions, the aggregation of discrete time lags leads to ordinary differential equations. In this analysis, the concern is with variables that are nearly continuous in nature and describable by differential equations. Until recently, the only digital simulation language capable of efficiently simulating large systems represented by differential equations was DYNAMO. Its large capacity, speed, convenience, and richness still recommend it for the class of systems for which it was designed. DYNAMO was selected for simulation of the plywood industry for the above reasons and because of its compatibility with available computing facilities. (DYNAMO is designed for the IBM 709, 7090, and 7094 and a DYNAMO pre-compiler is available whereby much program debugging can be accomplished on the IBM 1620). It should be noted that, while the analogue computer is well suited to the type of system being simulated here, the simulation to be described would exceed the capacity of all but the largest analogue computing facilities in operation today.

1.1) <u>A brief description of DYNAMO</u>. Background concerning the DYNAMO simulation language and relevant to the understanding of the simulation models to follow will be presented here. For a more detailed description of the language and its use, the reader is referred to the DYNAMO Users Manual (34) from which the following description was taken.

As mentioned above DYNAMO is capable of simulating systems representable by differential equations. In this and in other ways, DYNAMO is similar to an extremely large analogue computer. Since DYNAMO simulates differential equations by solving difference equations with an appropriately small time increment, it can also simulate systems which are inherently describable by difference equations.

The basic time notation upon which the DYNAMO representation and solution of difference equations is based is shown in Figure (4-1).

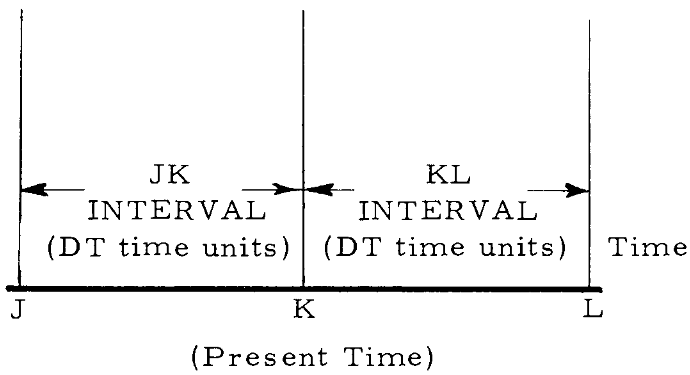


Figure (4-1) DYNAMO Time Notation

The time for which the calculations are currently being made is called TIME K. The previous time for which calculations were made is called TIME J and the next instant for which calculations will be made is TIME L. The intervals between these times are called JK and KL respectively and the length of these intervals is called DT. The names of instants (J, K, and L) and intervals (JK and KL) are used as subscripts on a variable to specify when that variable is calculated and when the variables used in the calculation were previously calculated. When all the variables have been calculated for the instant K and the interval KL, the computer moves forward one time step and the values that were associated with TIME K are now related to TIME J.

The three principal types of DYNAMO variables will be described here: levels, rates, and auxiliaries.

Level A level, which is calculated at TIME K, is a quantity that depends upon its previous value at TIME J and on other quantities at that time or in the JK interval. Levels result from a time integration of the net flow of a quantity into a storage medium for that quantity. Thus; accumulated inventory in a warehouse or charge on a capacitor are examples of levels. Levels also result from the time averaging of the rate of change of a level. A level variable will always have the subscript J or K.

Rate A rate is a variable that represents the time rate of flow of a quantity from one level to another. Electric current is an example of a rate as is production of plywood per unit time. Most rates have the units of a quantity per unit time. Rates are computed at time K for the interval KL from levels or auxiliaries at time K or rates in the interval JK and have the subscripts JK or KL.

Auxiliary Auxiliaries are variables that are introduced to simplify the algebraic complexity of rate equations and are calculated at time K from levels and other auxiliaries at time K and rates in the JK interval. They always carry the subscript K.

The order of computation of the three variable types at TIME K is as follows: First levels are calculated since they are based on previously calculated quantities from TIME J and interval JK. Next auxiliaries are calculated from levels and other previously calculated auxiliaries at TIME K and rates in the JK interval. Finally rates are calculated for the interval KL from previously calculated levels and auxiliaries.

2) Conventions

Certain conventions, used in naming variables, numbering equations, and in diagramming the interrelationship of system variables, will now be presented.

2.1) Designation of variables and constants. DYNAMO permits the use of as many as five digits or numbers (exclusive of subscripts) for the designation of variables. It is therefore possible to assign variables a mnemonic designation that conveys a good deal of information about the particular variable. The following scheme for variable designation has been established and applies to most, but not all, of the variables in the models to follow:

First Digit. The first letter in a variable designation indicates the model sector of which the variable is a part (M, P, C-D, L, O, or K).

Second Digit. The second letter designates the nature of the variable. For example the letter "P" in second position indicates that the variable is a price while "O" would indicate that the variable in question was an order (for plywood). An "A" in second position indicates that the variable is an auxiliary variable. The letter "A" is followed by a one or two digit number.

Third Digit. The third position in the variable is usually the first letter of an adjective describing the variable.

Fourth Digit. A fourth letter designated M, P, C-D, L, O, or K indicates a second sector to which the variable relates.

Fifth Digit. An S or a U in the fifth position indicates that the variable applies to a sanded or unsanded plywood model.

Unused Digits. Any of the five positions not used are filled with X's so that every variable is five letters long.

Example: MORWX.KL=M sector Orders Received from W sector in interval KL.

In the example, the letters KL following the decimal point are a subscript indicating that the variable is a rate in the KL time interval.

Constants always have the sector letter in first position and usually have the letter "K" in second position followed by a one or two digit number. The five digit designation for a constant is never followed by a subscript.

2.2) Equation Numbering. Equations in the models to follow are numbered according to the sector of which they are a part. The following numbering scheme applies:

1000-1999	Producing sectors
1100-1199	Integrated producers (P sector)
1200-1299	Independent producers (M sector)
2000-2999	Wholesale sectors
2200-2299	Integrated jobbers (C-D sector)
2100-2199	Independent jobbers (W sector)
2300-2399	Independent office wholesalers (O sector)
3000-3999	User-retailer sectors
3100-3199	LCL users and retailers (L sector)
3200-3299	CL users and retailers (K sector)

2.3) Conventions used in sector block diagrams. Block diagrams have been found to be of great value in describing and understanding the interaction of the many variables that are involved in the simulation models to follow. In fact, the procedure used in programming the model equations has been to first sketch the block diagram that interrelates the model variables and then to write the equations that mathematically represent the block diagram. The reason for this has been the great difficulty inherent in keeping track of dozens of interrelated variables when the interrelationships are hidden in a system of equations.

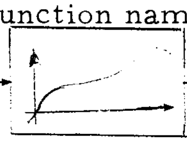
The block diagrams used here are similar in many ways to those used by control engineers with one exception--all variables in the diagrams are functions of time instead of the complex Laplace transform variable "S". The reason for this is twofold. The model contains many nonlinear operations such as the product and division of two time variables. Such nonlinear operations are not correctly represented as, in this case, product and division when variables have been Laplace transformed. Secondly, the time notation eliminates obstacles for those not acquainted with the Laplace transformation.

Figure (4-2) summarizes the conventions used in simulation model block diagrams. All variables in the figure are functions of time.

3) Independent Mills (M Sector)

In this section the simulation model of the independent mill sector will be developed in detail along with the mechanism by which price is determined in the mill market. This will be done by generating the dependent variables upon which the mill managers base their decisions and then incorporating these variables into the decision rules that determine the behavior of the mills in the sector and hence the sector itself. The key decisions to be considered here are: the production rate decision, the shipping rate decision, the order acceptance rate decision, and the price decision. A class of decisions that deal with grades and thicknesses produced are not considered here as there is strong evidence to indicate that prices of the individual grades and thicknesses move together as a function

FIGURE (4-2) BLOCK DIAGRAM CONVENTIONS

	Symbol	Definition
1.	$\pm I_n$ above, $\pm I_2(t)$ below; $I_1(t) \xrightarrow{\pm} \Sigma \to 0(t)$	$0(t) = \pm I_1(t) \pm I_2(t) \pm \ldots \pm I_n(t)$
2.	$I_1(t) \to \boxed{\Pi} \to 0(t)$, with $I_2(t)$ from below	$0(t) = I_1(t) \times I_2(t)$
3.	$I_1(t) \xrightarrow{N} \boxed{\div} \to 0(t)$, with $I_2(t) \xrightarrow{} D$ from below	$0(t) = I_1(t)/I_2(t)$ (N denotes numerator and D the denominator
4.	$I\ (t) \to \boxed{K} \to 0(t)$	$0(t) = K \times I(t)$ (K a constant)
5.	$I\ (t) \to \boxed{\int dt} \to 0(t)$	$0(t) = \int_o^t I(x)\ dx + 0(o)$
6.	$I_3(t)\ (\ )\ I_4(t)$ above; $I_1(t) \to \langle = , \neq \rangle \to 0(t)$; $I_2(t)$ below	$0(t) = I_1(t)$ if $I_3(t) = I_4(t)$ $0(t) = I_2(t)$ if $I_3(t) \neq I_4(t)$
7.	$I_3(t)(\ )\ I_4(t)$ above; $I_1(t) \to \langle \geq , < \rangle \to 0(t)$; $I_2(t)$ below	$0(t) = I_1(t)$ if $I_3(t) \geq I_4(t)$ $0(t) = I_2(t)$ if $I_3(t) < I_4(t)$
8.	T above; $I\ (t) \to \boxed{D\text{-}N} \to 0(t)$	Nth order exponential delay with time constant T/N. $0(S)/I(S) = 1/(S(T/N) + 1)^N$
9.	$I_1(t) \to \boxed{Min} \to 0(t)$, with $I_2(t)$ from below	$0(t) =$ Minimum of $I_1(t)$, $I_2(t)$
10.	$I_1(t) \to \boxed{Max} \to 0(t)$, with $I_2(t)$ from below	$0(t) =$ Maximum of $I_1(t)$, $I_2(t)$
11.	Function name $I\ (t) \to$  $\to$	$0(t)$ is the named function of $I(t)$

of over-all plywood supply and demand. That is, these decisions appear to be of importance to the individual firm but not to the industry as a whole insofar as average market price of all plywood and over-all production are concerned.

3.1) The production rate decision. According to the classical (static) theory of firm behavior, a firm maximizes profits in the short run by producing at the rate for which the marginal cost of producing a unit of output is equal to the price of a unit of output in the market. This policy, modified by a number of practical constraints to be discussed, appears, on the basis of industry data and interviews, to be followed in the industry. A cost function which relates the individual mill cost in dollars per week, C, to production rate, Q, appears below. From this cost function the production rate for maximum profit will be derived.

(4-1)[1] $C = C_o + nWh + MQ \qquad h \leq s$

$C = C_o + nWs + MQ + nW_o(h-s) \qquad h > s$

Where:

C = total cost ($/wk)
C_o = fixed cost ($/wk)
n = number of men required to operate mill
W = wage rate ($/man hour)
W_o = overtime wage rate ($/man hour)
h = total hours operated per week
s = hours worked per week on straight time
M = material cost (logs, glue, etc.) $/ft.^{2}
Q = total production (ft.^{2}/wk)

[1] Equations, such as (4-1) above, which are not a part of the simulation program will be numbered sequentially within each chapter.

The first part of Equation (4-1) represents cost when there is no overtime production while the second portion is valid for the case of overtime production. Total production, Q, is related to hours worked per week, h, by Equation (4-2):

(4-2) $Q = qh$

Where:
q = plant capacity in ft^2/hr

Combining Equations (4-1) and (4-2):

(4-3) $C = C_o + nWQ/q + MQ \qquad h \leq s$

$C = C_o + nWs + MQ + nW_o \cdot (Q/q - s) \qquad h > s$

The optimum production rate, Q, is derived from the following expression for profit rate:

(4-4) $P = pQ - C$

Where:
P = profit \$/wk
p = price \$/ft^2

To maximize profit with respect to production rate, Equation (4-4) is normally differentiated partially with respect to Q and set equal to zero; however, in this case the procedure breaks down since the resulting equation is independent of Q:

(4-5) $\partial P/\partial Q = p - (nW/q + M) \qquad h \leq s$

$\partial P/\partial Q = p - (nW_o/q + M) \qquad h > s$

Since p is an independent variable and n, W, q, and M are constants as far as the mill manager is concerned, it is impossible for him to equate price and marginal cost ($nW/q+M$ and $nW_o/q+M$). In spite of this difficulty, Equation (4-5) still tells the mill manager what he must do to maximize his profit. Since profit is an increasing function of production rate, Q, as long as price exceeds marginal cost (the right side of (4-5) positive) he maximizes profit by expanding output as long as price remains in excess of marginal cost. This can be seen more readily be examination of Figure (4-3).

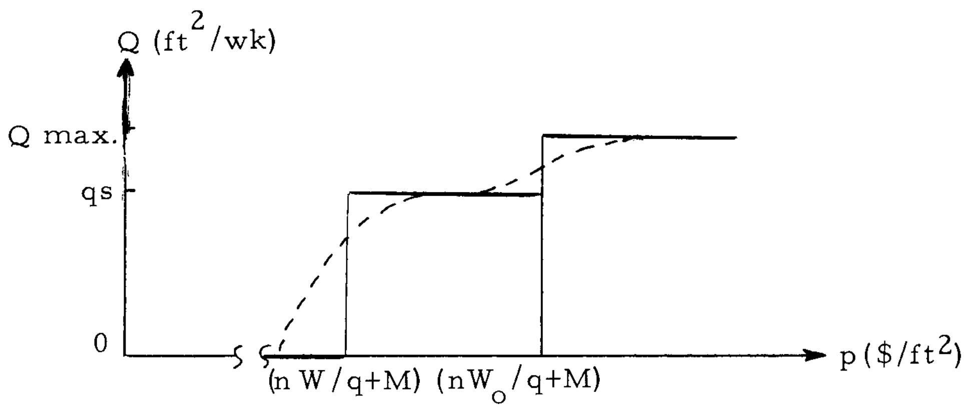


Figure (4-3) Mill Supply Curve

Three cases arise from Figure (4-3). If the market price is greater than the marginal cost on a straight time basis, ($nW/q+M$), but less than the overtime marginal cost, ($nW_o/q+M$), the mill maximizes profit by producing as much as possible without going to overtime production. Operation in this case, then, takes place s hours per week and output is qs as shown in the figure. The second case is that of market price in excess of the overtime marginal cost. In this case, profit is maximized by producing at the maximum production rate, Q max, in Figure (4-3). Case three is that of market price less than (nW/ q+M). If this situation prevails, profit rate is negative and, in the long run, a mill would be forced to cease operation. Due to shut down and start up costs, mills tend to operate for limited periods of time, perhaps at reduced output, when market price is less than the straight time marginal cost.

These three cases define the theoretical supply curve for a mill shown in heavy lines in Figure (4-3). The actual curve for an individual mill is probably more like the smoothed curve shown in the figure.

It is generally accepted in the industry that the nature of this supply curve is a cause of a major industry problem--overproduction and the attendant low market prices. As seen by the curve of Figure (4-3), a mill, in theory, maximizes profit by producing at normal straight time capacity until low prices force a cut in production. This behavior is not just theoretical, it is a very real part of the behavior of independent mills. As will be seen in later tests of the simulation model, maximization of profit by individual firms does not necessarily result in sector maximization of profit for the sector as a whole. Alternate production rate decision rules therefore provide a fertile field for improving the stability of market price.

The aggregate static supply curve for the sector is obtained by adding individual firm supply curves and can be expected to have the general shape of an individual firm curve. In the simulation model of M sector, shown in Figure (4-4), the function designated in DYNAMO language as MF3XX represents this aggregate sector supply curve with the ordinate divided by MNXXX, the number of firms in the sector. The function therefore represents the supply curve for a "typical" firm in the sector. By this representation, sector growth can be introduced into the simulation by making MNXXX a variable and thereby allowing capacity to increase.

From the block diagram it is seen that the independent variable for the supply function, MF3XX, is a function not only of price but also of the rate of change of price. This inclusion makes it possible to include mill managers expectations into the simulation. It should perhaps be pointed out that the inclusion of price rate does not affect the static profit maximization but does affect the dynamic behavior of the industry. The output (dependent variable) of MF3XX is MPDMX--M sector Production Desired per Mill. This variable, modified by constraints as described below, multiplied by the number of "typical" mills MNXXX, and lagged becomes MGIXX--M sector Goods to Inventory.

The first constraint upon the production rate decision to be discussed will be that of employee vacations. Most mills have written into union contracts the provision that employee vacations be scheduled during the summer months. Mills therefore are forced to curtail production during these months. Production desired per mill modified by summer vacation schedules, MA23X, is given by Equation 1264:

MA23X.K = SWITCH (MPDMX.K, MA22X.K, MBOX1*13.K) 1264

Where:

MA23X = Desired production rate/mill taking into account employee vacations. (ft^2/wk)

MPDMX = M sector Production rate Desired per Mill. (ft^2/wk)

MBOX1*13 = A variable that takes the value one during four week intervals in which vacations are scheduled and zero in other four week intervals during the year.

and

MA22X.K = (MK16X) (MPDMX.K) 1263

Where:

MK16X = A constant less than one

The net result of the above two equations, as indicated by the block diagram, can be paraphrased as follows:

MA23X.K = MPDMX.K if MBOX1*13 = O
MA23X.K = (MK16X) (MPDMX.K) if MBOX1*13 = 1

A second constraint upon the production rate decision is necessary. If the space available for a mill to store finished plywood is full and if there is no order backlog making shipment impossible, then it is mandatory that the mill curtail production. This constraint is introduced by Equation 1212:

MPFMX.K = CLIP (MA23X.K, MOMMX.K, MA20X.K, O) 1212

Where:

MPFMX = M sector Production rate Feasible per Mill (ft^2/wk)

MA23X = M sector production rate desired, adjusted for employee vacations.
MOMMX= M sector Order rate sMoothed per Mill (ft^2/wk)
MA20X = Sum of unused inventory capacity and unfilled order backlog (ft^2)

As seen from Figure (4-4) Equation 1212 states that:

MPFMX. K = MA23X. K if MA20X. K $\geq$ O
MPFMX. K = MOMMX. K if MA20X. K $<$ O

Production rate is therefore reduced to the smoothed (averaged) rate of incoming orders if MA20X is less than or equal to zero. One further modification of production rate is incorporated into the model. By means of Equation 1213 and the variable MA24X, production rate may be adjusted in any manner desired.

MPOXX. KL = (MPFMX. K) (MNXXX. K) (MA24X. K) 1213

Where:
MPOXX = M sector Production rate Ordered (ft^2/ wk)
MPFMX = M sector Production rate Feasible per Mill (ft^2/ wk)
MNXXX = M sector-Number of mills
MA24X = A variable that permits the introduction of modified production rate decision rules.

The variable MA24X will be used later to test modified production rate decision rules. Equation 1213 also includes the factor MNXXX which relates the decision rule to the entire sector.

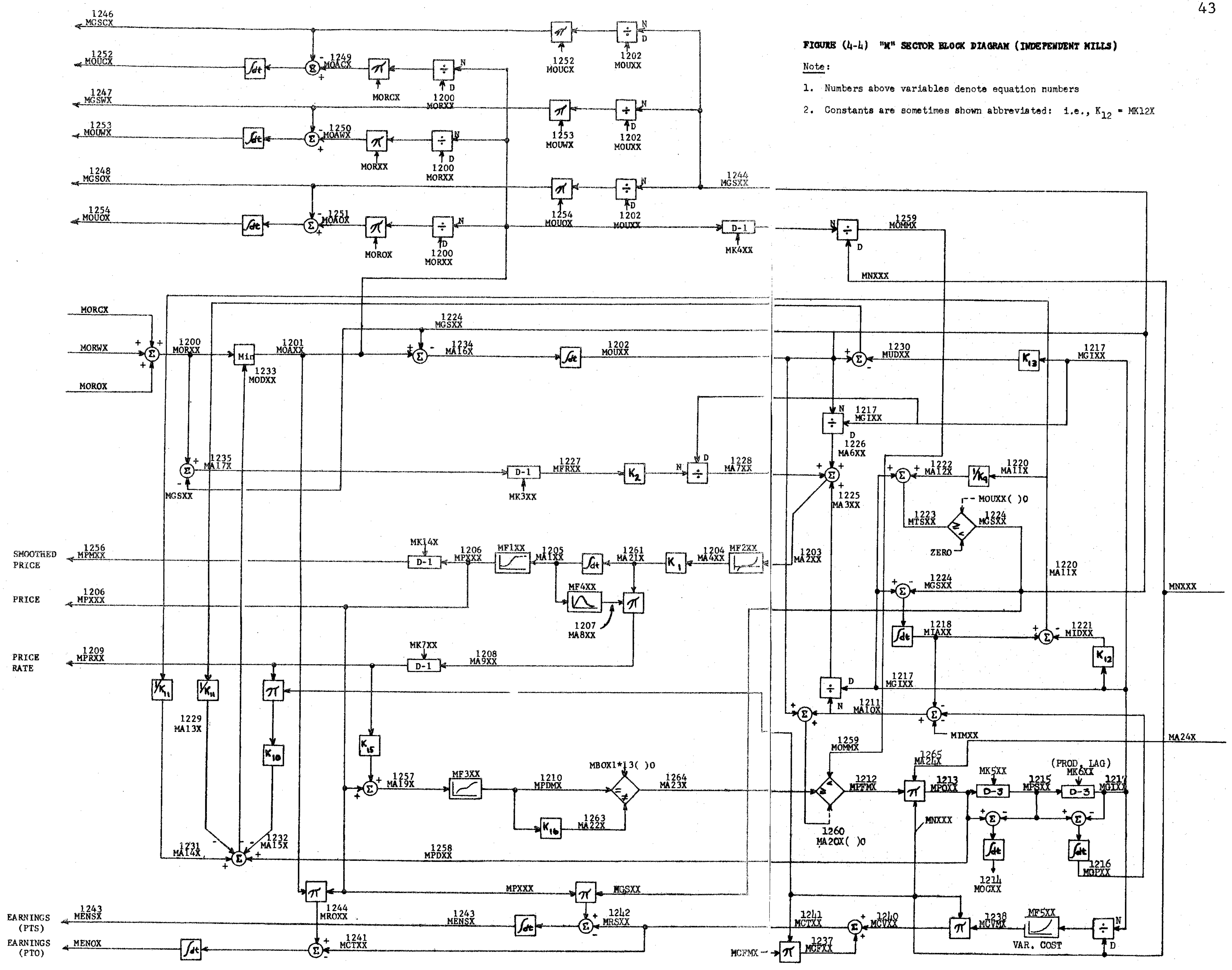
As shown in the block diagram of Figure (4-4), production rate, MGIXX, is related to the ordered production rate, MPOXX, by two third order exponential delays. For an individual mill there is some discrete time delay between the time a need arises for a

FIGURE (4-4) "M" SECTOR BLOCK DIAGRAM (INDEPENDENT MILLS)

Note:

1. Numbers above variables denote equation numbers

2. Constants are sometimes shown abbreviated: i.e., K_{12} = MK12X



production rate change and the time at which the production process actually starts changing to the new rate. This is the delay between production rate ordered and production rate started, MPOXX and MPSXX in the figure. In practice, the decision is considered to be an important one and a lag of one or two weeks may be involved while high level management considers the matter. A second pure time delay inherent in the operation of the individual mill is that shown between production rate started and the rate at which finished production is transferred to inventory, MPSXX and MGIXX in Figure (4-4). This delay is physically due to the time required to arrange for and implement an increase or decrease in the number of hours the plant is operated per week.

It has been stated above that, within an individual firm, the lags described are pure time delays. The representation of these lags as continuous exponential delays for the sector as a whole is due to a smoothing effect of aggregation and is discussed in chapter six. The model equations that specify these exponential delays are the following:

MPSXX.KL = DELAY 3(MPOXX.JK, MK5XX) 1215

MGIXX.KL = DELAY 3(MPSXX.JK, MK6XX) 1217

Where:

MPSXX = M sector Production rate Started (ft^2/ wk)
MPOXX = M sector Production rate Ordered (ft^2/ wk)
MGIXX = M sector Goods to Inventory (ft^2/ wk)
MGIXX = Time lag (weeks)
MK6XX = Time lag (weeks)

This concludes discussion of the significant factors affecting the production rate decision and its implementation. The next major independent mill sector decision to be discussed will be the shipping rate decision.

3.2) The shipping rate decision. Though the rate at which a mill ships plywood is strongly influenced by the production rate, the two rates are not necessarily equal. A mill with large warehouse capacity available at the mill site can store plywood during periods of low market price and ship at a greater rate during times of high market price while production rate remains fairly constant. Most independent mills, however, have little mill inventory capacity, less than one week of production in many cases, so sector shipping rate is very closely tied to sector production rate. There is, however, a growing awareness among independent mills of the need for sizeable mill inventory capacity to reduce the market pressure that forces output on the market at low prices. The simulation model is constructed to represent the M sector as it is now--with very little storage capacity at the mill site.

At the present time, with small aggregate independent mill warehouse capacity, the general shipping rate policy that emerged in industry interviews was that of shipping at the production rate plus a correction to adjust mill inventory to a "desired" level. The concept of a desired inventory level is a very real one in the industry. A certain level of inventory is desired by mills producing a variety of plywood grades and thicknesses to make possible longer more efficient production runs. On the other hand, excessive mill inventories also result in increased costs. Mill managers tend to think of desired inventory in terms of days or weeks of production so the level of desired inventory varies with production rate. With these background remarks, the mill shipping rate decision rule will now be developed.

In order to calculate the rate at which goods are shipped by the independent mill sector, the simulation model must first generate the variables which determine shipping rate. As discussed above, these are inventory level (MIAXX) and desired inventory (MIDXX) and will now be derived. Aggregate M sector mill inventory is given by Equation 1218:

MIAXX. K = MIAXX. J + (DT) (MGIXX. JK-MGSXX. JK) 1218

Where:

MIAXX = M sector Inventory Actual (ft^2)
MGIXX = M sector Goods to Inventory (ft^2/ wk)
MGSXX = M sector Goods Shipped (ft^2/ wk)
DT = Time interval between computer iterations (wks)

In words, Equation 1218 states that inventory level at the present time, K, is equal to inventory at the past time, J, plus the quantity put into inventory in the JK interval minus the quantity removed in the JK interval. Diagrammatically this equation is represented as the integration of the difference of the two rates in Figure (4-4). Aggregate M sector desired inventory is given by Equation 1221:

MIDXX. K = (MGIXX. JK) (MK12X) 1221

Where:

MIDXX = M sector Inventory Desired (ft^2)
MK12X = Weeks of inventory desired in weeks (a constant)
MGIXX = M sector Goods to Inventory (ft^2/ wk)

The shipping rate decision incorporated into the simulation model is given by Equation 1224:

MGSXX. KL = CLIP (MTSXX. K, MOOOO, MOUXX. K, MOOOO) 1224

Where:

MGSXX = M sector Goods Shipped (ft^2/ wk)
MOUXX = M sector Orders Unfilled (ft^2) as given by Equation 1202
MOOOO = zero
MTSXX = MGIXX + (MIAXX-MIDXX)/ MK9XX

and

MGIXX = M sector Goods to Inventory (ft^2/ wk)
MIAXX = M sector Inventory Actual (ft^2)
MIDXX = M sector Inventory Desired (ft^2)
MK9XX = Weeks to correct inventory

In the above equation, MTSXX, is a shipping rate variable that implements the policy that the shipping rate be the production rate plus a correction to adjust mill inventory to a desired level. This shipping rate is constrained in that if there is no order backlog, MOUXX, shipping rate goes to zero. This constraint is due to the physical impossibility of shipping without a customer to receive.[1] As seen from Figure (4-4), Equation 1224 can be restated as follows:

$$\begin{array}{lll} MGSXX = MGIXX + (MIAXX-MIDXX)/MK9XX & \text{if} & MOUXX \geq O \\ MGSXX = O & \text{if} & MOUXX < O \end{array}$$

Ideally the inequalities should read MOUXX>O and MOUXX≤O respectively but the net result in practice is essentially the same.

In effect the M sector shipping rate decision included in the simulation model provides for control of mill inventory. The block diagrams of Figure (4-5) illustrate this control mechanism.

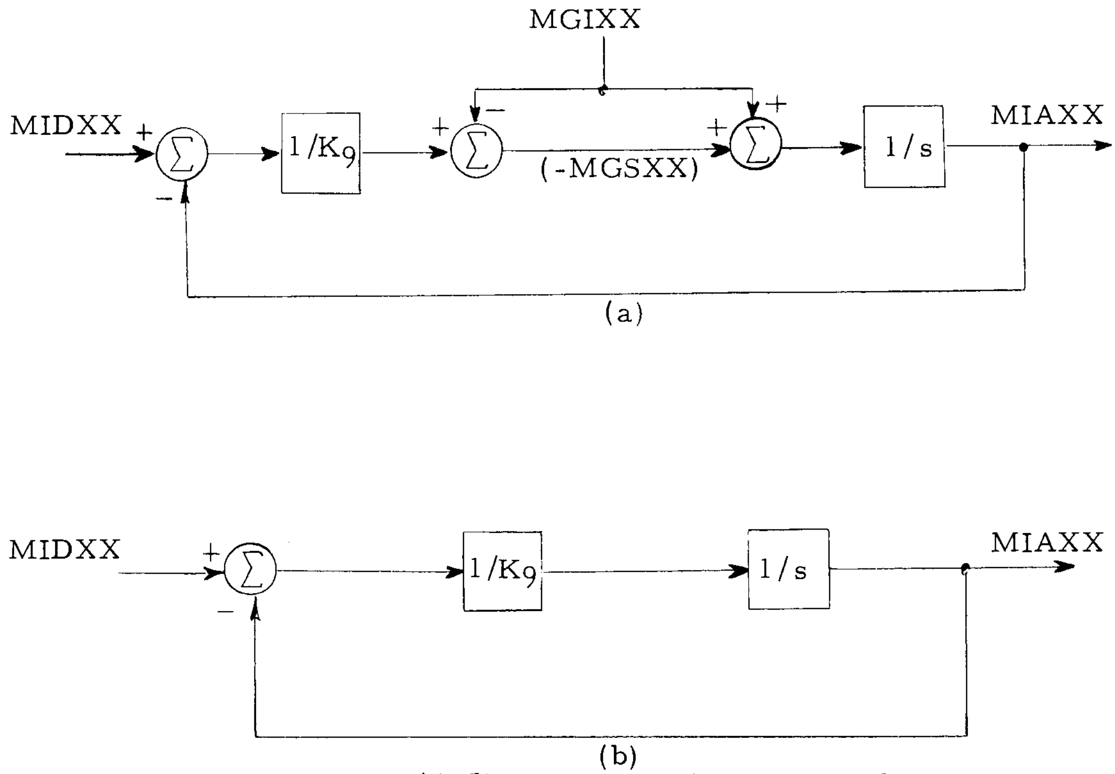


Figure (4-5) Inventory Control Mechanism

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[1] Some firms in the industry have been known to ship boxcars of plywood across the country and then attempt to sell them enroute. This behavior can be included in the simulation by considering boxcars used in this manner to be extentions of mill inventory capacity.

The two diagrams, (a) and (b), of the figure are seen to be equivalent with (b) being a simplification of (a). From feedback control theory it is known that control is always stable and that the speed of adjustment increases as MK9XX decreases.

Given the over-all shipping rate, MGSXX, shipping rates to the individual sectors which buy from M sector namely; O, W, and C must be determined in the model. Since there was no apparent reason for treating one sector differently from another, each individual sector shipping rate was taken as proportional to that sector's order backlog. Thus the individual sector shipping rates MGSOX, MGSWX, and MGSCX are determined as shown in Figure (4-4).

It should be emphasized that the shipping rate decision included in the simulation model is a representation of how independent mills appear, in general, to be behaving today and that alternate rules, perhaps based on larger mill inventory capacity, might well prove to be more profitable for the mills concerned.

3.3) The order acceptance rate decision. The order[1] acceptance rate is defined here as the rate at which firm transactions are made in the market and is a function of the rate at which orders are placed by buyers and the rate at which mills desire orders. The functional relationship is given by Equation 1201:

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[1] An "order" here is defined as a firm commitment to buy a quantity of plywood.

MOAXX. KL = MIN (MORXX. JK, MODXX. JK) 1201

Where:

MOAXX = M sector Orders Accepted (ft^2/ wk)
MORXX = M sector Orders Received (ft^2/ wk)
MODXX = M sector Orders Desired (ft^2/ wk)

The equation states that if rates demanded and offered are not equal, buyer and seller will transact at the lesser of the two rates. The rate at which orders are received by M sector, MORXX, is the sum of the rates orders are received from all sectors buying from independent mills and will be treated in later discussions of O, W, and C sectors. In what follows, the M sector desired incoming order rate, MODXX will be discussed.

If mill inventory and unfilled orders are at desired levels and if price is constant, M sector desired incoming order rate is simply the desired production rate at the prevailing market price since this incoming order rate results in continuance of desired unfilled order and inventory levels. Should a difference exist between desired and actual mill inventory, between desired and actual unfilled orders, or should market price be changing; desired incoming order rate will be other than the desired production rate. Thus, in order to generate this decision rule, the simulation model must have available the above variables. Of these, desired and actual inventory have been developed in connection with the shipping rate decision and unfilled orders, desired unfilled orders, and the rate of change of price will later be developed along with the discussion of the market price mechanism.

As shown in Figure (4-4), M sector order rate desired, MODXX, is given by the composite of Equations 1229, 1231, 1232, and 1258:

$$\begin{aligned} \text{MODXX.KL} = {} & \text{MPOXX.JK} - (\text{MK10X})(\text{MPRXX.K})(\text{MNXXX.K}) \\ & - (1/\text{MK11X})(\text{MOUXX.K} - \text{MUDXX.K}) \\ & + (1/\text{MK11X})(\text{MIAXX.K} - \text{MIDXX.K}) \end{aligned}$$

Where:

MODXX	=	M sector Order rate Desired (ft^2/ wk)
MPOXX	=	M sector Production Ordered (ft^2/ wk)
MK10X	=	Constant (ft^4/\$)
MPRXX	=	Mill Price Rate (\$/ft^2wk)
MK11X	=	Constant-weeks to correct MIAXX, MOUXX
MOUXX	=	M sector Orders Unfilled (ft^2)
MUDXX	=	M sector Unfilled orders Desired (ft^2)
MIAXX	=	M sector Inventory Actual (ft^2)
MIDXX	=	M sector Inventory Desired (ft^2)
MNXXX	=	M sector Number of firms

The first term on the right of the above equation is the desired production level at the given market price while the second term represents a correction to account for speculative behavior that is characteristic of independent mills. If market price is moving up, (MPRXX positive) mills tend to accept fewer orders as they would rather accept the orders later at a higher price. If market price is moving down the converse would be true. This factor has been included linearly in the order acceptance decision because it was not clear what nonlinear form was appropriate and because linearization of a nonlinear equation is usually useful from the practical standpoint in some finite region of the state space. The third and fourth terms in the equation for MODXX are respectively corrections for difference between actual and desired unfilled orders and between actual and desired inventories. Linear inclusion of these factors is justified on the basis that mill managers would logically think in this manner.

3.4) The mill price mechanism. The mill price mechanism was included in the simulation model of the independent mill sector because of the great influence independent mill behavior has upon market price. All sectors in the industry, of course, influence market behavior to some extent but, due to certain structural characteristics to be discussed, independent mills have a disproportionately large influence upon the market.

That facet of independent mill structure which lies at the source of their market influence is the production rate decision previously discussed. As described in section 3.1, the nature of costs induces most independent mills to produce at or in excess of normal capacity for all market prices for which profit rate is non-negative. In order to maintain this production rate when net industry supply is in excess of demand, mills are forced to cut price to maintain the order backlog necessary to continue production at the desired level (small mill inventories in this sector make it impractical to store excess production). The result of this behavior pattern is a low market price during times of excess supply that forces less efficient plants to curtail production. During times of excess demand, price rises until sufficient production is induced to equate supply and demand. Discussions with knowledgeable industry personnel have made it quite clear that net excess supply and structural characteristics of independent mills are responsible for downward price movements and the low prices experienced in the industry in recent years.

Variables which, from industry interviews, industry publications, and theoretical considerations, are known to significantly influence mill market price are: M sector Orders Received (MORXX), M sector Goods to Inventory (MGIXX), M sector Inventory Actual (MIAXX), M sector Inventory Maximum (MIMXX), M sector Orders Unfilled (MOUXX), and M sector Unfilled orders Desired (MUDXX). These variables, along with Mill Price (MPXXX) and Mill Price Rate (MPRXX), are mutually interdependent and are generated simultaneously by the simulation model. The decision rules which determine the first of the above variables (MORXX) as a function of MPXXX and MPRXX will be discussed in connection with O, W, and C sectors. Equations for the variables MGIXX, MIAXX, and MIDXX have previously been derived as functions of mill price and mill price rate. Before discussing the dependence of market price upon these variables, equations for the remaining two relevant variables, M sector Orders Unfilled and M sector Unfilled orders Desired, will be developed.

The M sector Orders Unfilled, or "unfilled order file" as it is known in the industry is obtained from an identity that follows from the definition of an unfilled order and is expressed by Equation 1202:

$$MOUXX.K = MOUXX.J + (DT)(MOAXX.JK - MGSXX.JK) \tag{1202}$$

Where:

MOUXX = M sector Orders Unfilled (ft^2)
MOAXX = M sector Order Acceptance rate (ft^2/ wk)
MGSXX = M sector Goods Shipped (ft^2/ wk)
DT = Time interval between computer calculations (wks)

The calculation of independent mill unfilled orders is shown diagrammatically in Figure (4-4).

The desired level of unfilled orders, MUDXX, was found from industry interviews to be a function of production rate. Mill managers tend to think of a "one week order file" or a "two week order file" meaning by this orders equivalent to one or two weeks of production respectively. This conversion to a time basis is probably due to the fact that efficient production runs (of a particular size or grade) and time delays inherent in changing production rate are expressed in time units. In interviews it was clear that mills had a desired unfilled order file length (in weeks) below which production planning became increasingly difficult and above which bargaining power was increasingly lost in the event of rising prices. The desired level of unfilled orders may also be thought of as a nonlinear function of mill price MPXXX, and the rate of change of price, MPRXX. At the time of the construction of the simulation model, the existence of this nonlinear dependence of desired unfilled orders upon price and price rate was not apparent. As a consequence, it was implicitly assumed that independent mills have a desired unfilled order level which is dependent only upon production rate:

MUDXX.K = (MGIXX.JK) (MK13X) 1230

Where:

MUDXX = M sector Unfilled orders Desired (ft^2)
MGIXX = M sector Goods to Inventory (ft^2/wk)
MK13X = Weeks of unfilled orders desired

During the course of tests of the simulation model, insight was gained into the nature of this nonlinear dependence of desired unfilled orders upon price and price rate. Time did not permit refinement of the original simulation model; however, a description of this improved relationship for a "second generation" model is presented in Appendix II.

In the determination of the price mechanism that was in operation in the mill market, feedback system theory played an important role. It was apparent from industry interviews that independent mills used price as a control variable to maintain a sufficient backlog of unfilled orders at the current production rate. It was also apparent that a difference between desired and actual unfilled orders was closely related to the rate of change of price. That is, if actual unfilled orders are less than desired, price rate is negative to provide the necessary unfilled order adjustment and vice versa in the case of excess actual unfilled orders. In terms of a linearized model, (at least valid for small excursions of variables) it was apparent that price rate, MPRXX, is directly proportional to the difference between actual and desired unfilled orders or, in other words, price, MPXXX, is directly proportional to the integral of the difference between desired and actual unfilled orders, (MOUXX-MUDXX). In the notation of the Laplace transformation:

$$MPXXX\ (S) = K_1\ (MOUXX(S) - MUDXX(S))/S$$

Again in a linearized model, M sector Orders Received, MORXX, is proportional to the negative of the market price:

$$MORXX(S) = -K_2 MPXX(S)$$

On the other hand, the level of unfilled orders, MOUXX is equal to the integral of the difference between MORXX and MGSXX the M sector Goods Shipping rate:

$$MOUXX(S) = (MORXX(S) - MGSXX(S))/S$$

The above equations define a feedback system in which the shipping rate, MGSXX, (closely related to desired production level) is the reference input and price, MPXXX, is allowed to vary in order to equate the incoming order rate, MORXX to the shipping rate. This simple model reflects the tendency of the mills of M sector to produce what they wish and allow price, within limits, to fall where it will.

Examination of the three equations that define this feedback system brought to light a significant fact. As this system, which determines market price, stands, it is not stable. This is apparent from the fact that the open loop transfer function has two poles at the origin of the "S" plane and no zeros in the left half plane. The system is therefore, in the parlance of control theory, an uncompensated type two system. Since the real world was known to be stable in this case and since the basic unfilled order control mechanism embodied in this simple model corresponded to that of reality, additional variables were sought which, when included, would provide the necessary stabilization of this unstable system. It became readily apparent that such a variable was the rate of change of unfilled orders. A mill manager is, for example, less prone to cut price to increase unfilled orders to a desired level if the level of unfilled orders is increasing. The inclusion of this variable results in a zero in the left half of the "S" plane and yields a system that, for a range of loop gain values, is stable. The simple linear model described above formed a nucleus which, when modified by appropriate nonlinearities, resulted in the price mechanism included in the simulation model.

The equations which determine the mill market price in the simulation model will now be discussed. The variable MA4XX, very closely related to the rate of change of mill price, is given by Equation 1204:

MA4XX.K = TABHL (MF2XX, MA2XX.K, *,*,*) 1204

Where:

MA4XX = Mill price rate (uncorrected)

,,* = Numbers used in the DYNAMO language in the specification of numerical values for a specific function

Equation 1204 states that MA4XX is the dependent variable of a table (or function) with name, MF2XX, and independent variable, MA2XX. This function, shown in Figure (4-4), introduces a dead zone into the market price mechanism so that, for a "normal" range of MA2XX, market price is constant. The independent variable, MA2XX, in the above equation is defined by the following equations:

MA2XX.K = MA7XX.K + MA6XX.K + MA3XX.K 1203

MA6XX.K = (MOUXX.K)(1)/ MGIXX.JK 1226

Where:

MA6XX = Weeks of unfilled orders at the current production rate

MOUXX = M sector Orders Unfilled (ft^2)

MGIXX = M sector Goods to Inventory (current production rate)-ft^2

MA3XX.K = (MA10X.K)(1)/ MGIXX.JK 1225

Where:

MA3XX = Weeks of unfilled mill inventory space at the current production rate

MA10X = Unfilled inventory space (ft^2)

MA7XX.K = (MFRXX.K)(MK2XX)/ MGIXX.JK 1228

Where:

MA7XX = Factor which introduces the rate of change of unfilled orders into the price mechanism
MGIXX = M sector Goods to Inventory (ft^2/wk)
MK2XX = Constant (wks)

In Equation 1228, MFRXX is the output of a smoothing delay which has an input MA17X. The variable MA17X is given by:

MA17X.KL = MORXX.JK-MGSXX.JK 1235

Where:

MA17X = Rate of change of unfilled orders (ft^2/wk)
MORXX = M sector Orders Received (ft^2/wk)
MGSXX = M sector Goods Shipped (ft^2/wk)

The variable MA2XX is thus seen to be equal to the order backlog in weeks (MA6XX) plus the unfilled inventory capacity in weeks (MA3XX) plus a factor directly proportional to the rate of change of unfilled orders (MA7XX). It is this latter term that introduces the zero into the open loop transfer function of the linearized model of the price mechanism and thereby yields stability of the mill market price. In summary, for values of MA2XX in the deadzone of the function MF2XX, MA4XX is zero and hence price rate is zero as well. For MA2XX to be in excess of the deadzone of MF2XX, unfilled orders and unfilled inventory space must exist or demand must be greater than supply (rate of change of unfilled orders positive) or both conditions must prevail. In any event, MA4XX is positive and market price is increasing. If MA2XX is smaller than the deadzone of the function MF2XX the converse of the previous statement applies and market price falls. This discussion is perhaps clarified by reference to the block diagram of Figure (4-4).

As has been mentioned above, the variable MA4XX is "nearly" equal to the rate of change of market price. The reason for this qualification will emerge in the discussion that follows. The equations which calculate mill market price, MPXXX, are the following:

MPXXX.K = TABHL (MF1XX, MA1XX.K, *, *, *) 1206

Where:

MPXXX = Mill market Price ($\$/\mathrm{ft}^2$)
MF1XX = Name of table (or function)
MA1XX = Independent variable of the table
*, *, * = Numbers used in the DYNAMO language in the specification of specific table values

MA1XX.K = MA1XX.J + DT(MA21X.J-O) 1205

MA21X.K = (MK1XX)(MA4XX.K) 1261

Where:

MK1XX = Constant
MA4XX = Price rate (unadjusted)

The above equations state that mill market price is MA4XX multiplied by the constant MK1XX, integrated with respect to time, and modified by the function MF1XX. The purpose of the function, MF1XX, is to constrain market price so that it remains above an absolute lower limit imposed by mill costs. This constraining mechanism appears to be a part of the thinking of both buyers and sellers in the market. Even buyers have a concept of a "fair price" that mills require in order to operate in the long run.

Inspection of the above equations indicate that the mill price rate, dMPXX/ dt may be expressed as follows:

$$dMPXX/dt = dMF1X(MA1XX)/dt$$

$$= (dMF1X/dMA1X)(dMA1X/dt)$$

$$dMA1X/dt = (MK1XX)(MA4XX) \qquad \text{therefore}$$

$$dMPXX/dt = (dMF1X/dMA1X)(MK1XX)(MA4XX)$$

The market price rate is thus seen to be MA4XX times the constant MK1XX times the derivative of the function MF1XX with respect to its independent variable. The computation of Mill Price Rate, MPRXX, is based on the foregoing discussion and shown diagrammatically in Figure (4-4).

This concludes discussion of the price mechanism included in the simulation model. As has been seen, the market price and price rate are a function of supply and demand in the industry which are in turn functions of price and its time rate of change. The plywood industry being simulated is therefore seen to be a highly complex feedback system.

3.5) M sector profits. The simulation model of M sector calculates the net profit of the sector from values of production rate, market price, and costs generated by the model. These computations are straight-forward and will not be discussed in detail here. To aid in interpreting the block diagram representation of the profit calculations shown in Figure (4-4), the following variables and constants are defined:

MENSX	M sector Earnings Net on a price at time of Shipment basis ($)
MENOX	M sector Earnings Net on a price at time of Order basis ($)
MRSXX	M sector Revenue on a price at time of Shipment basis ($/ wk)
MROXX	M sector Revenue on a price at time of Order basis ($/ wk)
MCTXX	M sector Cost, Total ($/ wk)
MCVXX	M sector Cost, Variable ($/ wk)
MCFXX	M sector Cost, Fixed ($/ wk)
MCFMX	M sector Cost, Fixed per Mill (constant) $/ wk
MNXXX	Number of M sector mills
MCVMX	M sector Cost, Variable per Mill ($/ wk)

3.6) Sector growth. The simulation model, as constructed, contains the variable, MNXXX, which specifies the number of mills in the sector. A number of possibilities exist with respect to the specification of MNXXX. If short run industry behavior is of interest MNXXX would be held constant. Should long run behavior of interest, the number of mills in the sector would be taken as an independent or dependent variable. It is known that industry growth is a function of profit (among other variables). The simulation model, as constructed, makes it possible to take MNXXX as a dependent variable dependent upon sector profit MENSX or MENOX.

4) Independent Jobbers (W Sector)

The next sector to be discussed will be W sector which represents the aggregation of independent jobbers over the nation that handle softwood plywood. As seen in Figure (3-1), these firms purchase about 50 percent of the output of the independent mills through what has been called the "mill market"--as much as all other wholesale outlets (for independent mill output) combined. The behavior of these firms can therefore be expected to have a strong influence upon mill market price.

In what follows, the simulation model of W sector will be described by considering individually the major decision rules that determine the behavior of the sector. These rules are: the order acceptance rate decision, the shipping rate decision, and the order rate decision. This latter decision rule is actually a composite based upon a number of component decisions concerning forecasting, speculation, and inventory control but will be discussed in toto. The block diagram for W sector is shown in Figure (4-6) and will be referred to in the discussion that follows:

4.1) The order acceptance rate decision. Before discussing this decision rule in detail, it would be well to define what is meant by an order as received by a firm of W sector. An "order" will be taken here as a definite offer to buy a quantity of plywood which, if accepted eventually leads to the shipment of the specified quantity to the purchaser. The individual firm's order acceptance rate (sales rate) is the rate at which transactions are made by the firm and is a function of a number of factors such as construction activity,

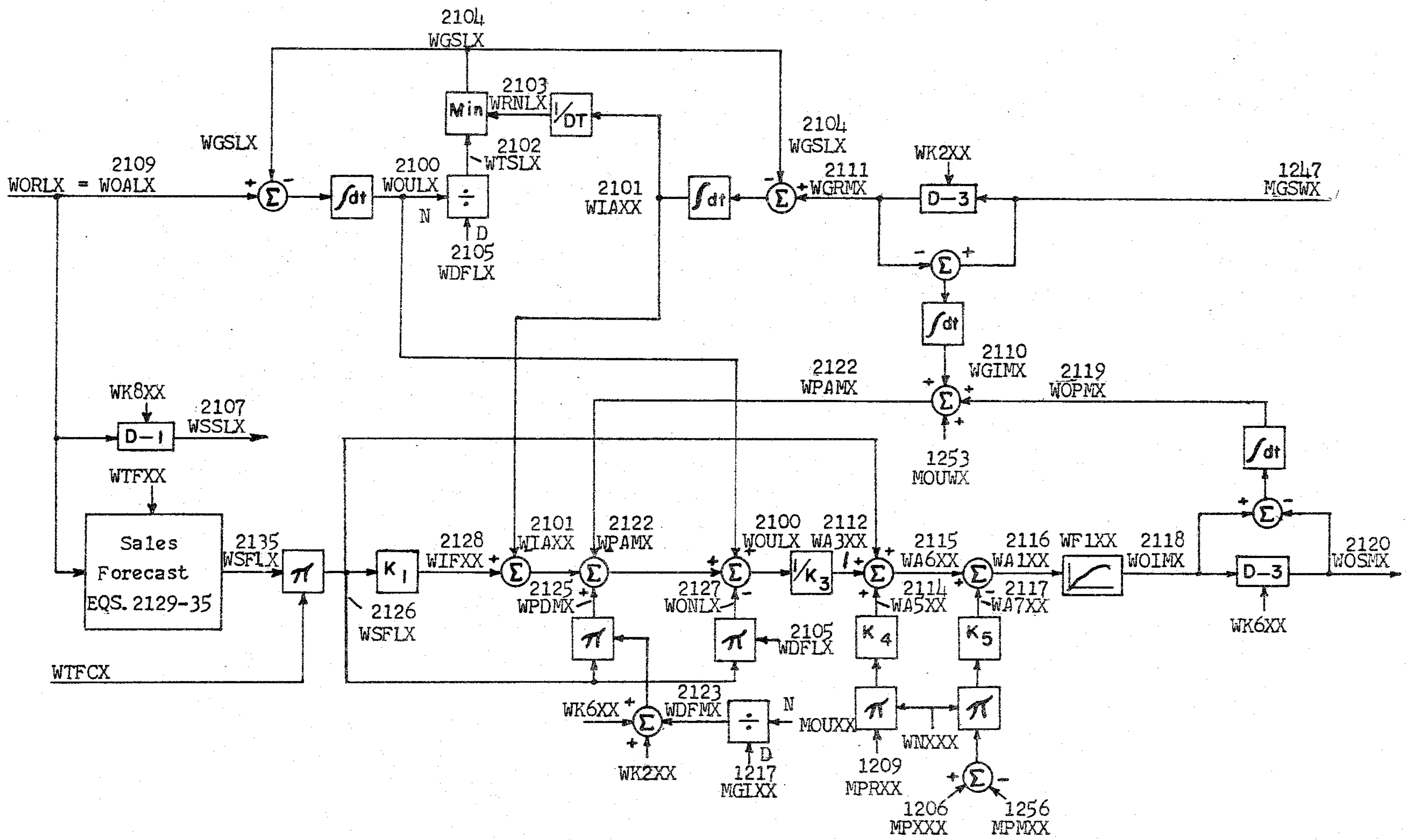

Figure (4-6) "W" SECTOR BLOCK DIAGRAM (INDEPENDENT JOBBERS) sales effort, quoted price of the individual firm, average or market price, actions of competitive firms, and quality of service. In the aggregate, however, the effects of certain of these factors tend to cancel out. For example, if one firm should increase sales by lowering price, providing superior service, or by increasing sales effort, other firms would lose sales and the net aggregate sales increase would be less than that of the individual firm. It was assumed, on the basis of this cancellation effect that the aggregate order acceptance rate is determined solely by the rate at which buyers place orders at the average market price. Price and service competition among sellers has been neglected as has any effect that increased sales effort might have upon aggregate demand for plywood. Inclusion of this latter factor might be a useful extension of the present work.

Equation 2109 of the simulation model is a mathematical state- of the above discussion:

WOALX.KL = WORLX.JK[1] 2109

[1] Actually, this equation states that the order acceptance rate in the current computation interval (KL) is equal to the rate at which orders were received in the previous computation interval (JK). A time delay equal to the computation interval DT has thus been introduced which may not exist in the real world. This one period delay is necessary due to a restriction imposed by the DYNAMO simulation language but insignificant in practice if the time interval DT is kept small enough. Forrester discusses the choice of an appropriate DT (15).

Where:

WOALX = W sector Orders Accepted from L sector (ft^2/ wk)

WORLX = W sector Orders Received from L sector (ft^2/ wk)

4.2) The shipping rate decision. The shipping rate decision rule incorporated in the simulation model of W sector is similar to that discussed by Forrester in connection with a single retail firm. The assumption is made that all firms in the sector behave in this manner and that this rule applies to the sector as a whole. This decision rule will first be presented as included in the simulation model and it will then be shown that the implications of this rule are realistic in several significant respects.

Stated in words, the W sector shipping policy is assumed to be that of shipping at a rate directly proportional to the backlog of unfilled orders, WOULX, as long as sufficient goods are available in inventory. The inventory restriction is necessary because it is impossible to ship goods which are not on hand. A mathematical description of the shipping rate decision will begin with Equation 2100 which computes the unfilled order backlog:

$$\text{WOULX.K} = \text{WOULX.J} + (\text{DT})(\text{WOALX.JK} - \text{WGSLX.JK}) \qquad 2100$$

Where:

WOULX = W sector Orders Unfilled with respect to L sector (ft^2)

WOALX = W sector Orders Accepted from L sector (ft^2/ wk)

WGSLX = W sector Goods Shipped to L sector (ft^2/ wk)

DT = Time interval between computations (wks)

The backlog of unfilled orders is seen from Equation 2100 and the sector block diagram of Figure (4-6) to be a time integration of the difference between the rate at which orders are received, WOALX, and the rate at which goods are shipped, WGSLX. Since WGSLX is the variable which is being derived, and since WGSLX is a function of itself, it is apparent that a feedback mechanism is present in the assumed decision rule. The trial shipping rate, WTSLX, which differs from the actual shipping rate in that it has not been modified by the inventory constraint, is given by Equation 2102:

WTSLX.K = WOULX.K/WDFLX.K 2102

Where:

WTSLX = W sector Trial Shipping rate to L sector (ft^2/wk)

WOULX = W sector Orders Unfilled with respect to L sector (ft^2)

WDFLX = W sector Delay in Filling orders to L sector (wks)

In the simulation model of W sector the order filling delay, WDFLX, has been taken as constant though in reality it is probably a function of the level of inventory WIAXX.[1] Experience indicates that the inclusion of this added complexity is not justified. The actual shipping rate is determined as shown in Figure (4-6) and specified by

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[1]Shipping delay will tend to increase with decreasing inventory level due to the decreased probability of the desired grade, thickness and quantity being in stock. Items not in stock are sometimes obtained from other warehouses or a mill with an additional time lapse.

Equation 2104:

$$WGSLX.KL = MIN (WTSLX.K, WRNLX.K) \qquad 2104$$

Where:

WGSLX = W sector Goods Shipped to L sector (ft^2/ wk)
WTSLX = W sector Trial Shipping rate to L sector (ft^2/ wk)
WRNLX = WIAXX/ DT (The maximum allowable shipping rate consistent with the restriction that WIAXX be non-negative)--ft^2/ wk

and:

WIAXX = W sector Inventory Actual (ft^2)

Since sector inventory level rarely, if ever, drops to the point where the limiting shipping rate comes into play, the shipping rate is essentially WTSLX.

Properties of this decision rule which recommend its inclusion in the simulation model will now be examined. Inspection of Figure (4-6), and in particular that part of the diagram which relates to Equations 2109, 2100, 2102, and 2104 brings to light the inherent feedback mechanism referred to above. If the inventory constraint is neglected, the shipping rate, WGSLX, can be considered to be the controlled variable of a first order, type-one control system with the order acceptance rate, WOALX, as the reference input. The properties of such a control system are well known. Importantly, the system is always stable. Secondly, in the steady state, the shipping rate, WGSLX, converges to the rate at which orders are received, WOALX. A third property of such a system is that the controlled variable, WGSLX, lags[1] the reference input, WGSLX. All three of these properties are observed in the behavior of the firms being simulated.

4.3) The order rate decision. Of the three decision rules under discussion in connection with the independent jobbers of W sector, the order rate decision is by far the most significant in terms of influence upon mill price and output. In what follows, the decision rule incorporated in the model will be discussed.

The variables which enter into the decision rule which determines the rate at which the independent jobbers of W sector order plywood from the independent mills of M sector are numerous. From industry interviews and published information, it became clear that the ordering rate of an individual firm of W sector is a function of at least the following variables: jobber inventory, desired jobber inventory, pipeline inventory,[2] jobber unfilled orders, desired jobber unfilled orders, current sales rate, expected (forecast) sales rate, current mill price, "normal" mill price, and rate of change of mill price. At the time the model was constructed, it was apparent that these variables should be combined in a nonlinear manner to best specify the ordering behavior of independent jobbers; however, it

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[1] In this particular case, the lag is first order exponential.

[2] The term "pipeline inventory" refers to orders and goods that are in process or in transit in the distribution system.

wasn't apparent what form this nonlinear relationship should logically take. The decision was therefore made to initially specify a linear combination of these variables; recognizing that a linear approximation to a nonlinear system is generally useful in a region of the state space about the point at which linearization is introduced. As will be seen in the following chapter, the simulation model with this linearized decision rule provided considerable insight into the behavior of the industry and reproduced some significant features of actual industry performance. Experience with this model also suggested nonlinear changes to the order rate decision rule worthy of future investigation. These possible modifications will be described in Appendix II.

The linearized order rate decision rule is shown diagrammatically in the lower portion of Figure (4-6). As seen in the diagram, the unlagged sector order rate, WOIMX, is a linear (through limited by WF1XX) combination of forecast (future) sales rate (WSFLX), a correction to adjust inventory and pipeline inventory (WA3XX), a price rate speculation factor (WA5XX), and a price speculation factor (WA7XX). The actual order rate, WOSMX, is WOIMX lagged by a third order exponential delay which represents, in the aggregate, the order processing delay of the individual firms.

The first of these terms, forecast sales rate WSFLX, is included because of a tendency on the part of jobbers to allow their expectation of future sales to influence current buying.[1] In particular, the strong seasonal variation of sales and price experienced by the industry causes jobbers to increase order rate prior to the spring construction boom and to reduce orders in the fall after the peak in construction has past. The origin of the forecast sales rate, WSFLX, is discussed below.

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[1]In a number of computer runs the smoothed current sales rate, WSSLX, was included in the W sector order rate decision rule in place of forecast sales rate, WSFLX. The inclusion of WSSLX was based upon the assumption that jobbers ordered to replace goods sold. Computer runs which included the forecast variable WSFLX, however, yielded results which closer resembled past industry experience. This fact would indicate that expectations of future sales play a significant role in the determination of W sector order rate. The smoothed order rate, WSSLX, is generated in the simulation model as shown in Figure (4-6) and is given by Equation 2107:

$$\text{WSSLX.K} = \text{WSSLX.J} + (\text{DT})(1/\text{WK8XX})(\text{WOALX.JK} - \text{WSSLX.J}) \qquad 2107$$

Where:

WSSLX = W sector Sales Smoothed to L sector (ft^2/ wk)
WOALX = W sector Orders Accepted from L sector (ft^2/ wk)
WK8XX = Smoothing time constant (wks)
DT = Computation interval

It is readily seen that WSSLX is related to WOALX through a first order exponential lag with time constant WK8XX.

To show that Equation 2107 defines a first order exponential lag, it is re-written as follows:

$$(\text{WK8XX})(\text{WSSLX.K} - \text{WSSLX.J})/\text{DT} + \text{WSSLX.J} = \text{WOALX.JK}$$

If DT is very small (as it is in the simulation model) the first term on the left of this equation becomes the time derivative of WSSLX, subscripts may be dropped, and the variables expressed as a function of time-t:

$$(\text{WK8XX})\, d(\text{WSSLX}(t))/dt + \text{WSSLX}(t) = \text{WOALX}(t)$$

The second equation is the time domain representation of a first order exponential lag with time constant WK8XX.

The second term in the order rate decision WA3XX in Figure (4-6), is introduced because of the need for individual jobbers to control the level of warehouse inventory. If inventories are too small, the firm will tend to lose sales to competitors because of inability to supply specific plywood grades and thicknesses. Excessive inventories are also undesirable due to increased costs and needless incapacitation of capital. Inventory control also implies control of goods and orders in the distribution pipeline because failure to adjust pipeline inventories results in a later imbalance in actual warehouse inventory. A number of variables which enter into the determination of WA3XX will now be derived.

A variable that plays a significant role in the control of the inventory level of the individual firm is a forecast of future sales rate. The simulation model of W sector includes a series of equations which provide a forecast of sales WTFXX weeks into the future. The variable WSF1X (W sector Sales rate, Forecast 1st approximation, shown in Figure (4-6), is an average of sales rate over past years, weighted as to give more emphasis to recent years, and projected WTFXX weeks into the future. The equations which compute WSF1X are given in Appendix I (Equations 2129-35) and will not be discussed here. This forecasting method is, however, described by Forrester (15). As seen in Figure (4-6), the actual forecast sales rate WSFLX is given by:

WSFLX.K = (WSF1X.K)(WTFCX.K) 2126

Where:

WSFLX = W sector Sales rate Forecast to L sector (ft^2/wk)

WSF1X = W sector Sales rate Forecast 1st approximation (ft^2/wk)

WTFCX = W sector Trend ForeCast adjustment factor

The purpose of Equation 2126 is to allow for introduction of information relating to the trend of sales over time or information obtained from national economic forecasts. In recent years sales of plywood have trended steadily upward so WTFCX is normally somewhat greater than unity. Efforts were made to generate the trend of sales as a dependent variable of the model but initial results were less than satisfactory. As shown in Figure (4-6), the adjustment for a trend in sales rate is introduced into the model as an independent variable. Since it is necessary to introduce information from national economic forecasts into the model as an independent variable, this information may be combined with trend information in the single independent variable, WTFCX.

Given the forecast of sales rate WTFXX weeks into the future, WSFLX, the simulation model calculates WIFXX--the future desired inventory level given by Equation 2128:

WIFXX.K = (WK1XX)(WSFLX.K) 2128

Where:

WIFXX = W sector Inventory Forecast (ft^2)

WSFLX = W sector Sales rate Forecast to L sector (ft^2/wk)

WK1XX = A constant equal to the weeks of inventory desired at the expected sales rate

The relationship of Equation 2128 is based on the tendency of jobbers to think of inventory levels in terms of weeks of sales. Desired inventory, then, varies directly with sales rate.

The concept of desired inventory is necessary in the model because it provides a reference for calculation of an order rate change to correct inventory level thus; the difference between actual inventory, WIAXX, and forecast inventory, WIFXX, enters into the determination of WA3XX, the order rate correction to adjust inventory level. The actual inventory level is given by a time integration of the difference between the rates at which W sector receives and ships goods as given by Equation 2101:

WIAXX. K = WIAXX. J + (DT)(WGRMX. JK-WGSLX. JK) 2101

Where:

WIAXX = W sector Inventory Actual (ft^2)
WGSLX = W sector Goods Shipped to L sector (ft^2/ wk)
WGRMX = W sector Goods Received from M sector (ft^2/ wk)
DT = Time interval used in computation

The rate at which goods are received, WGRMX, is simply the rate at which goods are shipped to W sector lagged by the transit time from mill to warehouse:

WGRMX. KL = DELAY3(MGSWX. JK, WK2XX) 2111

Where:

WGRMX = W sector Goods Received from M sector (ft^2/ wk)

MGSWX = M sector Goods Shipped to W sector (ft^2/wk)
WK2XX = Average time of transit (wks)

Equation 2111 is a DYNAMO statement which introduces a third order exponential lag with time constant WK2XX between WGRMX and MGSWX. The reasoning underlying the selection of this particular form of lag is given in chapter six.

As mentioned above, it is necessary not only to control actual inventory but also the levels of orders and goods in the distribution system pipeline. The actual and desired pipeline inventory terms necessary for the computation of WA3XX, the order rate correction to adjust inventory, will now be developed. The actual pipeline inventory for a firm or the sector as a whole is readily seen to be the sum of orders being processed at the warehouse plus unfilled orders at the mill plus goods in transit from mill to warehouse. This summation is shown by Figure (4-6) and is given by Equation 2122:

WPAMX. K = WGIMX. K + WOPMX. K + MOUWX. K   2122

Where:

WPAMX = W sector Pipeline inventory Actual with respect to M sector (ft^2)
WGIMX = W sector Goods In transit from M sector (ft^2)
MOUWX = M sector Orders Unfilled with respect to W sector (ft^2)
WOPMX = W sector Orders in Process to M sector (ft^2)

As seen in Figure (4-6), WGIMX is obtained by a time integration of the difference between the rate at which shipments are made to W sector and the rate at which W sector receives goods. WOPMX is obtained from a similar integration. The unfilled order level, MOUWX, is a dependent variable which is determined within M sector.

Attention will now be directed to the determination of the level of pipeline inventory desired by firms of W sector. This desired level of pipeline inventory is strongly dependent upon the rate at which goods are sold out of warehouse. If sales rate is constant and inventories are at desired levels, a certain level of pipeline inventory is necessary to maintain the existing sales rate without disturbing warehouse inventory levels. That is, there is a level of pipeline inventory which will maintain the desired warehouse inventory level at the existing sales rate. This pipeline inventory level which produces equilibrium at a given sales rate is what has been termed "desired pipeline inventory" and is given by Equation 2125:

$$\text{WPDMX.K} = (\text{WSFLX.K})(\text{WK6XX} + \text{WK2XX} + \text{WDFMX.K}) \qquad 2125$$

Where:

WPDMX	=	W sector Pipeline inventory Desired with respect to M sector (ft^2)
WSFLX	=	W sector Sales Forecast to L sector (ft^2/ wk)
WK6XX	=	Order processing lag (wks)
WK2XX	=	Shipping delay, mill-warehouse (wks)
WDFMX	=	W sector Delay in Filling orders at M sector (wks) is the time required for mills to fill warehouse orders.

Equation 2125 is true because the quantity of goods stored in exponential lags such as WK6XX, WK2XX, and WDFMX at a constant throughput rate is equal to the throughput rate (WSFLX here) times the duration of the lag.[1]

As seen in Figure (4-6) W sector unfilled orders, WOULX, and the normal level of unfilled orders, WONLX, also are included in the order rate decision rule factor, WA3XX. These factors are included because they behave like pipeline inventory terms. The equation for the normal level of unfilled orders is thus given by:

WONLX.K = (WSFLX.K)(WDFLX.K) 2127

Where:

WONLX = W sector unfilled Orders Normal with respect to L sector (ft^2)

WSFLX = W sector Sales rate Forecast to L sector (ft^2/wk)

---

[1] This may be seen by first considering the first order exponential lag given by:

$$T dO(t)/dt + O(t) = I(t)$$

I(t) represents the rate at which goods or orders enter the delay process, O(t) the rate goods or orders leave the delay process and T the time constant of the exponential delay. The quantity of goods stored in the delay process, Q(t), is given by:

$$Q(t) = \int (I(t) - O(t))dt + Q(o)$$

and

$$dQ(t)/dt = I(t) - O(t)$$

which with the first equation yields

$$dQ(t)/dt = T dO(t)/dt.$$

Integration of this latter equation gives

$$Q(t) = O(t)T.$$

In the steady state O(t) = I(t) and the quantity Q(t) is equal to the time constant, T, times the throughput rate. As seen in Figure (4-2) higher (Nth) order delays are equivalent to N cascaded first order delays each with a time constant of T/N where T is the length of the time delay. It follows, then, that for an exponential lag of any order the quantity stored in the delay process is equal to the throughput rate times the duration of the delay.

WDFLX = W sector Delay in Filling orders to L sector (wks)

With the above variables available, that factor of the order rate decision which provides for control of actual inventory, pipeline inventory, and unfilled orders is now specified by Equation 2112:

$$WA3XX.K = (1/WK3XX)(WIFXX.K - WIAXX.K + WPDMX.K - WPAMX.K + WOULX.K - WONLX.K) \qquad 2112$$

Where:

WA3XX = Factor in order rate decision rule which provides for control of actual inventory, pipeline inventory, and unfilled orders.
WK3XX = constant (wks)
WIFXX = W sector Inventory Forecast (ft^2)
WIAXX = W sector Inventory Actual (ft^2)
WPDMX = W sector Pipeline inventory Desired with respect to M sector (ft^2)
WPAMX = W sector Pipeline inventory, Actual with respect to M sector (ft^2)
WOULX = W sector Orders Unfilled with respect to L sector (ft^2)
WONLX = W sector unfilled Orders Normal with respect to L sector (ft^2)

The constant WK3XX determines the speed of adjustment of the controlled variables in Equation 2112.

The next factor occurring in the independent jobber order rate decision rule represents the influence of the price prevailing in the mill market. Independent jobbers, as a group, are strongly influenced in their buying by the current market price. Due to seasonal fluctuation in the mill price it is possible for these jobbers to substantially augment their normal profit by buying during times of the year when the price is low and selling during periods of high market price. Equation 2117 defines this price speculation factor entering into the order rate decision rule:

$$WA7XX.K = (WNXXX.K)(MPXXX.K-MPMXX.K)(WK5XX) \quad 2117$$

Where:

WA7XX = Price speculation factor (ft^2/ wk)
WNXXX = Number of independent jobbers
MPXXX = Mill market Price (\$/ ft^2)
MPMXX = Mill market Price sMoothed (averaged)
WK5XX = Demand constant for an individual warehouse, (ft^2/ wk)(\$/ ft^2)

Equation 2117 defines the amount by which the aggregate independent jobber order rate is changed as current price, MPXXX, varies with respect to smoothed or average price, MPMXX. The concept of an average or "normal" price is a very real one in the minds of industry decision makers. The model generates this average price by exponentially smoothing current price, MPXXX, over one or more years as shown in the M sector block diagram, Figure (4-4). The use of exponential smoothing is realistic in that it tends to weight recent data more heavily than past data as described by Forrester (15).

Independent jobbers are influenced in their ordering not only by market price but by the rate of change of market price as well. If price is moving up, buying will tend to increase in order to avoid buying later at a higher price. If price is falling the converse would be true. This behavior is introduced into the order rate decision rule by Equation 2114:

$$WA5XX.K = (WK4XX)(MPRXX.K)(WNXXX.K) \qquad 2114$$

Where:

WA5XX = Price rate speculation factor (ft^2/ wk)
WK4XX = Speculation constant for an individual warehouse, (ft^2/ wk)/ (\$/ ft^2 wk)
MPRXX = Mill market Price Rate (\$/ ft^2)/ (wk)
WNXXX = Number of Independent jobbers

The rate of change of mill price, MPRXX, is generated by the simulation model as shown in the block diagram of M sector, Figure (4-4). The number of independent jobbers, WNXXX, may be introduced into the model as a variable or a constant depending upon whether long or short run behavior is of interest.

The various factors which, when summed, limited as to preclude the possibility of a negative order rate, and lagged form the linearized W sector order rate decision rule, have been derived. The summation of these several factors is represented by WA1XX as shown in Figure (4-6). This summation, limited to eliminate the possibility of a physically impossible negative order rate, is the variable WOIMX. The limiting action is introduced by the function named WF1XX in Figure (4-6). This function has the property that the dependent variable (WOIMX) has the value zero for values of the independent variable (WA1XX) less than zero. For values of WA1XX greater than zero, WOIMX is equal to WA1XX up to some limiting value beyond which it does not increase. The actual rate at which

W sector places orders, WOSMX, is the variable WOIMX lagged by an order processing delay:

WOSMX.KL = DELAY3(WOIMX.JK, WK6XX) 2120

Where:

WOSMX = W sector Orders Sent to M sector (ft^2/ wk)
WOIMX = W sector Orders Impending to M sector (ft^2/ wk)
WK6XX = Average W sector order processing delay (wks)
DELAY3 = DYNAMO representation of a third order exponential lag.

This concludes discussion of simulation of the independent jobbers of W sector.

5) Users and Retailers (L Sector)

As stated previously, L sector represents an aggregation of users and retailers of plywood who buy plywood from jobbers in less than boxcar load lots. They are not to be confused with the users and retailers of K sector who buy at a lower wholesale price by purchasing boxcar load quantities. A lower price prevails in the latter case because of the elimination of jobber handling costs.

In important respects, the behavior patterns of firms in both L and K sectors resemble those of the jobbers of W sector. All these firms hold, and therefore must control, plywood inventory and all increase their profit by price and price rate speculation in their respective markets. For this reason, only variations from the previously discussed W sector decision rules will be described in detail in what follows.

The block diagram which defines the interaction of the significant L sector variables in shown in Figure (4-7). In addition to the three basic decisions discussed in connection with W sector; namely the order acceptance, shipping and order rate decisions, the firms of L sector have the additional decision of whether to buy from an independent jobber of W sector or an integrated jobber of C sector. These four basic decision rules will be discussed in the following sections.

5.1) The order acceptance rate decision. Previous discussion relating to the W sector order acceptance rate decision applies directly here. The order acceptance rate is given by Equation 3143:

LOAXX.KL = LORXX.JK 3143

Where:
LOAXX = L sector Orders Accepted (ft^2/ wk)
LORXX = L sector Orders Received

The variable, LORXX, is one of the very few independent or exogenous variables in the simulation model. It is determined by such factors as new construction and demand for industrial products which utilize plywood. These factors are in turn a function of the national economic environment.

5.2) The shipping rate decision. The shipping rate incorporated into the simulation model of L sector is exactly that previously described in connection with W sector. This decision rule is as shown in Figure (4-7) and is specified by the following equations:

LGSXX.KL = MIN(LA2XX.K, LA3XX.K) 3107

Where:
LGSXX = L sector Goods Shipped (ft^2/wk)
And:
LA2XX.K = LOUXX.K/LK2XX 3105
Where:
LOUXX = L sector Orders Unfilled (ft^2)
LA3XX.K = LIAXX.K/DT
Where:
LIAXX = L sector Inventory Actual (ft^2)

The level of unfilled orders, LOUXX, is in turn a function of the rate at which goods are shipped:

LOUXX.K = LOUXX.J + (DT)(LOAXX.JK - LGSXX.JK) 3104

Where:
LOUXX = L sector Orders Unfilled (ft^2)
LOAXX = L sector Orders Accepted (ft^2/wk)
LGSXX = L sector Goods Shipped (ft^2/wk)

5.3) The order rate decision. The order rate decision of L sector is essentially that of W sector with two modifications. The first of these is the omission of a term in the pipeline inventory correction to adjust the levels of unfilled orders at W and C sectors. The effect of this factor was not deemed significant enough to justify inclusion. The second modification is the inclusion of the factors LSGKX and LSLKX shown in Figure (4-7). The first of these is

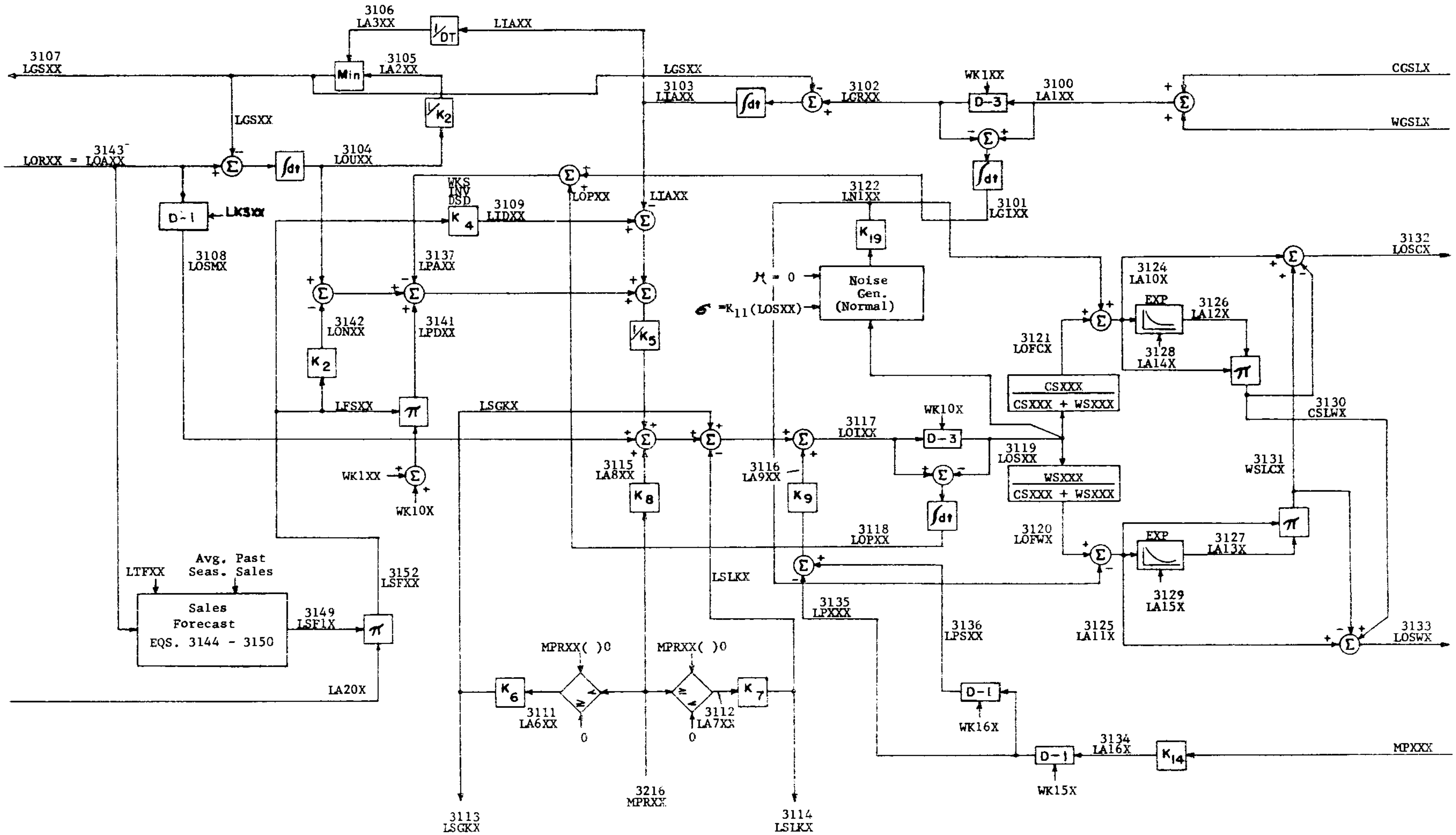

FIGURE (4-7) "L" SECTOR BLOCK DIAGRAM (LCL USERS AND RETAILERS) given by Equation 3113:

LSGKX = (LA6XX. K)(LK6XX) 3113

Where:

LSGKX = L sector Sales Gained from K sector (ft^2/ wk)
LK6XX = Constant, (ft^2/ wk)/ (\$/ wk. ft^2)
LA6XX = O if MPRXX is greater than or equal to zero
LA6XX = MPRXX if MPRXX is less than zero

This equation introduces into the model a behavior pattern of those decision makers who may purchase in either carload or less than carload lots. Equation 3113 states that L sector will gain sales that would otherwise have gone to K sector if the price rate, MPRXX, is negative. The rationale here is that when price is falling customers prefer to buy in small (less than carload) lots from L sector so they can purchase in carload lots (from K sector) at lower prices at a later time. The variable LSLKX, on the other hand, specifies the sales L sector loses to K sector when the mill price is rising:

LSLKX. K = (LA7XX. K)(LK7XX) 3114

Where:

LSLKX = L sector Sales Last to K sector (ft^2/ wk)
LK7XX = Constant, (ft^2/ wk)/ (\$/ wk ft^2)
LA7XX = MPRXX if MPRXX is greater than or equal to zero
LA7XX = O if MPRXX is less than zero

Should mill price be rising, customers would prefer to buy from K sector in carload lots and as a result L sector would lose sales as specified by Equation 3114.

The total rate at which the firms of L sector order, LOSXX, is seen from Figure (4-7) to be the lagged sum of an inventory, pipeline inventory and unfilled order correction (LA4XX), a correction for sales lost or gained from K sector (LSLKX or LSGKX), a price rate speculation factor (LA8XX), current smoothed sales (LOSMX) and a price speculation factor (LA9XX). Before leaving the L sector order rate decision rule it would be well to discuss the origin of wholesale price, LPXXX, upon which the price speculation factor is based. In industry interviews it soon became apparent that a plurality of wholesale prices existed in numerous regional wholesale markets over the country. Prices in these regional markets may vary widely due to variation in local supply-demand relationships. It was also apparent from interviews that regional wholesale prices, in the absence of competitive factors, were determined by the mill market price plus a wholesale mark up and that the wholesale price tended to follow the mill price up and down. Since it is impractical and probably unnecessary to include these many regional wholesale markets in the simulation model, the wholesale price in the less than carload market, LPXXX, was taken as a lagged function of the mill market price, MPXXX. This relationship is shown diagrammatically in Figure (4-7) and is given by Equations 3134 and 3135:

$$\text{LPXXX.K} = \text{LPXXX.J} + (\text{DT})(1/\text{LK15X})(\text{LA16X.J} - \text{LPXXX.J}) \qquad 3135$$

Where:

LPXXX = Less than carload market Price ($\$/ft^2$)
LK15X = Time constant of first order lag (wks)

The variable LA16X in Equation 3135 is, in turn, given by Equation 3134:

$$LA16X.K = (MPXXX.K)(LK14X) \qquad 3134$$

Where:

MPXXX = Mill Market Price ($\$/ft^2$)

LK14X = Average ratio of wholesale to mill price

The mill market price is determined in the mill market as discussed in connection with M sector.

5.4) The "where to buy" decision. Attention will now be turned to a decision rule which is uniquely a part of L sector. As reference to Figure (3-1) indicates, L sector has the option of buying from W sector or C sector--independent or integrated jobbers. It was therefore necessary to pose the question: is there any rational basis for firms of L sector favoring one sector over the other? Information obtained from industry interviews brought to light two factors which could possibly have such an influence. The first of these is relative sales effort on the part of independent and integrated jobbers. "Sales effort" includes such factors as advertising, the number and quality of sales personnel and the number of personal sales contacts with prospective customers. Contacts with industry personnel indicated that, as a group, integrated jobbers tend to be more aggressive and more inclined to seek increased sales.

Relative sales effort was introduced into the simulation model by means of Equations 3120 and 3121:

LOFWX. K = (LOSXX. JK)(WSXXX)/ (CSXXX + WSXXX) 3120

Where:

LOFWX = L sector Orders Feasible to W sector (ft^2/ wk)
LOSXX = L sector Orders Sent (ft^2/ wk)
WSXXX = W sector Sales effort
CSXXX = C sector Sales effort

LOFCX. K = (LOSXX. JK)(CSXXX)/ (CSXXX + WSXXX) 3121

Where:

LOFCX = L sector Orders Feasible to C sector (ft^2/ wk)

It is readily seen that the sum of LOFWX and LOFCX is the total L sector order rate, LOSXX. As programmed, sales efforts, CSXXX and WSXXX, have been considered as constants; however, these factors could readily be included as functions of variables within W and C sectors should it be of interest to do so. It was felt that "sales effort" was sufficiently stochastic in nature to justify the inclusion of a random or noise disturbance at this point. As shown in the figure, the variable LN1XX is this noise disturbance term:

LN1XX. K = (LK19X) NORMRN (O, LN1SX. K) 3122

Where:

LN1XX = Noise disturbance (ft^2/ wk)
LK19X = Constant
(O, LN1SX. K) = Mean and standard deviation of NORMRN

The variable LN1XX, defined by Equation 3122 is a normally distributed random variable with mean zero and standard deviation

(LN1SX)(LK19X). This random variable is added to LOFCX and subtracted from LOFWX to yield the new random variables LA10X and LA11X respectively:

LA10X.K = LOFCX.K + LN1XX.K 3124

Where:

LOFCX = L sector Orders Feasible to C sector (ft^2/wk)

LN1XX = Noise disturbance term (ft^2/wk)

LA11X.K = LOFWX.K - LN1XX.K 3125

Where:

LOFWX = L sector Orders Feasible to W sector (ft^2/wk)

LN1XX = Noise disturbance term (ft^2/wk)

The sum of the randomized feasible order rates, LA10X and LA11X, is still equal to the total orders sent by L sector, LOSXX.

A second factor entering into the division of L sector order rate, LOSXX, between W and C sectors is introduced at this point. As has been discussed in connection with W sector, independent jobbers as a group allow mill price to strongly influence their ordering policy. This factor gives rise to wide fluctuations in independent jobber inventory levels which result in periods of low inventory. Integrated jobbers, on the other hand, usually maintain inventory levels at or above some desired lower limit. The net result of this difference in inventory control policies is a tendency for independent jobbers to lose sales to integrated jobbers because of not being able to fill certain orders due to out of stock items. This effect is, in part at least, compensated for by independent jobbers assisting one another in supplying customer needs.

The simulation of this second factor affecting distribution of L sector orders between W and C sectors will now be discussed. The probability of losing an order due to an item being out of stock is strongly dependent upon the level of inventory held. If inventory is zero, the probability of not being able to fill the order is unity assuming the item is not available from other sources. On the other hand, if inventory levels are very large, the probability of losing a sale due to an out of stock item approaches zero. This strongly suggests an exponential relationship between inventory level as independent variable and the probability of losing sales as dependent variable. This is the relationship included in the model by Equations 3126 and 3127:

LA12X.K = (1)EXP(-LA14X.K) 3126

Where:

LA12X = Probability of C sector losing sales to W sector

LA14X.K = (LK12X)(CIAXX.K)/ LA10X.K 3128

Where:

LK12X = Constant

CIAXX = C sector Inventory Actual (ft^2)

LA10X = L sector orders feasible to C sector (randomized), ft^2/ wk

LA13X.K = (1)EXP(-LA15X.K) 3127

Where:

LA13X = Probability of W sector losing sales to C sector

LA15X.K = (LK13X)(WIAXX.K)/ LA11X.K 3129

Where:

LK13X = Constant

WIAXX = W sector Inventory Actual (ft^2)

LA11X = L sector orders feasible to W sector (randomized), ft^2/ wk

The rates at which C and W sectors lose sales to one another are calculated in the model as Equations 3130 and 3131:

CSLWX.K = (LA10X.K)(LA12X.K) 3130

Where:

CSLWX = C sector Sales Lost to W sector (ft^2/ wk)

LA10X = L sector orders feasible to C sector (randomized), ft^2/ wk

LA12X = Probability of C sector losing sales to W sector

WSLCX.K = (LA11K)(LA13X.K) 3131

Where:

WSLCX = W sector Sales Lost to C sector (ft^2/ wk)

LA11X = L sector orders feasible to C sector (randomized), ft^2/ wk

LA13X = Probability of W sector losing sales to C sector

The actual rates at which L sector places orders with C and W sectors are given respectively by Equations 3132 and 3133:

LOSCX.KL = LA10X.K + WSLCX.K - CSLWX.K 3132

Where:

LOSCX = L sector Orders Sent to C sector (ft^2/ wk)

LOSWX.KL = LA11X.K + CSLWX.K - WSLCX.K 3133

Where:

LOSWX = L sector Orders Sent to W sector (ft^2/ wk)

It is readily seen that the sum of LOSCX and LOSWX is equal to the total L sector order rate, LOSXX, as required. This completes discussion of L sector--the aggregation of plywood users and retailers who buy plywood in less than carload quantities.

6) Integrated Jobbers and Office Wholesalers (C-D Sector)

As has been discussed in connection with the General System Model of Figure (3-1), C-D sector represents the aggregation of wholesalers who are organizationally tied to the plywood producers of P sector. Sector variable names which begin with the letter "C" refer to that part of the sector's business that relates to plywood that is sold out of warehouse into the less-than-carload (LCL) market while variables beginning with an initial "D" pertain to sector transactions which relate to plywood shipped directly from mills to the carload (CL) market.

Firms which are included in this and the "P" sector are four: Georgia Pacific Corporation, United States Plywood Corporation, Weyerhaeuser Company, and Evans Products.

As seen in Figure (3-1), these four firms in 1962 produced 40 percent and sold 45 percent of industry output. In spite of this heavy concentration of production and sales capability, all evidence indicates that it is primarily the numerous independent producers and wholesalers who, by their actions in a competitive market, determine the mill price. Since each of these integrated firms has a unique organizational structure and corporate philosophy it was necessary for reasons of model tractability to build a simulation model that would approximate the composite behavior of the four firms. This composite representation was deemed adequate on the basis of the secondary role that these firms appear to have upon the mill market.

In industry interviews, the following appeared, in general, to typify the behavior of these integrated firms. Taken together, these firms are net buyers in the mill market. The dominate ordering policy on the part of wholesalers appeared to be one of placing sufficient orders with their own mills and mills under contract to keep these mills running at normal capacity and to order from the mill market as needed to keep inventory levels within acceptable limits. In what follows, discussion will center around major sector decision rules and in particular the order rate decision which implements the foregoing policy by specifying the order rates to the integrated and independent mills, COSPX and COSMX respectively.

6.1) The order acceptance rate decision rule. The C-D sector, as seen from Figure (3-1), receives orders from both L and K sectors. In both cases it is assumed that the rates at which orders are accepted, COALX and DOAKX, are equal to the rates at which orders are received. The reasons for this assumption are exactly those discussed in connection with the independent jobbers of W sector.

6.2) The shipping rate decision rule. The shipping rate decision rule incorporated into the model of C-D sector is also that previously discussed along with the description of the independent jobbers of W sector. This decision rule is illustrated diagrammatically in the upper left of Figure (4-8) by the interaction of COALX, COULX, CA2XX, CRNLX, and CGSLX where these variables are defined as follows:

COALX = C sector Orders Accepted from L sector (ft^2/ wk)
COULX = C sector Orders Unfilled with respect to L sector (ft^2)
CA2XX = Desired shipping rate (ft^2/ wk)
CRNLX = Maximum shipping rate (ft^2/ wk) permitted by existing inventory, CIAXX

and

CDFLX = C sector Delay in Filling orders to L sector (constant in weeks)

6.3) The order rate decision rule. Certain portions of the C sector order rate decision rule are similar in structure to corresponding parts of the W and L sector order rate decision. In particular, the term that provides for correction of integrated jobber inventory, CA7XX in Figure (4-8), is similar to the corresponding term in W sector. As shown in the figure, CA7XX is given by the following equation:

$$CA7XX.K = (1 / CK5XX)(CIFXX.K - CIAXX.K + CPDXX.K - CPAXX.K + COULX.K - CONLX.K)$$

Where:

CA7XX = Order rate correction to adjust inventory,

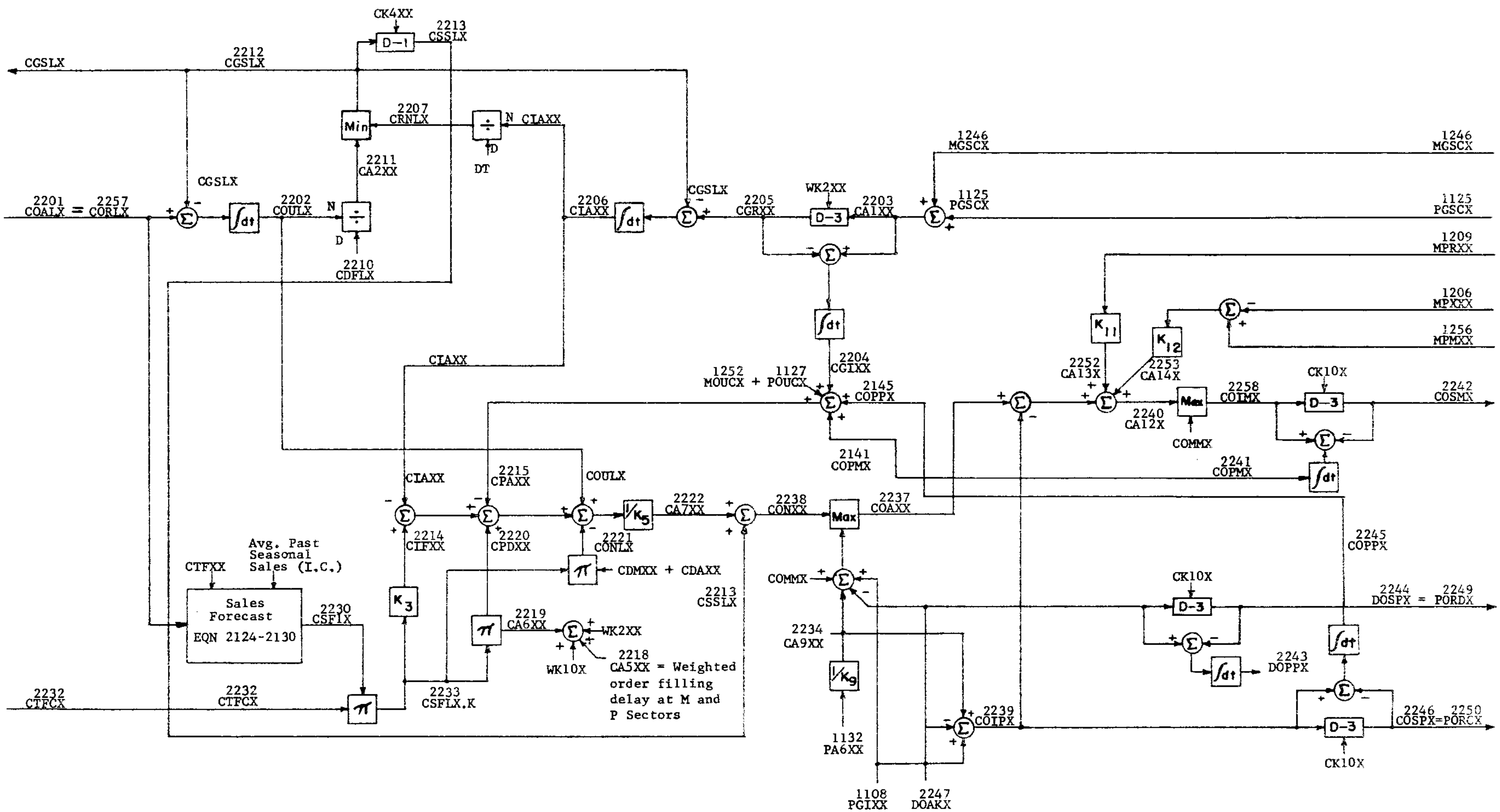

FIGURE (4-8) "C-D" SECTOR BLOCK DIAGRAM

pipeline inventory, and unfilled orders (ft^2/ wk)

CIFXX = C sector Inventory Forecast (ft^2)
CIAXX = C sector Inventory Actual (ft^2)
CPDXX = C sector Pipeline inventory Desired (ft^2)
CPAXX = C sector Pipeline inventory Actual (ft^2)
COULX = C sector Orders Unfilled with respect to L sector (ft^2)
CONLX = C sector Orders unfilled Normal with respect to L sector (ft^2)
CK5XX = Constant (wks)

For discussion of the origin of each of the variables included in the above equation, the reader is referred to the description of W sector. Another term common to the order rates of both W and C sectors is a smoothed or forecast sales rate, CSSLX in the case of C sector. This is shown in Figure (4-8) and given by Equation 2238:

CONXX.K = CA7XX.K + CSSLX.K   2238

Where:

CONXX = C sector Order rate Normal (ft^2/ wk)
CA7XX = Term to provide for control of C-D sector inventory (including pipeline inventory and unfilled orders) ft^2/ wk
CSSLX = C sector Sales Smoothed to L sector (ft^2/wk)

The variable CONXX is the C sector order rate which results in "normal" operation of warehouses--that is, the order rate which provides for sales at the current sales rate and adjustment of actual inventories, pipeline inventories, and unfilled orders toward desired levels. This "normal" order rate will now be subjected to the constraint that the mills of P sector, to which the firms of C-D sector are organizationally tied, must be supplied with enough orders to permit these mills to operate at a desired rate[1] and that independent mills be supplied with a minimum order rate, COMMX, necessary to keep lines of supply open. As shown in Figure (4-8), the variable COAXX is the normal order rate, CONXX, constrained as discussed above. Equations 2237 and 2235 specify COAXX, the actual (constrained) C sector order rate:

$$COAXX.K = MAX\ (CONXX.K,\ CA10X.K) \qquad 2237$$

Where:

COAXX = C sector Order rate Actual (ft^2/ wk)
CONXX = C sector Orders Normal (to provide for normal warehouse operation) ft^2/ wk

The variable CA10X in Equation 2237 represents the order rate necessary to keep the integrated mills of P sector operating as desired and independent mills supplied with a minimum order rate, COMMX:

$$CA10X.K = CA9XX.K + PGIXX.JK - DOAKX.K + COMMX \qquad 2235$$

Where:

CA9XX = A term which provides for adjustment of P sector unfilled orders and inventory to desired levels (ft^2/ wk)
PGIXX = P sector Goods to Inventory (production rate-ft^2/ wk)
COMMX = Minimum order rate to M sector to keep supply lines open (ft^2/ wk)
DOAXX = D sector Orders Accepted from K sector and forwarded to P sector)--ft^2/ wk

---

[1]The "desired rate" in the industry is usually the maximum mill output possible without necessitating the payment of overtime wage rates. It is shown on page 36 that over a range of market prices such operation results in maximum mill efficiency. It was learned from industry interviews that this mode of operation is common among integrated mills of P sector.

The actual C sector order rate, COAXX, must now be allocated between integrated mills of P sector and independent mills of W sector. The rate at which C must send orders to P sector is readily seen to be that of Equation 2239:

$$COIPX.K = PGIXX.JK + CA9XX.K - DOAKX.K \qquad 2239$$

Where:

COIPX = C sector Orders Impending to P sector (ft^2/ wk)
PGIXX = P sector Goods to Inventory (production rate) ft^2/ wk
CA9XX = Correction factor to adjust P sector inventory and unfilled orders (ft^2/ wk)
DOAXX = D sector Orders Accepted from K sector and forwarded to P sector)--ft^2/ wk

From Equation 2239 it is seen that the rate at which orders are impending to P sector, COIPX plus DOAKX, is equal to the desired production rate, PGIXX, plus the term to correct P sector inventory and unfilled orders CA9XX. The actual rate at which orders are sent to P sector is given by:

$$COSPX.KL = DELAY3(COIPX.JK, CK10X) \qquad 2246$$

Where:

COSPX = C sector Orders Sent to P sector (ft^2/ wk)
COIPX = C sector Orders Impending to P sector (ft^2/ wk)
CK10X = Order processing lag (wks)
DELAY3 = DYNAMO designation of a third order exponential lag

With the order rate to P sector determined, the rate at which C sector places orders with the mills of M sector follows. In the absence of speculative buying this order rate would be COAXX minus the order rate impending to C sector, COIPX. It was, however, decided to include in the simulation model terms which would give C sector the option of engaging in price and price rate speculation in the mill market (CA14X and CA13X in Figure 4-8). With these terms included, the variable COAXX, C sector Order rate Actual, should be thought of as the actual order rate in the absence of speculation. With the option of speculation introduced, the impending order rate to M sector is given by Equation 2258:

$$COIMX.K = MAX\ (CA12X.K,\ COMMX) \qquad 2258$$

Where:

COIMX = C sector Orders Impending to M sector (ft^2/ wk)

COMMX = Minimum order rate to M sector (ft^2/ wk)

And:

$$CA12X.K = COAXX.K + CA13X.K - COIPX.K + CA14X.K \qquad 2240$$

Where:

COAXX = C sector Orders Actual (In the absence of speculation) ft^2/ wk

CA13X = Price rate speculation factor (ft^2/wk)

COIPX = C sector Orders Impending to P sector (ft^2/ wk)

CA14X = Price speculation factor (ft^2/ wk)

As discussed in the case of W sector, the speculation terms have been introduced linearly into the model. From Figure (4-8) it may be seen that the speculation terms are given by the following equations:

$$CA14X.K = (CK12X)(MPMXX.K - MPXXX.K) \qquad 2253$$

Where:

CA14X = Price speculation term (ft^2/ wk)
CK12X = Constant--(ft^2/ wk)/ (\$/ ft^2)
MPMXX= Mill market Price sMoothed (averaged)-\$/ ft^2
MPXXX = Mill market Price (\$/ ft^2)

CA13X.K = (MPRXX.K)(CK11X) 2252

Where:

CA13X = Price rate speculation term
MPRXX = Mill market Price Rate (\$/ ft^2/ wk)
CK11X = Constant (ft^2/ wk)/ (\$/ ft^2 wk)

Equation 2258 insures that, even in the presence of speculation, orders are placed at the minimum rate, COMMX, with independent mills of M sector. As discussed above, this minimum rate is necessary to maintain satisfactory business relations with sellers. The actual rate at which C sector places orders with M sector is COIMX lagged by an order processing delay.

COSMX.KL = DELAY3(COIMX.K, CK10X) 2242

Where:

COSMX = C sector Orders Sent to M sector (ft^2/ wk)
COIMX = C sector Orders Impending to M sector (ft^2/ wk)
CK10X = Order processing delay (wks)
DELAY3 = DYNAMO designation of a third order exponential lag.

As has been mentioned, the C-D sector represents both the wholesaling and office wholesaling functions of integrated firms. The variable, DOAKX. represents the rate at which the sector receives boxcar load orders which result in shipments directly from mill to customer. It is assumed in the model that all these orders are filled by mills of P sector (rather than being divided in some manner between P and M sectors). This assumption is expressed by Equation 2244:

DOSPX.KL = DELAY3(DOAKX.K, CK10K) 2244

Where:

DOSPX	=	D sector Orders Sent to P sector (ft^2/ wk)
DOAKX	=	D sector Orders Accepted from K sector (ft^2/ wk)
CK10X	=	Order processing lag (wks)
DELAY3	=	DYNAMO specification for a third order exponential lag.

Before leaving discussion of this particular sector, it would be well to take a somewhat larger view of the policies built into the simulation model. As constructed, the model is based on the fact that, as a group, the four integrated firms which make up the C-D and P sectors are able to sell somewhat more plywood than they are able to efficiently produce. The C-D sector, then, must purchase plywood from the mill market and in 1962 integrated wholesalers purchased about 10 percent of their needs from this market. The order rate decision rule incorporated into the model allows for this mill market buying and also insures that the mills of P sector receive sufficient orders to operate at an efficient rate.

The effect of these policies upon the control of jobber inventories should be considered. As stated, these policies provide adequately (through control of mill market purchases) for the maintenance of inventories above a desired lower limit and, for moderate fluctuations in final demand for plywood, they also permit upper limit control of inventory. These policies may not be able, however, to cope with prolonged periods during which final demand is less than P sector production rate plus the minimum order rate to independent mills, COMMX. As the model is constructed, C sector inventories can increase to unreasonable levels during such periods.[1] In such cases, the integrated firm has three options: it can "dump" plywood on the wholesale markets by cutting price, it can cut production, or it can carry excess inventory until demand conditions permit a reduction. The effect of the first option upon the mill market is quite different from those of the latter two. Dumping, with its attendant price cutting, would depress the mill market price while a production cut or the carrying of large inventories would not have such an effect. Unfortunately, industry interviews disclosed no predictable behavior pattern at this point and indicated that one or all courses of action might be followed at the same time by the four integrated firms. The simulation model assumes that any excessive C sector inventory buildup due to a sustained period of low demand is reduced to normal during later periods of normal or high demand.

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[1] As will be seen in the discussion of the integrated mills of P sector, integrated mill production rate is taken as a function of mill market price and decreases as market price falls. This tends to alleviate the problem of high jobber inventory but it does not provide for positive upper limit control of C sector inventory.

7) Integrated Producers (P Sector)

As has been discussed previously, the producers of P sector are tied organizationally to the wholesalers of C-D sector. It has been assumed that sufficient orders are sent by C-D sector (COSPX and DOSPX) to sustain the production rate, PGIXX, established by P sector producers. This is in accordance with industry policies which establish mill production rates on the basis of efficient mill operation. In what follows, the key decision rules which govern the behavior of the sector; namely the production rate decision and the shipping rate decision[1] will be discussed. Since in many respects these decision rules are similar to those of M sector, emphasis will be placed upon differences which exist between the models of the two sectors.

7.1) The production rate decision. The production rate decision included in the simulation of the integrated producers of P sector is almost identical to that of M sector discussed previously; hence the discussion of section 3.1 is applicable here except as noted below. In Figure (4-9) the function PF1XX specifies the aggregate relationship that exists between mill market price, MPXXX, as independent variable and the dependent variable, PA1XX, and may be

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[1] The order acceptance rate decision, included in M sector is not applicable to P sector because P sector producers receive orders from affiliated warehouses and not through a competitive market.

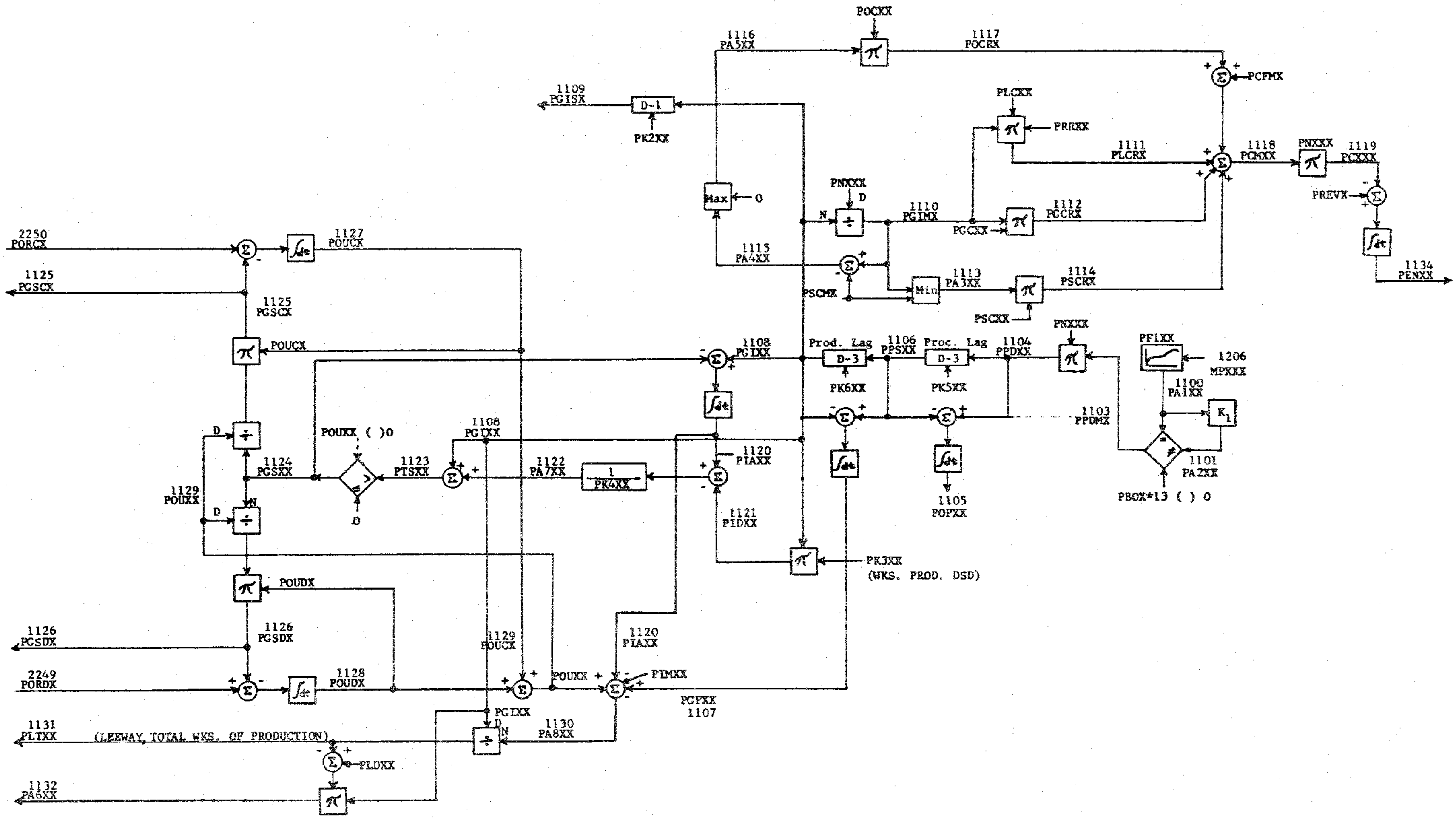

FIGURE (4-9) "P" SECTOR BLOCK DIAGRAM (INTEGRATED PRODUCERS) thought of as the sector supply curve with the ordinate (PA1XX) equal to 1/ PNXXX times desired industry production rate. The variable PA1XX can therefore be thought of as the desired production rate of a "typical" sector firm of which there are PNXXX in number. As in the case of M sector, desired production rate must be constrained to allow for employee vacations and the variable PPDMX represents PA1XX with this vacation constraint imposed. The P sector Production rate Desired (PPDXX) is given by PPDMX (P sector Production Desired per Mill) times the number of mills, PNXXX. Absent from P sector is the constraint included in M sector for limiting production when mill unfilled orders are zero and mill inventory capacity is filled. The warehouses of C-D sector provide storage for P sector production and make this constraint unnecessary. As seen from Figure (4-9) and as discussed in connection with M sector, the actual production rate, PGIXX, is the desired rate, PPDXX, lagged by an administrative lag, PK5XX, and the production lag PK6XX:

PPSXX.KL = DELAY3(PPDXX.JK, PK5XX) 1106

Where:

PPSXX = P sector Production rate Started (ft^2/ wk)
PPDXX = P sector Production rate Desired (ft^2/ wk)
PK5XX = Administrative lag (wks)

PGIXX.KL = DELAY3(PPSXX.JK, PK6XX) 1108

Where:

PGIXX = P sector Goods to Inventory (production rate) ft^2/ wk

PPSXX = P sector Production rate Started (ft^2/wk)
PK6XX = Production lag (wks)

7.2) The shipping rate decision. As in the case of M sector the shipping rate is determined by the current production rate plus a correction to adjust mill inventory and is constrained to make shipments impossible if there are no mill unfilled orders. The shipping rate decision included in the model of P sector is, in fact, exactly that of M sector. The equations which determine the P sector shipping rate, PGSXX, are given below:

$$\begin{aligned} PGSXX.K &= PTSXX.K \text{ for } POUXX \geq O \\ &= O \quad\quad\quad \text{ for } POUXX < O \end{aligned} \qquad 1124$$

Where:
PGSXX = P sector Goods Shipped (ft^2/wk)
POUXX = P sector Orders Unfilled (ft^2)

$$PTSXX.K = PGIXX.JK + PA7XX.K \qquad 1123$$

Where:
PTSXX = P sector Trial Shipping rate (ft^2/wk)
PGIXX = P sector Goods to Inventory (ft^2/wk)

$$PA7XX.K = (1/PK4XX)(PIAXX.K - PIDXX.K) \qquad 1122$$

Where:
PA7XX = Correction to shipping rate to adjust mill inventory (ft^2/wk)
PK4XX = Constant (wks)

$$PIDXX.K = (PK3XX)(PGIXX.JK) \qquad 1121$$

Where:
PIDXX = P sector Inventory Desired (ft^2)
PK3XX = Constant-wks inventory desired
PGIXX = P sector Goods to Inventory (ft^2/wk)

$$PIAXX.K = PIAXX.J + (DT)(PGIXX.JK - PGSXX.J) \qquad 1120$$

Where:

PIAXX = P sector Inventory Actual (ft^2)
PGIXX = P sector Goods to Inventory (ft^2/ wk)
PGSXX = P sector Goods Shipped (ft^2/ wk)

Given the shipping rate, PGSXX, determined above, the model apportions this shipping rate between direct shipments to retailers and users PGSDX,[1] and shipments to integrated jobbers, PGSCX. This is done in proportion to order backlogs, POUDX and POUCX as shown in the figure and given by the following equations:

PGSDX. KL = (POUDX. K)(PGSXX. K)/ POUXX. K 1126

Where:

PGSDX = P sector Goods Shipped to D sector (ft^2/ wk)
POUDX = P sector Orders Unfilled with respect to D sector (ft^2)
PGSXX = P sector Goods Shipped (ft^2/ wk)
POUXX = P sector Orders Unfilled (ft^2)

PGSCX. KL = (POUCX. K)(PGSXX. K)/ POUXX. K 1125

Where:

PGSCX = P sector Goods Shipped to C sector (ft^2/ wk)
POUCX = P sector Orders Unfilled with respect to C sector (ft^2)
PGSXX = As defined for Equation 1126
POUXX = As defined for Equation 1126

The sum of the two shipping rates, PGSDX and PGSCX, is readily seen to be equal to the total shipping rate, PGSXX, knowing that POUXX is the sum of POUDX and POUCX.

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[1]It will be recalled that D sector does not physically take possession of plywood but serves as an intermediary by arranging transactions between the mills of P sector and the users and retailers of K sector.

7.3) Calculation of desired and actual "leeway". These calculations are necessary in order to arrive at the variable, PA6XX, which is used in C-D sector to generate an order rate correction which adjusts P sector inventory and unfilled orders to desired levels. The term "leeway" is here taken to be the time in weeks required for the sector to deplete its backlog of orders and to fill mill inventory capacity assuming production at the rate PGIXX and no incoming orders. A certain level of leeway is required by mills in order to plan production runs and to allow for contingencies such as fluctuations in incoming orders. The weeks of P sector leeway is given by Equations 1131 and 1130:

$$PLTXX.K = PA8XX.K / PGIXX.JK \qquad 1131$$

Where:

PLTXX = P sector Leeway Total-weeks of production
PGIXX = P sector Goods to Inventory (production rate) ft^2/ wk

$$PA8XX.K = POUXX.K + PIMXX - PIAXX.K - PGPXX.K \qquad 1130$$

Where:

POUXX = P sector Orders Unfilled (ft^2)
PIMXX = P sector Inventory capacity Maximum (constant)-ft^2
PIAXX = P sector Inventory Actual (ft^2)
PGPXX = P sector Goods in Process (ft^2)

The variable PA6XX which is used in C-D sector to provide P sector orders to correct leeway is given by Equation 1132:

$$PA6XX.K = (PGIXX.K)(PLDXX - PLTXX.K) \qquad 1132$$

Where:

PGIXX = P sector Goods to Inventory (ft^2/ wk)
PLDXX = P sector Leeway Desired (a constant in weeks)
PLTXX = P sector Leeway Total (wks)

Before leaving P sector brief mention will be made of the sector profit calculation. As shown in the upper right hand corner of Figure (4-9) P sector net earnings, PENXX, is computed. The calculation follows from the time integration of the difference between the rate at which revenue is generated by the sector and the sector cost rate:

PENXX. K = PENXX.J + (DT)(PREVX.JK - PCXXX.JK) 1134

Where:

PENXX = P sector Earnings Net (\$)
PCXXX = P sector Cost rate (\$/ wk)

PREVX. KL = (MPXXX. K)(PGSXX. K) 1135

Where:

PREVXX = P sector REVenue (\$/ wk)
MPXXX = Mill market Price (\$/ ft^2)
PGSXXX = P sector Goods Shipped (ft^2/ wk)

The cost rate calculation, a rather involved one, is shown diagrammatically in Figure (4-9) and is based on the cost function discussed in connection with M sector.

8) Independent Office Wholesalers (O Sector)

This sector represents the aggregation of firms that act as independent office wholesalers--firms that purchase plywood in the mill market in boxcar load lots and sell to users and retailers of

K sector without actually taking physical possession of the plywood. Typically these firms are small in size; however, the sector also includes the office wholesaling operation of large independent jobbers who deal in direct carload shipments from mill to customer as well as in out-of-warehouse sales.

The transactions of firms in this sector are of two basic types. In the first or "normal" type of transaction, the office wholesaler acts simply as a middleman between customer and mill and receives a markup of approximately three percent for his services. In the second or "speculative" type of transaction, the office wholesaler takes advantage of a changing market price to engage in "short selling" or "position buying". Short selling is a means of increasing profit when the rate of change of price is negative. The office wholesaler will offer to sell in a falling market at a price equal to or somewhat less than current market price and attempt to buy, to cover these sales, at a later time when prices are low enough to yield a greater than normal profit. Position buying is the corresponding gambit employed when market price is increasing. The office wholesaler buys in a rising market and takes advantage of the time lag in delivery at the mill and in shipping across the country. Due to these lags, the market price may be considerably more than the purchased price by the time the carload of plywood reaches buyers in the Midwest or East. Both types of speculation have inherent risks but experienced traders in the industry make an appreciable part of net profit from speculative transactions. As will be seen in the following chapter, plywood price varies quite widely over the year due to the seasonal nature of construction activity. This encourages speculation and makes this type of transaction significant in the behavior of the firms of O sector.

In what follows the simulation model of O sector, which includes both "normal" and "speculative" behavior, will be discussed by considering, again, the major sector decision rules. For the office wholesaler these major decisions are the order rate decision and the sales rate decision.

8.1) The order rate decision. The order rate decision rule determines the variable OOSMX (O sector Orders Sent to M sector) shown in Figure (4-10). As shown in the figure, OOSMX is the smoothed sum of the rate at which orders are received from K sector (OORKX), a term which introduces speculative position buying (OA13X), and a term which provides for adjustment of unfilled orders (OA12X). The position buying term, OA13X, is determined by Equations 2320 and 2325 as follows:

OA13X.K = (OA8XX.K)(OK5XX) 2325

OA8XX.K = MAX(MPRXX.K, O) 2320

Where:

MPRXX = Mill market Price Rate--($/ ft^2)/ wk

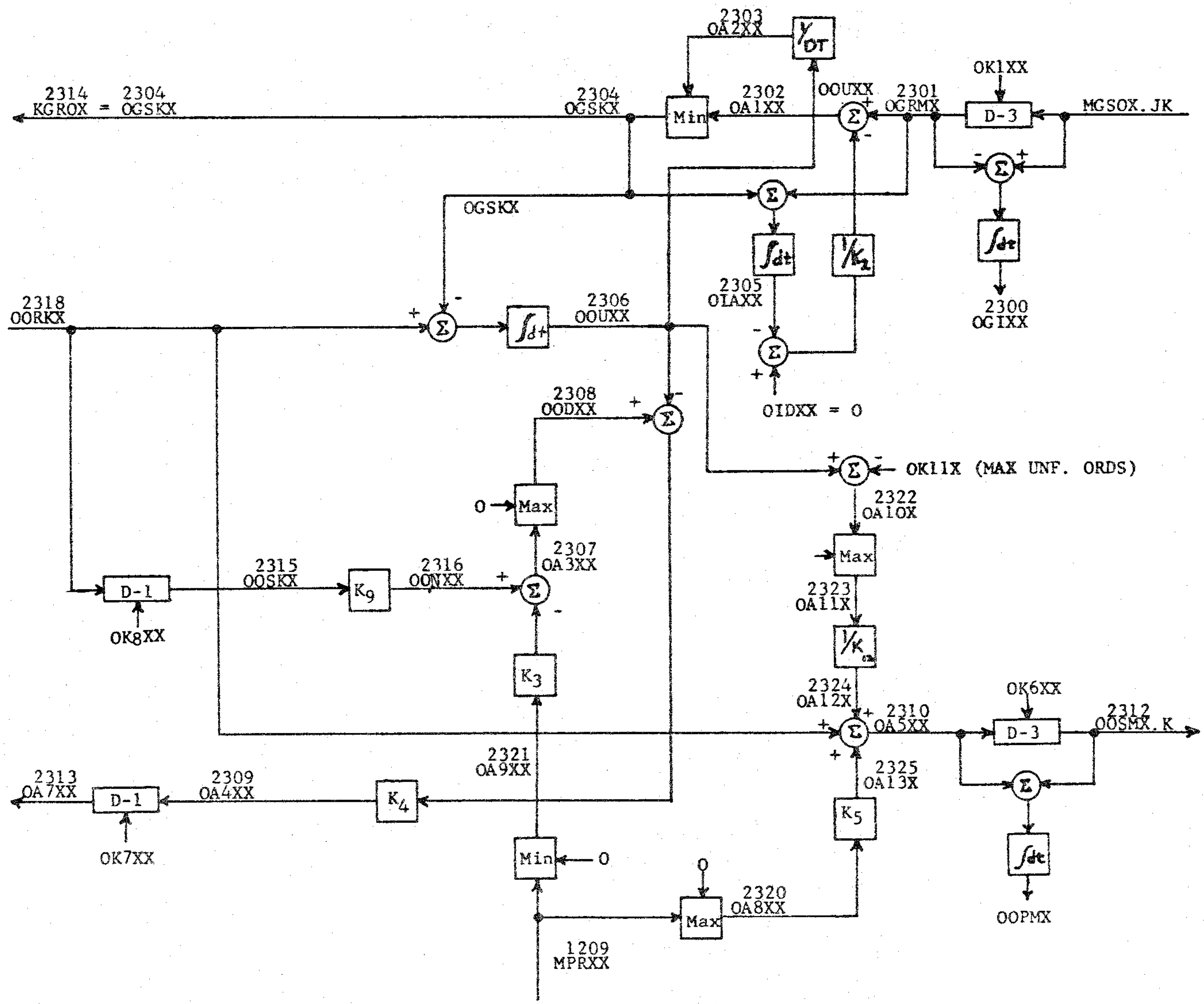

FIGURE (4-10) "O" SECTOR BLOCK DIAGRAM (OFFICE WHOLESALERS)

These equations introduce an increase in order rate when price is increasing. The unfilled order correction term, OA12X, provides for an increase in sector order rate when unfilled orders exceed an upper limit (OK11X) thereby introducing upper limit control of unfilled orders. This term is given by Equations 2324, 2323, and 2322:

OA12X.K = OA11X.K/OK12X 2324

Where:
OK12X = Constant (wks)

OA11X.K = MAX(OA10X.K, O) 2323

OA10X.K = OOUXX.K - OK11X 2322

Where:
OOUXX = O sector Orders Unfilled (ft^2)
OK11X = Maximum O sector unfilled orders (ft^2)

The rate at which O sector places orders with M sector is thus given by:

OOSMX.K = DELAY3(OA5XX.K, OK6XX) 2312

Where:
OOSMX = O sector Orders Sent to M sector (ft^2/wk)
OK6XX = Order processing lag (wks)
and
OA5XX.KL = OORKX.JK + OA12X.K + OA13X.K 2310

8.2) The sales rate decision. Since the office wholesaler engages in short selling he, at times, cuts his selling price below the average market price and thus has some control over his sales rate. In what follows, the simulation model sales rate, which provides for this speculative short selling, will be discussed. Stated simply, the O sector sales rate is taken as a share of the market plus, during times of falling prices, an additional rate due to price cutting. This latter factor represents the short sales. In the simulation model, the O sector sales rate is its normal market share when the variable OA7XX is less than a threshold value (KK14X) and its market share plus a percentage of market share when OA7XX is in excess of the threshold value. The price cutting mode of O sector operation therefore corresponds to values of OA7XX in excess of KK14X.

The origin of the variable, OA7XX, will now be discussed. As seen from the block diagram of Figure (4-10), the variable OA7XX is the difference between desired and actual unfilled orders (OODXX and OOUXX) multiplied by the constant OK4XX and smoothed by a first order exponential delay. These relationships are given by Equations 2313 and 2309:

$$OA7XX.K = OA7XX.J + (DT)(1 / OK7XX)(OA4XX.J - OA7XX.J) \qquad 2313$$

Where:

OK7XX = Smoothing time constant (wks)

$$OA4XX.K = (OK4XX)(OODXX.K - OOUXX.K) \qquad 2309$$

Where:

OK4XX = A constant
OODXX = O sector Orders unfilled Desired (ft^2)
OOUXX = O sector Orders Unfilled (ft^2)

The desired level of unfilled orders, OODXX, is given by a "normal" level, OONXX, equal to OK9XX weeks of sales, plus an amount due to a falling price:

OODXX. K = MAX(OA3XX. K, O) 2308

OA3XX. K = OONXX. K + (OK3XX)(-OA9XX. K) 2307

Where:
OK3XX = constant--$(ft^2)/(\$/ \text{wk } ft^2)$

OONXX. K = (OOSKX. K)(OK9XX) 2316

Where:
OOSKX = O sector Order rate Smoothed (smoothed sales rate)
OK9XX = weeks of unfilled orders desired (constant)

OA9XX. K = MIN(MPRXX. K, O) 2321

Where:
MPRXX = Mill market Price Rate $(\$/ ft^2 \text{ wk})$

The purpose of the "MIN" function in Equation 2321 is to ensure that only negative values of MPRXX influence sector sales. The "MAX" function in Equation 2308 constrains desired unfilled orders (OODXX) to non-negative values. As may be seen from Figures (4-10) and (4-11) the short selling mechanism operates as follows: when price rate is non-negative and when desired and actual unfilled orders are nearly equal, the variable OA7XX is less than the threshold, KK14X, and O sector receives its normal market share from K sector. Should mill price rate be sufficiently negative or should desired unfilled orders (OODXX) be substantially less than actual orders (OOUXX), OA7XX exceeds the threshold, KK14X, and O sector enters a price cutting mode that results in an order rate from K sector that is in excess of market share. This increase in sales increases OODXX to the point where OA7XX is once again less than the threshold value and price cutting ceases. The mechanism described, therefore, introduces speculative short selling into the simulation model and, at the same time, provides for lower limit control of unfilled orders, OOUXX. The operation of this segment of the simulation model will perhaps be more clear after the reader has seen the discussion of related portions of K sector.

Before leaving discussion of O sector, portions of the simulation model relating to the generation of O sector unfilled orders will be described. The level of unfilled orders is given by Equation 2306:

$$OOUXX.K = OOUXX.J + (DT)(OORKX.JK - OGSKX.JK) \qquad 2306$$

Where:

OOUXX = O sector Orders Unfilled (ft^2)
OORKX = O sector Orders Received from K sector (ft^2/ wk)
OGSKX = O sector Goods Shipped to K sector (ft^2/ wk)

The terminology "goods shipped to K sector" is actually a misnomer. The office wholesalers of O sector hold no inventory and therefore cannot ship goods. The variable OGSKX above is, in reality, the rate at which O sector transfers ownership of carloads of plywood to firms of K sector. The variable, OGSKX, is given by Equation 2304:

$$OGSKX.KL = MIN\ (OA1XX.K,\ OA2XX.K) \qquad 2304$$

The purpose of this equation is to ensure that the shipping policy does not result in a negative value for sector unfilled orders. The variable OA2XX is the maximum shipping rate possible consistent with positive values of unfilled orders and is given by Equation 2303:

$$OA2XX.K = OOUXX.K / DT \qquad 2303$$

Where:

OOUXX = O sector Orders Unfilled (ft^2)
DT = Time interval of computation

The variable OA1XX in Equation 2304 is the shipping rate that normally prevails and is given by:

$$OA1XX.K = OGRMX.JK + (1 / OK2XX)(OIAXX.K - OIDXX) \qquad 2302$$

Where:

OGRMX = O sector Goods Received from M sector (ft^2/ wk)
OK2XX = Weeks to adjust inventory (constant)
OIAXX = O sector Inventory Actual (ft^2)
OIDXX = O sector Inventory Desired (ft^2)

The variable OGRMX in Equation 2302 is actually the rate at which goods arrive at their destinations (the firms of K sector) and is the rate goods are shipped by M sector, MGSOX, lagged by the shipping lag from mill to customer. This interpretation is necessary because O sector does not physically handle the goods they sell. Though the firms of O sector do not normally hold inventory, the introduction of inventory into Equation 2302 is necessary because, if unfilled orders are zero, goods cannot be transferred to customers and will accumulate in boxcars and other means of conveyance or will be unloaded and stored at some cost to the office wholesaler. The concept of O sector inventory was introduced into the simulation model to allow for this possibility. The value of desired inventory (OIDXX) for O sector is hence zero and Equation 2302 provides for control of "inventory" to this desired level. This completes discussion of O sector--the aggregation of independent office wholesalers.

9) Users and Retailers (K Sector)

As discussed in chapter three, K sector represents the aggregation of users and retailers who, due to the large volume of their plywood utilization, purchase plywood in boxcar load lots (from wholesalers of O and C-D sectors through what has been termed the CL or Car Load market).

In many important respects the simulation model of K sector resembles that previously discussed for L sector. In particular, the order acceptance decision and the shipping rate decision are identical to those of L sector. The sales forecasting and inventory control policies are also identical to those previously discussed as is the method by which price is generated in the CL market. The only significant difference between the two sectors occurs in the manner in which total orders are divided between wholesale sectors. In what follows only this area of departure from the L sector model will be discussed in detail.

The K sector block diagram is shown in Figure (4-11) and the simulation model equations corresponding to the diagram are given

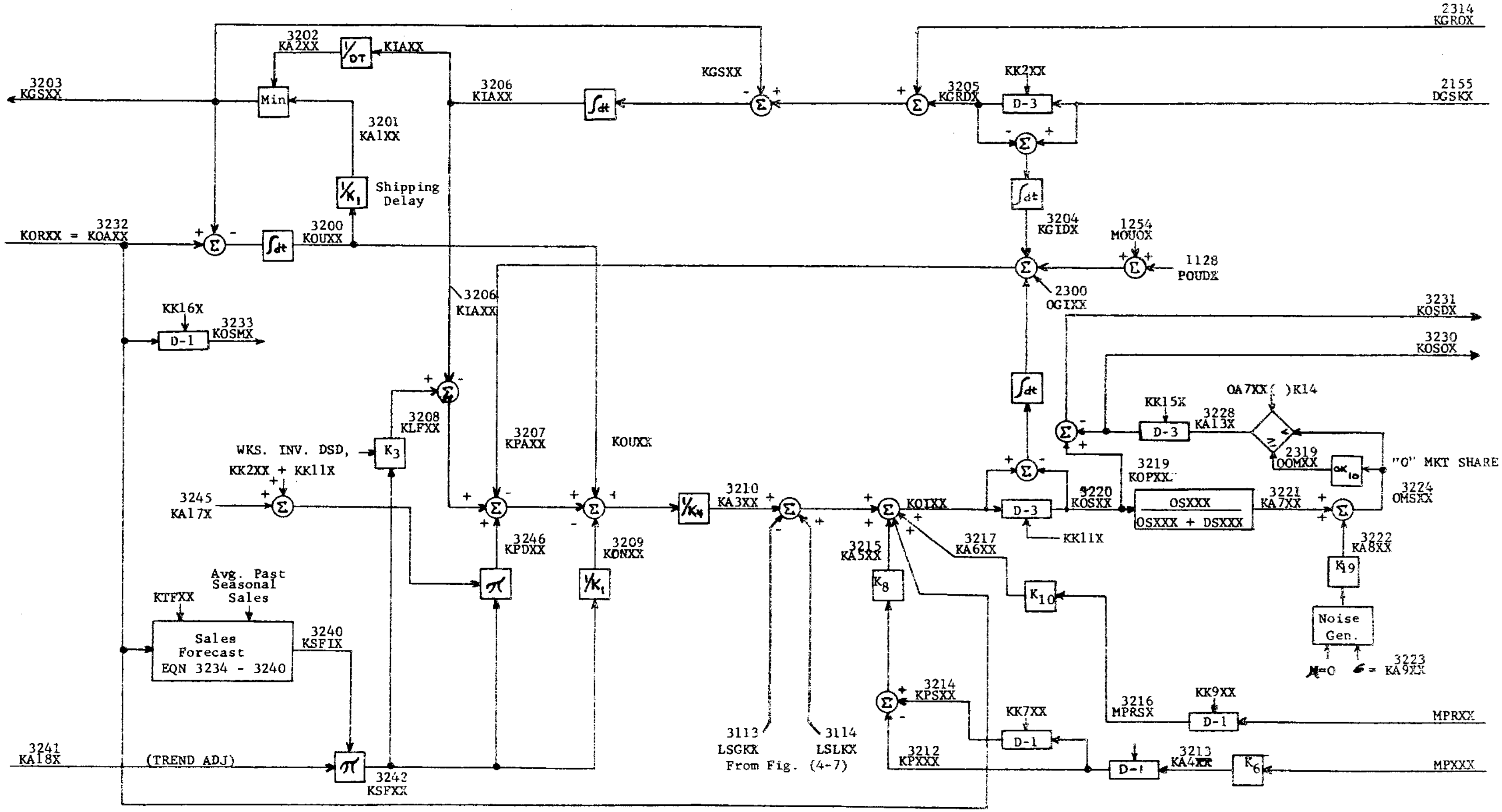

FIGURE (4-11) "K" SECTOR BLOCK DIAGRAM

in Appendix III as a part of Model III. As mentioned above, the main difference between the simulation models of L and K sectors lies in the apportionment of orders between the relevant wholesale sectors. The users and retailers of K sector have the option of dealing with either independent office wholesalers of O sector or the integrated office wholesaling portion of the C-D sector. Sales effort and inventory levels were the factors that determined, in the simulation model of L sector, the allocation of L sector orders between wholesale sectors. Since office wholesalers hold no inventory, this latter factor obviously does not apply in the case at hand. Another factor affecting allocation of K sector orders did, however, emerge during the course of industry interviews. As has been mentioned in the discussion of O sector, independent office wholesalers realize an appreciable portion of net profit by engaging in speculative activities, including position buying. Short selling on the part of O sector results in increased O sector sales due to price cutting action. The allocation of K sector orders between O and C-D sectors is therefore influenced by price cutting on the part of O sector.

The variable OMSXX (<u>O</u> sector <u>M</u>arket <u>S</u>hare) in Figure (4-11) represents the rate at which O sector receives orders in the absence of speculative price cutting and is given by Equation 3224:

OMSXX. K = KA7XX. K + KA8XX. K 3224

Where:

OMSXX = O sector Market Share (ft^2/ wk)
KA8XX = A normally distributed random variable introduced to account for random factors affecting "sales effort" (ft^2/ wk)

and:

KA7XX. K = (KOSXX.JK)(OSXXX)/ (OSXXX + DSXXX) 3221

Where:

KOSXX = K sector Orders Sent (ft^2/ wk)
OSXXX = O sector Sales effort
DSXXX = D sector Sales effort

The variable KOSXX in Equation 3221 is seen, from Figure (4-11), to be the lagged sum of current sales (KOAXX), a price speculation factor (KA5XX), a price rate speculation factor (KA6XX), the factor KA3XX to adjust inventory (including pipeline inventory and unfilled orders) and the factors LSGKX and LSLKX which include the effect that a changing price has upon the distribution of exogenous demand between L and K sectors.

In the presence of O sector price cutting, the variable OMSXX is modified as shown in Figure (4-11). The variable KA13X represents OMSXX augmented to include effects of price cutting on the part of O sector and is given by:

KA13X.K = CLIP (OOMXX.K, OMSXX.K, OA7XX.K, KK14X) 3228

Where:

KA13X = Unlagged O sector order rate (ft^2/ wk)
OMSXX = O sector Market Share (ft^2/ wk)
OA7XX = A variable in O sector that indicates by its value when O sector is cutting price.
KK14X = constant

and:

OOMXX.K = (OK10X)(OMSXX.K) 2319

Where:

OOMXX.K = O sector Order rate Maximum (ft^2/wk)

OK10X = A constant greater than unity.

The operation of Equations 3228 and 2319 may be described as follows: When the variable OA7XX is greater than or equal to KK14X (indicating price cutting on the part of O sector), KA13X is equal to OOMXX (larger than the market share, OMSXX, by the factor OK10X) and, when OA7XX is less than KK14X, KK13X is just the market share, OMSXX. The variable KOSOX is the rate at which K sector sends orders to O sector and is given by:

KOSOX.KL = DELAY3(KA13X.K, KK15X) 3230

Where:

KOSOX = K sector Orders Sent to O sector (ft^2/wk)

KA13X = As defined above

KK15X = Decision making lag (perhaps negligible)--wks

The simulation model assumes that orders diverted to O sector due to O sector price cutting are orders lost to D sector therefore the rate at which K sector sends orders to D sector is given by:

KOSDX.KL = KOSXX.JK - KOSOX.JK 3231

Where:

KOSDX = K sector Orders Sent to D sector (ft^2/wk)

KOSXX = K sector Orders Sent (ft^2/wk)

KOSOX = K sector Orders Sent to O sector (ft^2/wk)

Before leaving discussion of the users and retailers of K sector, another factor which tends to make K sector behavior somewhat different from that of L sector should be noted. Since K sector, in effect, receives plywood from mills instead of from local distribution warehouses, as do firms of L sector, the time delay between order and receipt of plywood is considerably greater for a firm of K sector. Due to this relatively long delay, K sector firms are inclined to hold larger inventories than L sector firms. The firms of K sector would therefore tend to be more conscious of market price than those of L sector.

CHAPTER V

SIMULATION MODEL TESTS

The purpose of this chapter is to discuss the results of simulation model tests. Tests of the simulation model performed four general functions. The first function was that of checking the consistency of the system decision rules as originally conceptualized. Inconsistencies apparent from model tests gave rise to modifications of the simulation model and thus the simulation was an integral part of the evolutionary process which resulted in the model described in the foregoing chapter.

A second function of model tests was that of isolating those parameters which had a significant influence upon model behavior. These tests, while determining the key parameters, also indicated that the majority of the model parameters could be varied over wide limits without greatly influencing the time path of important model variables. In addition to isolating key system parameters, these tests, in certain cases, established bounds within which unknown parameter values must lie in order to maintain "reasonable" model behavior. Criteria such as model stability and excursions of model variables provide measures of model "reasonableness".

A third function of model tests was to provide comparisons of model behavior with that of the real world system. Extensive tests of this nature were not carried out due to the large amount of additional work involved in obtaining initial conditions, statistical estimates of key parameters, and adequate data from past behavior of the industry variables; however tests conducted with "rough" estimates of parameters and initial conditions indicated that the simulation model behaved like the real world system in a number of significant qualitative respects.

The fourth, and last, function of model tests was to seek areas of further work which might bear fruit in terms of improved system behavior--the simulation model was used to test the influence of changes in corporate policies and decision rules upon model behavior. In what follows, model tests will be described which indicate the influence of changes in key model parameters, compare model behavior with industry behavior, and which point to areas of possible system improvement. Most of the tests described are in connection with a two sector model of the industry composed of the M and W sectors which represent, respectively, the aggregation of independent jobbers. The two sector model was selected because of its relative simplicity and because it represented realistically important aspects of mill market behavior. Tests of the larger five and seven sector models will be briefly discussed at the close of the chapter.

1) Influence of Changes in Key Model Parameters

During the course of simulation model tests, it became apparent that model behavior was much more sensitive to changes in certain parameters than others. These parameters, the values of which significantly influence model performance, are called the key or critical parameters. The key parameters of the two sector system model are tabulated in Table 5-1. Conspicuous by their absence from the table are the many model time and smoothing delays. These delays, while necessary in the model, could be individually varied by 50 to 100 percent without having a significant effect on the important model variables listed in the table.

Before discussing the implications of Table 5-1, the test upon which the table is based will be described. A two sector model of the industry was assumed which included M and W sectors, essentially as described in the previous chapter.[1] The W sector sales rate was assumed as constant plus 28 percent sinusoidal variation with a period of one year. This is in accordance with past industry experience and reflects the strong seasonal influence of construction activity upon end user demand for plywood. This seasonal input

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[1] The model tested differed slightly from that discussed in Chapter four . In particular the test model omitted the terms WPAXX and WPDXX. This difference was found to have little influence upon model behavior.

TABLE (5-1)

RUN	DATE	MK1XX	MK2XX	MK15X	MK16X	MNXXX	WK3XX	WK4XX	WK5XX	MENOX	MP (MAX)	MP (MIN)	WIA (MAX)	WIA (MIN)	T (MAX)	REMARKS
1.2A	4/29	1	4	2	.9	60	8	2.4	2.4	118	72.4	58.5	430	271	11	STANDARD RUN
1.2B	4/30	4								144	73.0	59.0	473	275	10	
1.2C	4/30		16							139	73.0	58.7	486	290	10	
1.2E	4/30	4	16													OVERFLOW
1.2L	4/30		2													UNSTABLE
1.2AC	5/28		16						4	130	70.1	59.8	505	271	12	
1.2AD	5/28	2	16						4							OVERFLOW
1.2I	4/30			0						149	73.7	57.6	417	282	10	
1.2J	4/30			8						142	70.4	60.8	453	254	8	
1.2Y	5/26			4					4	118	69.3	59.8	468	251	12	
1.2K	4/30				.75					162	78.7	59.5	446	231	10	
1.2AA	5/28					66			4	9	66	57.7	455	273	10	
1.2C'	4/28						6			141	73.4	58.3	433	283	9	
1.2O							4			152	74.8	57.8	437	231	8	
1.2P	4/30						12			129	71.8	58.8	418	249	12	
1.2D	4/30							20								OVERFLOW
1.2AB	5/28							10	4	115	70.3	59.8	471	238	12	
1.2F	4/30								4.8	118	69	60	476	242	12	
1.2G	4/30								9.6	148	67.4	62.1	520	255	12	
1.2H	4/30								1.2							OVERFLOW
1.2A'	4/28								4	119	69.8	59.5	465	250	12	

NOTE: Parameter entries denote changes from Run 1.2A caused variations in price, unfilled order levels, inventory levels and other variables which, as will be seen in section two, provided a comparison with past industry behavior. The system variables tabulated in Table 5-1 for various values of key parameters are as follows:

MENOX	=	M sector Earnings Net ($)
MPXXX(MAX)	=	Maximum Mill market Price ($/thousand ft^2)
MPXXX(MIN)	=	Minimum Mill market Price ($/thousand ft^2)
WIAXX(MAX)	=	Maximum W sector Inventory Actual (millions of ft^2)
WIAXX(MIN)	=	Minimum W sector Inventory Actual (millions of ft^2)
T(MAX)	=	Time between maximum sales and maximum W sector inventory

The values of MENOX tabulated represent M sector profit at the end of ten years of simulated operation. The values of the remaining variables were tabulated during the tenth year after initial transients had decayed to negligible levels. In the table, Run A was taken as the standard run with parameter values as indicated. In subsequent runs, new parameter values are as recorded and parameters unchanged from the standard run are left blank.

Runs B through AD in the table demonstrate the influence of changes in the market mechanism parameters, MK1XX and MK2XX. In a linearized model of the market mechanism the loop gain is directly proportional to the product (MK1XX)(MK2XX) and the location of the left half plane zero (necessary to compensate an otherwise unstable type two system as discussed in Chapter four Section 3.4) is inversely proportional to MK2XX. The effect of reducing MK2XX by a factor of two is given by run L. The model was found to be unstable which is reasonable in light of the linear theory. For the larger values of MK1XX and MK2XX of runs E and AD an overflow condition caused by a division by zero was encountered. Overflow, due here to either mill unfilled orders or warehouse inventory going to zero, is indicative of system instability or, at best, unrealistic underdamping. This latter result is also reasonable in light of linear theory. As shown by Run B, an increase in MK1XX by a factor of four does not markedly alter system behavior. Run C demonstrates that the same is true of MK2XX.

In Table 5-1, Runs I, J, and Y indicate the influence of changes in MK15X upon model behavior. As shown in Figure (4-4), the parameter MK15X introduces a change in mill production due to a rate of change of market price. The effect of MK15X upon the linearized system is also the introduction of a zero into the left half plane with an attendant increase in stability. With MK15X reduced to zero as in Run I, seasonal price variations are increased--a symptom of reduced system stability. The decreased W sector inventory variations of Run I, on the other hand, are not necessarily symptomatic of increased stability due to the fact that the jobbers of W sector seek to achieve inventory levels which vary in proportion to seasonal sales. In run J, MK15X has been increased by a factor of four over the value of Run A. As theory would indicate, system stability is increased as evidenced by the reduction of price variations.

In Table 5-1, Run K indicates the influence upon model behavior of reducing MK16X--the percentage of normal production produced by M sector during summer months when employee vacations are scheduled. Run AA was made with MNXXX, the number of mills in M sector increased by 10%.

The effects of changes in WK3XX inversely proportional to the gain of the W sector inventory control loop gain, are indicated by Runs C', O, and P of the table. As would be suspected from theory, price fluctuations diminish for increasing values of WK3XX. Run D compared with Run A as a "standard" run and Run AB compared with A' give an indication of how changes in WK4XX, the W sector price rate speculation constant, affect model behavior. As would be expected, system response becomes less stable as this parameter is increased.

The last parameter tabulated is, WK5XX, the price speculation constant. Importantly, WK5XX is the slope of the demand curve of the independent jobbers of W sector. As shown by Runs F, G, H, and A' this parameter has a strong influence upon the magnitude of price variations. As shown by Run H, the model tends to instability for small values of WK5XX. The reason for this is evident given the production policy of independent mills and the seasonal end user demand for plywood. Independent mills tend to produce at or near capacity throughout the year while end user demand fluctuates markedly during the year. As a result of this mismatching of supply and demand, market price varies significantly over the year. Independent jobbers, by allowing price to strongly influence their buying, buy excess production during times of excess supply at a low price and sell during times of excess demand at a higher price. In so doing, they act as a buffer in matching supply to end user demand. Were these jobbers not strongly influenced in their buying by price, price excursions would be greater and widespread seasonal production shutdowns would be necessary.

The value of the parameter WK5XX in the standard run (Run A) was taken as 2. 4 however; later information indicated that this figure was probably low. In his econometric study of the industry Simpson estimated the value 2. 7 for the sanded market. This figure applied to the industry as a whole and included purchases of integrated wholesalers from their own mills. Since such transactions are not normally influenced by the market price, the value of four was assigned to WK5XX in later computer runs to compensate for this latter factor.

2) Comparison of Simulation Model Behavior with That of the Industry

As discussed above, the data of Table (5-1) was based upon a jobber sales rate that varied sinusoidally over a year. If minimums of this independent variable occur near the end of the year the sinusoidal variation in sales bears a close resemblance to the seasonal variation of sales experienced by the industry. This is illustrated by Figure (5-1). In the figure, the dashed curve represents seasonal variation in jobber sales as reported by 273 jobbers in the Plywood Manufacturer's Institute 1960 Market Study (33). With this seasonal variation of jobber sales introduced into the two sector simulation model, seasonal behavior of price, production rate, mill unfilled orders, and jobber inventories were generated by the model. These simulation results will be presented here and compared with seasonal variations in industry variables.

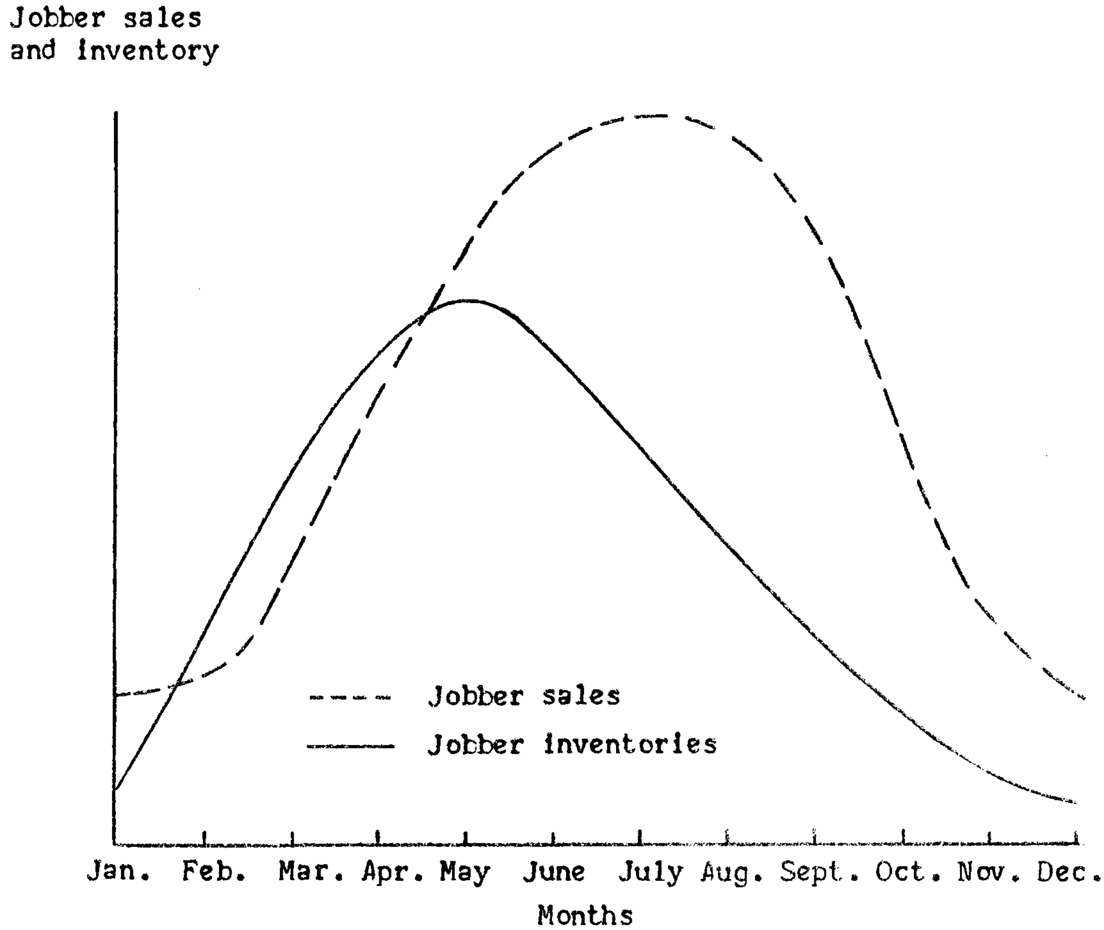
Figure (5-2) indicates the response of the two sector simulation model to the periodic jobber sales rate. At the left of the figure are represented the scales for the various variables plotted. The curve labeled "D" in the figure represents jobber sales rate which is given by:

$$\text{WORLX.KL} = 60 + 16.8\ \text{COS}(2\pi T/52)$$

Where:

WORLX = W sector Orders Received from L sector $(ft^2 \times 10^6/WK)$

T = Time (wks)



Months of relative jobber inventory and sales maxima

Source: Based on responses of 273 jobbers to questionnaires of the Plywood Manufacturers Institute 1960 market study.

Figure (5-1)

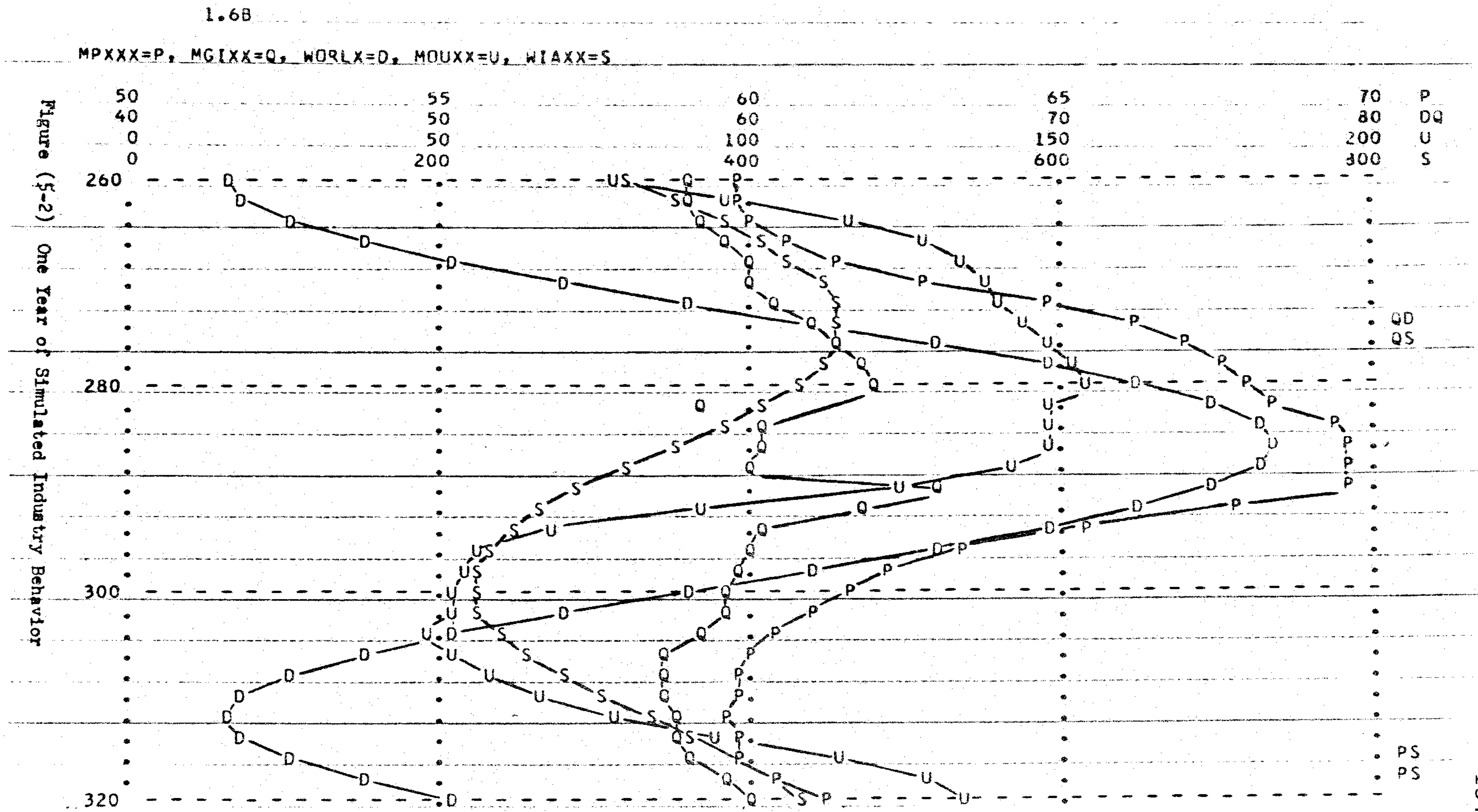
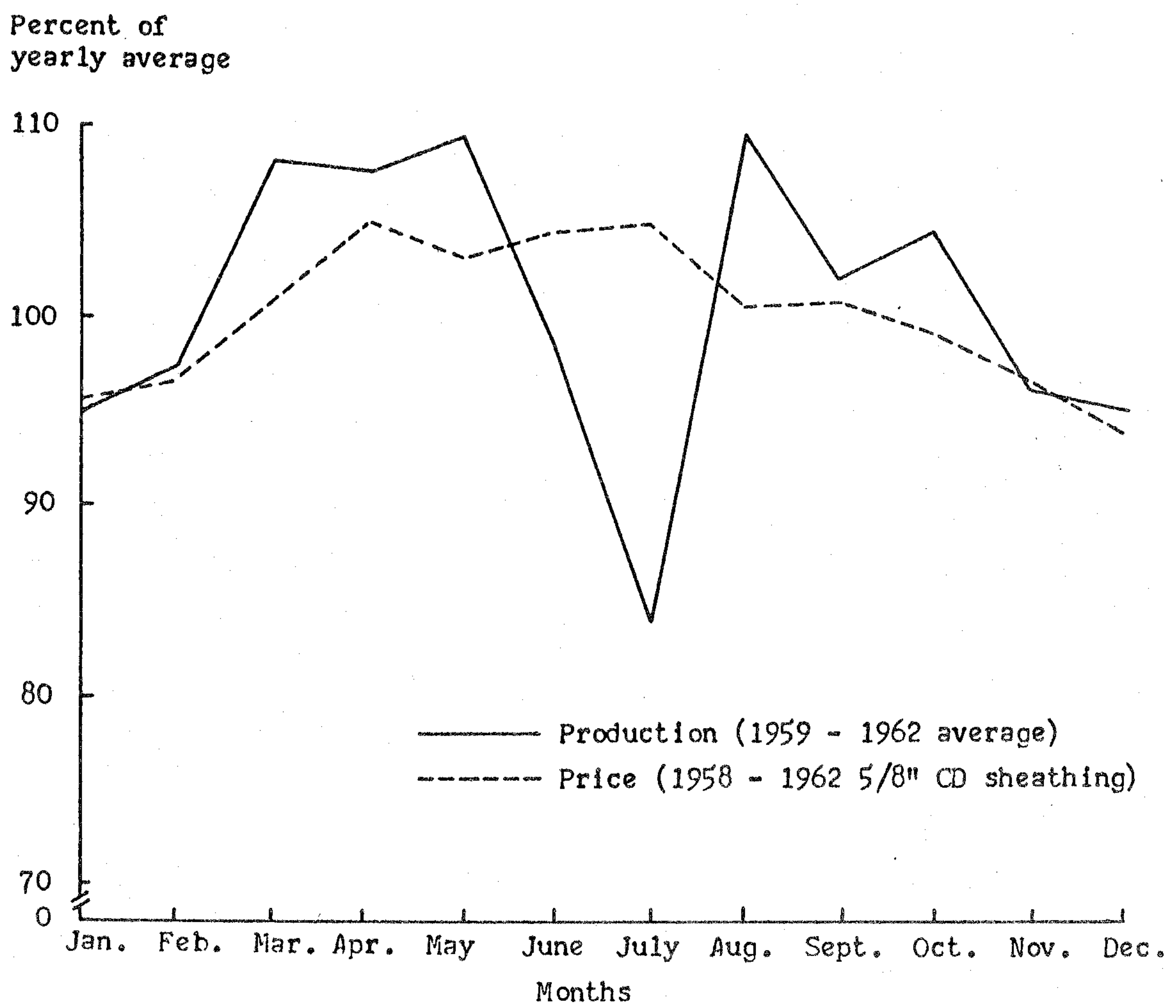


Figure (5-2) One Year of Simulated Industry Behavior



Average seasonal production and prices for plywood

Figure (5-3)

The coefficient 16.8 in the above equation represents a plus and minus 28 percent variation in sales rate and was obtained from the fact that jobber inventories varied by this percentage in Figure (5-1) and from the tendency of jobbers to adjust inventories in proportion to sales. An indirect approach was necessary here because no magnitudes were given for the sales data of Figure (5-1). The remaining curves in Figure (5-2) are defined as follows:

P = Mill market price based on $\frac{1}{4}$'' AD sanded plywood as index (\$/thousand ft^2)
Q = M sector production rate ($ft^2 x 10^6$/WK)
U = M sector unfilled orders ($ft^2 x 10^6$)
S = W sector inventory ($ft^2 x 10^6$)

The time scale in the figure is in weeks with one full year of industry simulation shown. It should be pointed out that no one particular year has been selected but rather a typical year. For this typical year, the minimum in jobber sales rate was assumed to occur at the beginning of the year with the maximum occurring exactly 26 weeks later. In practice, sales minima and maxima vary in timing from year to year but the average pattern is similar to that assumed as seen from the industry data of Figure (5-1).

The simulation model data of Figure (5-2) will now be compared with the industry data of Figures (5-1) and (5-3). Figure (5-1) illustrates the previously mentioned seasonal jobber sales rate together with the seasonal variation in jobber inventories. Figure (5-3) depicts the average seasonal behavior of mill market price and production rate. As seen in Figure (5-1) the jobber inventory maximum leads the peak value of jobber sales by about three months which is very close to the value generated by the simulation model in Figure (5-2). This lead in inventory buildup is a direct result of the policy of independent jobbers to build up inventories during times of low market price and is affected but little by changes in model parameters (other than WK5XX which determines the extent to which independent jobbers are influenced by price in their buying). As seen in Table (5-1) T (MAX), the time by which the inventory maximum preceded the sales maximum, is generally quite close to 12 weeks.

A comparison of Figures (5-2) and (5-3) indicates that price and production, as generated by the simulation model, have the same general characteristics as the industry data. The reduced production during summer months is caused by cutbacks due to employee vacations. Assuming that the 28 percent seasonal variation in sales rate introduced in the simulation is realistic, the price excursions generated by the model are somewhat too large. A possible explanation of this might be the assumption that M sector unfilled orders (MUDXX) are independent of price MPXXX. Including such a dependence would have the same effect upon price as increasing WK5XX: namely a reduction of the amplitude of price variations. Another cause of excessive price variations might be a W sector order rate decision rule that weights inventory control policy too heavily. As seen in Table (5-1), increased emphasis on inventory control, corresponding to smaller values of WK3XX, is a cause of increased price oscillations.

3) Model Tests With Modified Decision Rules

The purpose of the model tests described in this section was to explore areas where modifications in decision rules might result in improved system behavior. While it is undoubtedly true that "improved system behavior" means different things to different decision makers in various sectors of the industry, a major problem area in the plywood industry has been a low mill price which has made survival difficult for many producers. In conversations with industry personnel, it became apparent that mill production policies were a cause of this problem. For this reason alternate independent mill production policies were tested in the simulation model and the results are discussed in what follows:

To determine the influence of curtailed production during times of low seasonal demand for plywood M sector was modified as given by Equation 1213:

MPOXX. KL = (MPFMX. K)(MNXXX. K)(MA24X. K) 1213

Where:

MPOXX = M sector Production Ordered (ft^2/wk)

MPFMX	=	M sector Production Feasible per Mill (ft^2/wk)
MNXXX	=	Number of M sector mills
MA24X	=	1 - (MK17X)(COS 2π T/52)

and:

T	=	Time

This modification results in a production rate that is in phase with seasonal demand variations. Production over a year is virtually unchanged but less production occurs during times of low demand and more during periods of high demand. The results of computer runs with different values of MK17X are given in Table (5-2).

TABLE (5-2)

Run#	MK17X	Price (Max)	Price (Min)	Profit 10^6\$/yr.	% Profit Increase
1.4A	0	68.8	62.4	25.6	---
1.4E	.03	68.6	63.0	26.7	4.7
1.4C	.05	68.5	63.4	27.4	6.3
1.4D	.10	67.9	63.7	27.9	9.2

As may be seen from the table, M sector profit increases significantly as a policy of production control is implemented. Also of significance is the fact that with production control price oscillations are reduced in amplitude. Such a reduction results in a corresponding reduction in undesirable revenue oscillations.

Another means of achieving the above results is the use of information concerning the rate of change of price in controlling production. This may be seen by comparing runs 1.2A and 1.2J of Table (5-1). Increasing MK15X, which determines the degree to which the rate of change of price is allowed to influence production, is seen to markedly increase M sector profits while decreasing the amplitude of price fluctuations.

It is interesting to note that the effects of production control described above can be realized without varying production rate if large mill-site warehouses are available. By using warehouses to store excess production during times of low demand and by depleting inventory during peak demand periods, the amount of plywood placed on the market can be regulated. This problem is presently under investigation by Z. B. Orzech of the Economics Department at Oregon State University.

4) Tests of Five and Seven Sector Models

Larger models of the plywood industry were contructed and preliminary tests were run to ensure consistency of decision rules. Due to time and computation limitations, however, testing did not proceed to the point where conclusions could be drawn regarding these larger models. The computer programs for a five sector model (M, W, L, P, and C-D sectors) and a seven sector model (M, W, L, P, C-D, O, and K sectors) are included in Appendix I.

5) Concluding Remarks

Before leaving discussion of model tests two additional remarks are in order. The first pertains to conclusions drawn from the data of Table (5-2). It should be emphasized that the computer model from which this table was taken contained parameter values which, in some cases, were educated guesses at true values. For this reason the data of the table should not be used as a basis for policy recommendations to the plywood industry. The data of the table does, however, indicate a promising area worthy of further investigation with improved parameter estimates.

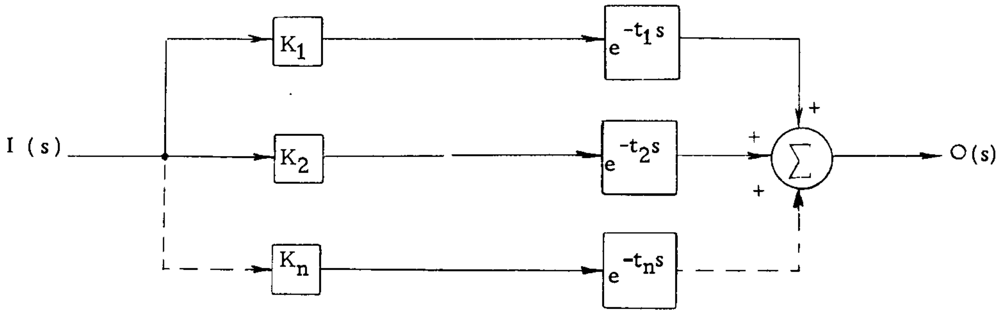
The second general remark is in regard to the deterministic nature of the models tested. In the model tests described in the foregoing pages, stochastic or random disturbances were ignored. These disturbances were neglected in the runs described because the task of evaluating changes in system parameters and decision rules is a much simpler one if randomness is absent from the models. It is recognized that, in reality, the system simulated is not structly deterministic and that random disturbances enter such a system in a number of ways.

CHAPTER VI

THE USE OF EXPONENTIAL LAGS IN THE SIMULATION OF AGGREGATED PROCESSES

In the foregoing exponential lags have been used extensively in connection with the aggregated variables of the system model. In what follows, it will be shown that, under certain assumptions, the aggregate behavior of n discrete (or transport) lags can be represented by an exponential lag.

A real world economic system, such as the plywood industry, is characterized at the microscopic level by discrete time lags -- decision makers ponder a situation for a time and then act, a boxcar of plywood requires some discrete time to travel to its destination. The properties of discrete time delays taken together in an aggregation will be examined by considering the representation of Figure (6-1):



Representation of Aggregated Discrete Time Delays

Figure (6-1)

In the figure, the notation is that of the Laplace transformation. The input and output of the aggregated process are respectively I(s) and O(s). The discrete time delay, t, is assumed to be a random variable and t_1, t_2, . . . t_n in the figure is a random sample from a distribution with density function given by a member of the Erlang family of Equation 6-1 (35, p. 69):

$$f(t) = a(at)^{(k-1)} e^{-at} / (k-1)\,! \tag{6-1}$$

Where:
- t = time delay--a random variable independent of time
- e = base of natural logarithms

In the equation, a and k[1] are parameters which in practice can be selected to represent a wide variety of real world situations. It can be shown that the mean of t is k/a and it will be noted that with the parameter k unity, t has the exponential distribution with mean 1/a. As k increases, the density function shifts to the right and represents a process in which time delays in some region about the mean, k/a, are more probable than very small or very large delays. In what follows, it will be seen that the parameter k, importantly, determines the order of the approximating exponential lag.

Attention will first be turned to the case in which k is unity and the random variable, t, has the exponential distribution. With this assumption and using Figure (6-1), a transfer function will be

[1] The parameter, k, should not be confused with the capital letter "K" of Figure (6-1).

derived which represents the aggregate relationship between O(s) and I(s) when n, the number of discrete time delays, is large. From the figure, the transfer function relating output to input is given by:

$$O(s)/I(s) = \sum_{i=1}^{n} K_i e^{-t_i s} \qquad 6\text{-}2$$

At this point, the simplifying assumption will be made that all K_i are equal to some K and, by expanding the exponential into an infinite series, Equation 6-3 results: 6-3

$$O(s)/I(s) = K \sum_{i=1}^{n} (1 - t_i s/1! + (t_i s)^2/2! + \ldots + (-t_i s)^j/j! + \ldots)$$

Equation 6-4 results upon distributing the summation indicated in Equation 6-3.

$$O(s)/I(s) = K(n - \sum_{i=1}^{n} t_i s/1 + \sum_{i=1}^{n} t_i^2 s^2/2! + \ldots + \sum_{i=1}^{n} t_i^j (-s)^j/j! + \ldots) \qquad 6\text{-}4$$

The summations on t_i in the foregoing equation are seen to bear a close resemblance to the jth moment of t (16, p. 100). In what follows, the moments of t will be derived by means of the moment generating function and using these results, Equation 6-4 will be modified to a form recognizable as the series expansion for a first order exponential lag. The moment generating function of the random variable, t, is given by

$$M_t(r) = E(e^{tr}) \qquad 6\text{-}5$$

where the symbol E denotes the expected value operator. By expanding the exponential, Equation 6-6 results:

$$M_t(r) = 1 + E(t)r + E(t^2)\, r^2/2! + \dots + E(t^j)\, r^j/j! + \dots \qquad 6\text{-}6$$

The term $E(t^j)$ is the jth moment of t and is obtained by differentiating the moment generating function, $M_t(r)$, j times with respect to r and setting r equal to zero in the resulting expression:

$$E(t^j) = \left. \frac{\partial^j Mt(r)}{\partial_r^j} \right|_{r=o} \qquad 6\text{-}7$$

The moment generating function is obtained from Equation 6-5 knowing that (by assumption) t has the exponential distribution:

$$M_t(r) = \int_o^\infty e^{tr} ae^{-at} dt \qquad 6\text{-}8$$

on performing the integration, $M_t(r)$, is seen to be:

$$M_t(r) = a/a-r \qquad 6\text{-}9$$

Using Equation 6-7, the jth moment of t is seen to be:

$$E(t^j) = j!/a^j \qquad 6\text{-}10$$

At this point the assumption will be made that n, the number of delay elements summed in Figure 6-1 is very large and, from this assumption, it follows that:

$$\sum_{i=1}^{n} t_i^{\,j} \approx n\, E(t^j) = nj!/a^j \qquad 6\text{-}11$$

Upon insertion of this result into Equation 6-4, the desired form of Equation 6-12 is obtained:

$$O(s)/I(s) = Kn(1-s/a + (s/a)^2 + . . . + (-s/a)^j + . . . \qquad 6\text{-}12$$

Equation 6-12 is readily seen to be the infinite series representation of a first order exponential lag with time constant 1/a since:

$$1/(s/a+1) = 1 - (s/a) + (s/a)^2 + . . . + (-s/a)^j + . . . \qquad 6\text{-}13$$

It has thus been shown that for large n and the delay time, t, distributed exponentially (k unity in Equation 6-1) the aggregation of discrete delays--shown in Figure (6-1) can be represented by the transfer function

$$O(s)/I(s) = Kn/(s/a+1). \qquad 6\text{-}14$$

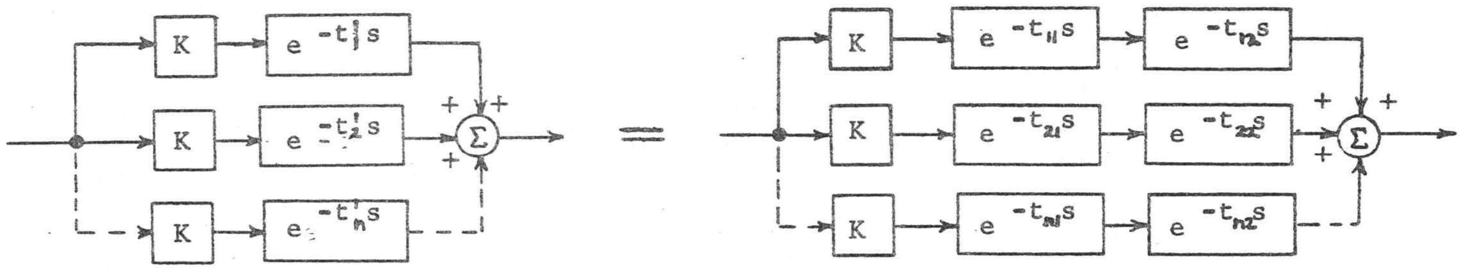
In exactly the manner described above, it can be shown that, if n is large and the parameter k in Equation 6-1 has the value two, the resulting process can be represented in the aggregate by the second order exponential lag

$$O(s)/I(s) = Kn/(s/a+1)^2 \qquad 6\text{-}15$$

On the basis of these two results, the question arises: is the order of the approximating exponential lag for large n equal to the parameter k in the density function of the random variable, t? The answer to this question is yes as will be shown in what follows.

Development of this general result is based on an important property of the density function for the time delay, t, in Figure (6-1). As shown by Saaty (35, p. 59), a random process

(a)



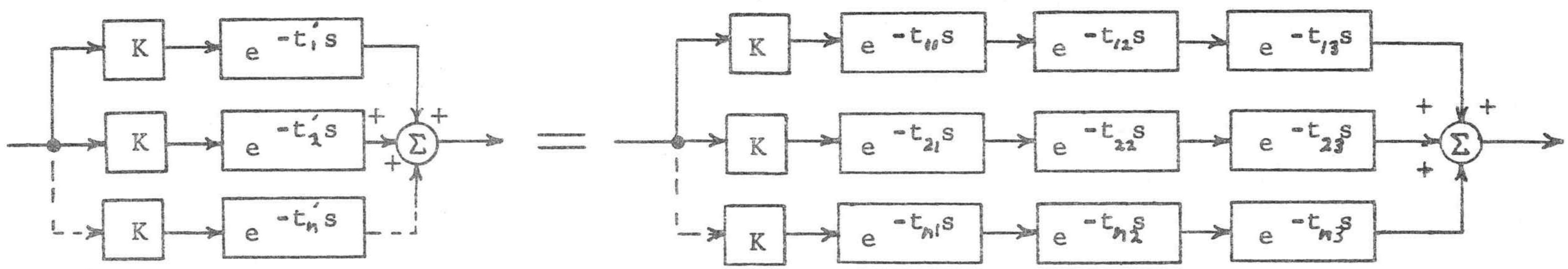
Density function:

$f(t') = a^2 t' \cdot e^{-at'}$

Density function:

$f(t) = a \cdot e^{-at}$

(b)



Density function:

$f(t') = (a^3 t'^2 e^{-at'})/2!$

Density function:

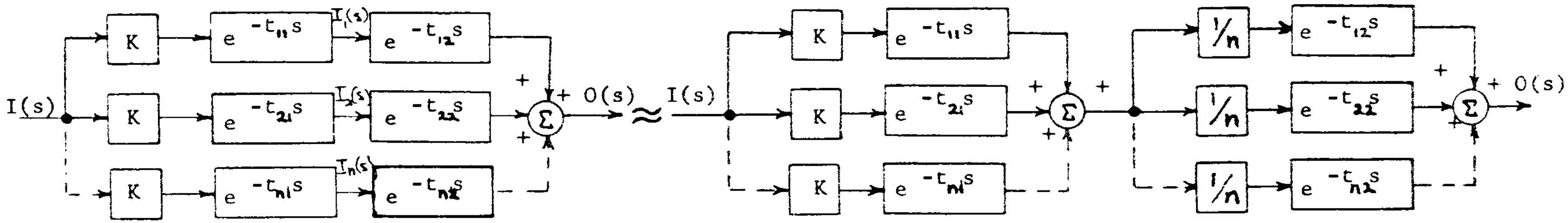
$f(t) = a \cdot e^{-at}$

Equivalent Representations
Figure (6-2)

characterized by a time delay with the Erlang distribution of Equation 6-1 with parameter, k, is exactly equivalent to k cascaded time delay elements each with the density function ae^{-at}. This result is shown in Figure (6-2) for k equal to two and three. The t_2', t_2' . . . t_n' and the t_{11}, t_{12} . . . . t_{n3} in the figure represent random samples from their respective distributions. From the properties of the Laplace transformation it is known that two cascaded first order lags are equivalent to a single second order lag. This fact gives rise to the equivalence relationships of Figure (6-3) which exist for the case of n large. The relationship of part (b) of the figure follows directly from the equivalence of part (a). By use of relationship (b) of Figure (6-3), the random process of Figure (6-2b) can be decomposed as shown in Figure (6-4). That is, Figure (6-2b) with k equal to three is equivalent, for large n, to second and first order exponential lags in cascade and must therefore represent, itself, a third order exponential lag. By similar reasoning, random processes with time lags distributed as Equation 6-1 with arbitrary k can be shown equivalent to kth order exponential lags.

The above results can be summarized as follows: Given the random process of Figure (6-1) with time delay, t, distributed in accordance with Equation 6-1. As n, the number of discrete delay elements, becomes large the transfer function of the random process approaches

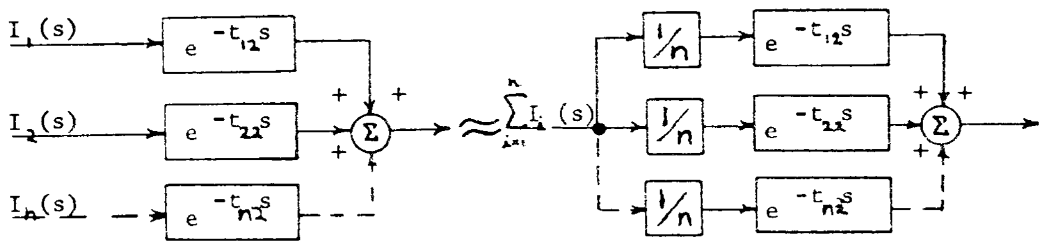
(a)



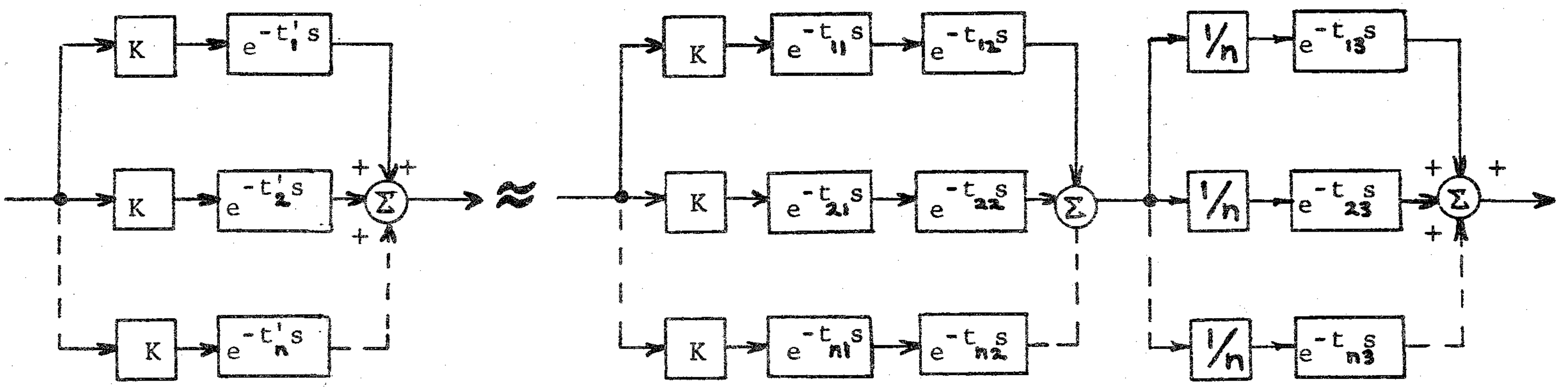
Transfer function for large n: $1/(s/a + 1)^2$

Transfer function for large n: $1/(s/a + 1)^2$

(b)



Equivalent Representations For Large "n"
Figure (6-3)



Density function: $a^3 t'^2 e^{-at'}/2!$

Transfer function: $Kn/(s/a+1)^3$

Equivalent Representations for Large "n"

Figure (6-4)

$$O(s)/I(s) = Kn/(sa+1)^k \qquad 6\text{-}16$$

where "k" and "a" are parameters in the density function of the random variable, t.

As seen from Figure (6-1), the above result was obtained for the case of all discrete time delays having the common input, I(s). This restriction applies in certain practical cases as, for example, delayed decisions based on market price as a common input variable. In many cases, though, this assumption is restrictive. Fortunately this restriction can be removed in an important case. This may be seen by reexamining Figure (6-3). The (a) part of the figure illustrates two random processes which are both equivalent to a second order exponential lag for large n. This equivalence implies the relationship of part (b) of the same figure. Stated in words, Figure (6-3b) says that for large n the random process shown, with individual inputs, I(s) . . . $I_n(s)$ arising from a common input I(s), can be replaced by the same process with a common input which is the mean of the individual inputs $I_1(s)$ . . . $I_n(s)$. This result extends the potential realm of application of exponential lags greatly.

The foregoing discussion of the use of exponential lags to represent, in the aggregate, the behavior of a large number of discrete time lags leaves unanswered some important questions: How large is "large" in the case of n, the number of discrete lags? What are the properties of the aggregation error for finite n and how does it vary with n and with the system inputs? It has been assumed for tractability that each time delay element has associated with it the same gain constant K. How does the relaxation of this assumption affect the aggregation error? These are important questions worthy of attention; however they are beyond the scope of this work.

A final comment is in order here in connection with the widespread use of third order lags in the plywood industry simulation model. Higher order lags were deemed appropriate in these applications because it was known that the probability density functions of the relevant lags were more realistically approximated by Erlang density functions with k greater than one. The selection of the third order lag as a first approximation was based upon the experience of Forrester and that of his students and upon the ease with which the third order lag is represented by the DYNAMO simulation language.

CHAPTER VII

CONCLUSIONS

In this chapter conclusions drawn from the study as a whole will be presented. The order of presentation of conclusions is as follows: those relating to simulation state-of-the-art, those of relevance to the plywood industry and, finally, conclusions which deal with educational patterns in the interdisciplinary area spanned by this thesis.

1) Conclusions Relating to Simulation State-of-the-Art

Simulation, as a skill acquired by experience, is definitely an art. Though based on certain fundamental principles, simulation of large scale systems is to no small extent dependent upon the judgment of the investigator(s) which is a by-product of experience. Since simulation is an art, it would seem appropriate to present here certain "rules of thumb" which have proven useful in the foregoing study.

The first of these concerns the use of linearized approximations. At a number of points in the model previously described, linearized approximations were made because the nature of more appropriate nonlinear relationships was not clear at that particular stage of model development. These approximations, though bold ones, were on sound ground theoretically (for limited excursions of model variables) and made possible simulation runs which greatly increased understanding of the system and made possible further model improvements. In important instances, models with certain decision rules linearized provided insight into more appropriate non-linear representations of these linearized rules as described in Appendix II.

A second "rule of thumb" deals with the use of block diagrams in the development of simulation models. In the course of this study, the interrelationships among system variables, at each stage of model development, were described in the language of block diagrams. Diagrams present these interrelationships at a glance and eliminate the onerous task of studying a system of dozens or even hundreds of equations. It was found that the block diagrams could lead directly to the simulation program without an intervening and redundant system of equations. It was also learned that the block diagram representations of variable interrelationships greatly reduced the likelihood of programming errors when changes were introduced into the model. Since the time required to locate program errors increases at least as rapidly as program size, the block diagrams introduce significant economies into the simulation process.

The last "rule of thumb" to be discussed has to do with simulation model complexity. In the foregoing study, an evolutionary process moving from "simple" to more complex models was found to be the best approach to a large scale system in which a "simple" model is complex by many standards. Ideally, the initial "simple" modely should embody those aspects of the system which appear to the investigator to be of dominant significance in determining system behavior. With an understanding of the "simple" model additional complexities can be added and meaningfully evaluated. Experience gained during the course of this study indicates that overly complex models in the early phases of investigation can be baffling and a waste of human and computational resources.

Another conclusion relating to the state of the simulation art has to do with wider applications of the DYNAMO simulation language. As has been mentioned, DYNAMO makes an IBM-7090 class computer "look like" an extremely large analog computer with a large number of function generators, function multipliers and logic elements. For this reason, though DYNAMO was developed primarily for study of systems involving human decision-makers, it would appear to be a useful tool in the study of more conventional engineering systems.

The last conclusion dealing with the art of simulation is drawn from Chapter six which dealt with the use of exponential lags to simulate, in the aggregate, the behavior of many individual system elements each reacting to a common stimulus but with some discrete time delay between stimulus and response. Specifically, the results of Chapter Six may be stated as follows:

> If n system elements each with transfer function Ke^{-ts}/n relating output $O_i(s)$ to input $I(s)$, t being a random variable distributed as the Erlang distribution with density function $f(t) = a(at)^{(k-1)}e^{-at}/(k-1)!$, have the common input $I(s)$, then the transfer function relating $O(s) = \sum_{i=1}^{n} O_i(s)$ to input $I(s)$ approaches the kth order exponential lag $K/(as+1)^k$ as n becomes very large.

In practical situations where the assumptions apply, this result specifies how to correctly obtain a single equation to describe the aggregate behavior of the n system elements. In this case, estimates of the Erlang parameters a and k (obtained from data taken from the system being simulated) lead directly to the correct aggregate transfer function, $K/(as+1)^k$.

2) <u>Conclusions Relevant to the Plywood Industry</u>

In this section, conclusions which bear either directly or indirectly on industry operating policies or possible changes thereto will be discussed.

On the basis of tests of the two sector industry model (including independent mill and independent jobber sectors), it is concluded that simulation model behavior, in terms of variable excursions and phase relationships, bears a definite resemblance to data reflecting past industry performance. Further refinement of model parameter estimates and decision rules for the purpose of applying the study to specific industry problems would appear justified.

A second industry related conclusion deals specifically with the independent mills of M sector. Preliminary model tests indicate that independent mills can substantially increase net profits beyond what is generally conceded to be minimal by restricting supply during times of low seasonal demand. Supply can be curtailed either by reducing production, as was assumed in model tests, or by storing output in mill site warehouses. The feasibility of the latter approach is being investigated by Z. B. Orzech of the Economics department at Oregon State University.

Another possible industry application of the simulation model is related to policies underlying the operation of large integrated organizations which both produce and distribute plywood (firms which span the P and C-D sectors). Such firms can pursue a sales orientation in which production levels determine sales or some hybrid orientation based on a weighted combination of the first two. A good deal of disagreement was apparent within companies of the industry as to the best policy to pursue. An interesting and perhaps useful extension of the present work would be an investigation directed at this particular problem.

3) Conclusions Relating to Applied Social Science

The conclusions stated here were formed on the basis of a doctoral program, course work as well as thesis, that was designed specifically to explore the application of the engineering art and its more general theory to the social science of economics. Conclusions in this inter-disciplinary area follow.

In the construction of the plywood industry simulation model a basic grounding in the theory of feedback systems was indispensable. It is not overstating the case to say that this theory, acquired through an engineering curriculum, was as important in the construction of an economic system model as was economic theory.

A second conclusion has grown out of stimulating contacts with economists and economic literature during the past several years. It has been observed, and a number of economists have concurred, that an educational gap exists in the area of applied social science. That is, few students are being formally trained to apply social science in the sense that engineers are trained to apply natural science.

A third conclusion follows from the first two. It is concluded that engineering schools can significantly contribute to the filling of this gap if they are willing to broaden their definition of engineering to include applications of social science. This conclusion is based upon increasing evidence (1, 5, 6, 12, 13, 14, 15, 18, 23, 24, 30, 39, 44, 47) that bodies of system theory developed primarily by workers in engineering fields are applicable to certain social phenomena as well and upon the belief that the engineering method or "art of applying knowledge" is general in nature and can be related to a growing list of disciplines. This belief is supported by the emergence of engineering design as an engineering core course divorced from any specialized discipline.

On the basis of the above discussion, it would seem that the engineering school with its expanding bodies of system theory and problem solving heritage, wedded to modern social science, would provide an educational base for a powerful attack on an important class of social problems.

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APPENDIX I

SIMULATION PROGRAMS

Included in this appendix are samples of simulation programs for two, five, and seven sector models of the plywood industry. The models include the equations which simulate the industry structure, initial conditions, and assigned parameter values.

As listed, the programs are capable of being run on any IBM 709-90-94 computer given a magnetic tape containing the DYNAMO system. The DYNAMO system is available from SHARE Distribution Agency, IBM Corporation, 112 East Post Road, White Plains, New York. It should be emphasized that parameter values and initial conditions specified are not necessarily "correct" values. In many cases, particularly in the five and seven sector modes, assigned values are "ballpark" estimates of true values.

```
*     206I-1,DYN,RUN1,14,15
RUN   1.6B
NOTE  MODEL OF PLYWOOD INDUSTRY SECTORS M AND W
NOTE  MODEL OF PLYWOOD INDUSTRY SECTORS M AND W
NOTE
8R    MORXX.KL=MORCX.JK+MORWX.JK+MOROX.JK                    ORDERS RECEIVED  1200
54R   MOAXX.KL=MIN(MORXX.JK,MODXX.JK)                        ORDERS ACCEPTED  1201
1L    MOUXX.K=MOUXX.J+(DT)(MOAXX.JK-MGSXX.JK)                ORDERS UNFILLED  1202
8A    MA2XX.K=MA7XX.K+MA6XX.K+MA3XX.K                                         1203
58A   MA4XX.K=TABHL(MF2XX,MA2XX.K,0,8.5,.5)                                   1204
1L    MA1XX.K=MA1XX.J+(DT)(MA21X.J-M0000)                                     1205
58A   MPXXX.K=TABHL(MF1XX,MA1XX.K,0,100,10)             PRICE                 1206
58A   MA8XX.K=TABHL(MF4XX,MA1XX.K,30,110,10)                                  1207
12A   MA9XX.K=(MA8XX.K)(MA21X.K)                                              1208
3L    MPRXX.K=MPRXX.J+(DT)(1/MK7XX)(MA9XX.J-MPRXX.J) PRICE RATE               1209
58A   MPDMX.K=TABHL(MF3XX,MA19X.K,56,78,2)                   PROD DESIRED/M   1210
8A    MA10X.K=MIMXX-MIAXX.K-MGPXX.K                                           1211
51A   MPFMX.K=CLIP(MA23X.K,MOMMX.K,MA20X.K,M0000)            PROD FEAS/M      1212
13R   MPOXX.KL=(MPFMX.K)(MNXXX.K)(MA24X.K)                                    1213
1L    MOCXX.K=MOCXX.J+(DT)(MPOXX.JK-MPSXX.JK)                ORDS IN CLER     1214
39R   MPSXX.KL=DELAY3(MPOXX.JK,MK5XX)                        PROD STARTED     1215
1L    MGPXX.K=MGPXX.J+(DT)(MPSXX.JK-MGIXX.JK)                GOODS IN PROD    1216
39R   MGIXX.KL=DELAY3(MPSXX.JK,MK6XX)                        GOODS TO INV     1217
1L    MIAXX.K=MIAXX.J+(DT)(MGIXX.JK-MGSXX.JK)                INV ACTUAL       1218
7A    MA11X.K=MIAXX.K-MIDXX.K                                                 1220
12A   MIDXX.K=(MGIXX.JK)(MK12X)                    INV DESIRED                1221
20A   MA12X.K=MA11X.K/MK9XX                                                   1222
7A    MTSXX.K=MGIXX.JK+MA12X.K                               TRIAL SHIPMENT   1223
51R   MGSXX.KL=CLIP(MTSXX.K,M0000,MOUXX.K,M0000)             GOODS SHIPPED    1224
44A   MA3XX.K=(MA10X.K)(1)/MGIXX.JK                                           1225
44A   MA6XX.K=(MOUXX.K)(1)/MGIXX.JK                                           1226
3L    MFRXX.K=MFRXX.J+(DT)(1/MK3XX)(MA17X.JK-MFRXX.J) FACTOR RATE             1227
44A   MA7XX.K=(MFRXX.K)(MK2XX)/MGIXX.JK                                       1228
21A   MA13X.K=(1/MK11X)(MOUXX.K-MUDXX.K)                                      1229
12A   MUDXX.K=(MGIXX.JK)(MK13X)                              UNFORDS DESRD    1230
20A   MA14X.K=MA11X.K/MK11X                                                   1231
13A   MA15X.K=(MPRXX.K)(MNXXX.K)(MK10X)                                       1232
9R    MODXX.KL=MPDXX.K+MA14X.K-MA15X.K-MA13X.K                                1233
7A    MA16X.K=MOAXX.JK-MGSXX.JK                                               1234
7A    MA17X.K=MORXX.JK-MGSXX.JK                                               1235
12A   MCFXX.K=(MCFMX)(MNXXX.K)                                                1237
58R   MCVMX.KL=TABHL(MF5XX,MGIMX.JK,0,1.4,.2)           COST VAR              1238
20R   MGIMX.KL=MGIXX.JK/MNXXX.K                                               1239
12R   MCVXX.KL=(MCVMX.JK)(MNXXX.K)                                            1240
7R    MCTXX.KL=MCVXX.JK+MCFXX.K                              COST TOT         1241
12R   MRSXX.KL=(MGSXX.JK)(MPXXX.K)                           REV PTS          1242
1L    MENSX.K=MENSX.J+(DT)(MRSXX.JK-MCTXX.JK)                EARNINGS NET PTS 1243
12R   MROXX.KL=(MOAXX.JK)(MPXXX.K)                           REV PTO          1244
1L    MENOX.K=MENOX.J+(DT)(MROXX.JK-MCTXX.JK)                EARNINGS NET PTO 1245
44R   MGSCX.KL=(MOUCX.K)(MGSXX.JK)/MOUXX.K                   GOODS SHPD C     1246
44R   MGSWX.KL=(MOUWX.K)(MGSXX.JK)/MOUXX.K                   GOODS SHPD W     1247
44R   MGSOX.KL=(MOUOX.K)(MGSXX.JK)/MOUXX.K                   GOODS SHPD O     1248
44R   MOACX.KL=(MORCX.JK)(MOAXX.JK)/MORXX.JK                 ORDS ACC C       1245
44R   MOAWX.KL=(MORWX.JK)(MOAXX.JK)/MORXX.JK                 ORDS ACC W       1250
44R   MOAOX.KL=(MOROX.JK)(MOAXX.JK)/MORXX.JK                 ORDS ACC O       1251
1L    MOUCX.K=MOUCX.J+(DT)(MOACX.JK-MGSCX.JK)                ORDS UNFD C      1252
1L    MOUWX.K=MOUWX.J+(DT)(MOAWX.JK-MGSWX.JK)                ORDS UNFD W      1253
1L    MOUOX.K=MOUOX.J+(DT)(MOAOX.JK-MGSOX.JK)                ORDS UNFD O      1254
3L    MOMXX.K=MOMXX.J+(DT)(1/MK4XX)(MOAXX.JK-MOMXX.J) ORDS S M THD            1255
3L    MPMXX.K=MPMXX.J+(DT)(1/MK14X)(MPXXX.J-MPMXX.J)  PRICE S M THD           1256
14A   MA19X.K=MPXXX.K+(MK15X)(MPRXX.K)                                        1257
6A    MPDXX.K=MPOXX.JK                                                        1258
20A   MOMMX.K=MOMXX.K/MNXXX.K                                                 1259
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7A    MA20X.K=MA10X.K+MOUXX.K                              TOTAL LEEWAY MMSQFT
12A   MA21X.K=(MK1XX)(MA4XX.K)                                          1261
35B   MBOX1=BOXCYC(13,4)                                                1262
12A   MA22X.K=(MK16X)(MPDMX.K)              VAC ADJ DSD PRO             1263
49A   MA23X.K=SWITCH(MPDMX.K,MA22X.K,MBOX1*13.K)                        1264
7A    MA24X.K=1+MA25X.K                                                 1265
32A   MA25X.K=(-MK17X)COS((2PI)(TIME)/52)                               1266
1L    WOULX.K=WOULX.J+(DT)(WOALX.JK-WGSLX.JK)                           2100
1L    WIAXX.K=WIAXX.J+(DT)(WGRMX.JK-WGSLX.JK)                           2101
20A   WTSLX.K=WOULX.K/WDFLX.K                                           2102
20A   WRNLX.K=WIAXX.K/DT                                                2103
54R   WGSLX.KL=MIN(WTSLX.K,WRNLX.K)                                     2104
14A   WDFLX.K=WDMXX+(WDAXX)(WA2XX.K)                                    2105
12A   WIDXX.K=(WSSLX.K)(WK1XX)                                          2106
3L    WSSLX.K=WSSLX.J+(DT)(1/WK8XX)(WOALX.JK-WSSLX.J)                   2107
6A    WA2XX.K=1                                                         2108
6R    WOALX.KL=WORLX.JK                                                 2109
39R   WGRMX.KL=DELAY3(MGSWX.JK,WK2XX)                                   2111
24A   WA3XX.K=(1/WK3XX)(WIFXX.K-WIAXX.K+WPDMX.K-WPAMX.K+WOULX.K-WONLX.K)
X1                                                                      2112
1L    WGIMX.K=WGIMX.J+(DT)(MGSWX.JK-WGRMX.JK)                           2113
13A   WA5XX.K=(WK4XX)(MPRXX.K)(WNXXX.K)                                 2114
8A    WA6XX.K=WSF1X.K+WA5XX.K+WA3XX.K                                   2115
7A    WA1XX.K=WA6XX.K-WA7XX.K      XX.K)                                2116
18A   WA7XX.K=(WA12X.K)(MPXXX.K-MPMXX.K)                                2117
58R   WOIMX.KL=TABHL(WF1XX,WA1XX.K,0,200,50)                            2118
1L    WOPMX.K=WOPMX.J+(DT)(WOIMX.JK-WOSMX.JK)                           2119
39R   WOSMX.KL=DELAY3(WOIMX.JK,WK6XX)                                   2120
6R    MORWX.KL=WOSMX.JK                                                 2121
8A    WPAMX.K=WGIMX.K+WOPMX.K+MOUWX.K                                   2122
20A   WDFMX.K=MOUXX.K/MGIXX.JK                                          2123
8A    WA8XX.K=WK6XX+WK2XX+WDFMX.K                                       2124
12A   WPDMX.K=(WSFLX.K)(WA8XX.K)                                        2125
12A   WSFLX.K=(WSF1X.K)(WTFCX.K)                           SALES FCST L 2126
12A   WONLX.K=(WSFLX.K)(WDFLX.K)                                        2127
12A   WIFXX.K=(WK1XX)(WSFLX.K)                             INV FCST     2128
35B   WSAVB=BOXCYC(13,4)                    SEAS AVG BXCR CYC           2129
3L    WSAVB*13.K=WSAVB*13.J+(DT)(1/WK9XX)(WOALX.JK-WSAVB*13.J)          2130
37B   WTLSB=BOXLIN(1,4)                     TIME SIN LST SHFT           2131
1L    WTLSB*1.K=WTLSB*1.J+(DT)(1-0)                                     2132
8A    WTFBC.K=WTFXX+WTLSB*1.K-2             TIME FR CEN BOT CAR         2133
7A    WINTD.K=48-WTFBC.K                    INTERP DIST FR TOP TRN      2134
59A   WSF1X.K=TABLE(WSAVB,WINTD.K,0,48,4)   FCST SALES 1ST APP          2135
21A   WA9XX.K=(1/WSSLX.K)(WSSLX.K-WSAVB*12)                             2136
6A    WTFCX.K=1                                TREND FORECAST           2137
12A   WA12X.K=(WNXXX.K)(WK5XX)                                          2138
NOTE  INITIAL CONDITIONS W SECTOR                                   IC1
NOTE                                                                IC2
18N   WOULX=(WORLX)(WDMXX+WDAXX)                                    IC3
12N   WIAXX=(WORLX)(WK1XX)                                          IC4
6N    WSSLX=WORLX                                                   IC5
12N   WGIMX=(WORLX)(WK2XX)                                          IC6
6N    MGSWX=WORLX                                                   IC7
12N   WOPMX=(WORLX)(WK6XX)                                          IC8
6N    WOIMX=WORLX                                                   IC9
NOTE  INITIAL CONDITIONS M SECTOR                                   IC12
NOTE                                                                IC13
6N    MORXX=WORLX                                                   IC13
6N    MOUXX=150  MMSQFT                                             IC15
6N    MA1XX=55 DOLLARS                                              IC16
6N    MPRXX=0                                                       IC17
12N   MOCXX=(WORLX)(MK5XX)                                          IC18
12N   MGPXX=(WORLX)(MK6XX)                                          IC20
```

```
6N      MIAXX=42  MM SQ FT                                                    IC22
6N      MERXX=0                                                               IC23
6N      MGSXX=WORLX                                                           IC24
6N      MODXX=WORLX                                                           IC25
20N     MGIMX=WORLX/MNXXX                                                     IC26
12N     MCVXX=(MCVMX)(MNXXX)                                                  IC27
6N      MENSX=0                                                               IC28
6N      MOAXX=WORLX                                                           IC29
6N      MENOX=0                                                               IC30
6N      MOUCX=0                                                               IC31
6N      MOUOX=0                                                               IC32
6N      MOUWX=MUDXX                                                           IC33
6N      MOMXX=WORLX                                                           IC34
6N      MPMXX=MPXXX                                                           IC35
NOTE                                                                          INP1
NOTE    INPUT                                                                 INP2
NOTE                                                                          INP3
28R     WORLX.KL=(WA11X.K)EXP(WA10X.K)                                        INP4
32A     WSEAS.K=(-INK1X)COS((2PI)(TIME)/52)                                   INP5
6R      MORCX.KL=0                                                            INP6
6R      MOROX.KL=0                                                            INP7
28A     WNXXX.K=(1000)EXP(WA10X.K)                                            INP8
28A     MNXXX.K=(60)EXP(WA10X.K)                                              INP9
12A     WA10X.K=(INK2X)(TIME)                                                 INP10
7A      WA11X.K=60+WSEAS.K                                                    INP11
NOTE                                                                          CON1
NOTE    CONSTANTS                                                             CON2
C       MCFMY=6 MDOLS/WKPER MILL                                              CON3
C       MF5XX*=0/10.8/21.6/32.4/43.2/54/66.8/79.6                             CON4
C       MK15X=2                                                               CON5
C       MK1XX=1                                                               CON7
C       MK2XX=4                                                               CON8
C       MK3XX=.4 WK                          TIME TO SM UFO RATE              CON9
C       MK5XX=1.0 WK                         ADMIN LAG                        CON10
C       MK6XX=.20 WK                         PROD LAG                         CON11
C       MK7XX=.40 WK                         TIME TO SM PRICE RATE            CON12
C       MK9XX=4.0 WK                         TIME TO ADJ MILL INV             CON13
C       MK10X=.04                                                             CON14
C       MK11X=4.0 WK                         TIME TO ADJ UFO                  CON15
C       MK12X=.5  WK                         WKS MILL INV DSD                 CON16
C       MK13X=2.5                                 WKS UFO DSD                 CON17
C       MK14X=100 WK                         TIME TO SM PRICE                 CON18
C       MK4XX=2.0 WK                         TIME TO SM ORDS ACC              CON19
C       M0000=0                              ZERO                             CON20
C       MIMXX=60 MMSQFT                      MAX MILL INV                     CON21
C       MF1XX*=56/56/56/56/56/58/62/70/80/90/100                              CON23
C       MF4XX*=0/.1/.3/.65/.95/1/1/1/0                                        CON24
C       MF2XX*=-2.5/-2/-1/-.2/0/0/.1/.8/1.5/2/2.5/3/3.5/4/4.5/5/5.5/6         25
C       MF3XX*=.6/.85/.98/1/1/1.02/1.06/1.12/1.16/1.18/1.195/1.2              CON26
C       WK1XX=6.5 WK                         WKS INV DSD                      CON27
C       WK2XX=1.5 WK                         SHIPPING LAG                     CON28
C       WK3XX=12                             WKS TO CORRECT INV               CON29
C       WK4XX=.0024                                                           CON30
C       WK5XX=.004                                                            CON31
C       WK6XX=.5 WK                          ORD PROC LAG                     CON32
C       WK7XX=0                                                               CON33
C       WK8XX=2 WK                           TIME TO SM SALES                 CON34
C       WDMXX=.2 WK                          MIN ORD FIL DEL                  CON35
C       WDAXX=.2 WK                          AVG ORD FIL DEL                  CON36
C       WF1XX*=0/50/100/150/200                                               CON39
C       WK9XX=8 YR(4X2)                    TIME TO AVG SEAS SALES             CON42
C       WTFXX=8 WKS                          FCST TIME                        CON43
C       WK10X=1                              TREND CONSTANT                   CON44
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C      WSAVP*=43.5/47.5/54/62/69.5/75/76.8/75/69.5/62/54/47.5/43.5  CON45
C      WTLSB*=0                                                      CON46
C      INK1X=16.8                     MAG SEAS VARIATION             CON47
C      MK16X=.9                       VAC ADJ TO PROD                CON48
C      MBOXI*=0/0/0/0/0/0/1/1/0/0/0/0/0/0                            CON49
C      INK2X=0                                                       CON50
C      MK17X=0                                                       CON51
NOTE                                                                 R1
PRINT  1)WORLX,WGSLX/2)WOULX/3)WIAXX,WIDXX/4)MORXX,MODXX,MOAXX/5)MOUXX,MO
X1     UWX,MUDXX/6)MPXXX,MPMXX/7)MPRXX/8)MA7XX,MA2XX/9)MPDMX,MPOXX/10)MGI
X2     XX,MGSXX,MGSWX/11)MIDXX,MIAXX/12)MENOX,MENSX/13)MA16X,MA17X,WPAMX/
X3     14)WTECX                                                      R5
PLOT   MPXXX=P/MGIXX=Q,WORLX=D/MOUXX=U/WIAXX=S
SPEC   DT=.050/LENGTH=500/PRTPER=4/PLTPER=2                          R8
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*      2061-1,DYN,RUN2,14,15
RUN    2.1A!!!
NOTE   MODEL OF PLYWOOD INDUSTRY SECTORS M,W,CD,P,L
NOTE
8R     MORXX.KL=MORCX.JK+MORWX.JK+MOROX.JK                  ORDERS RECEIVED  1200
54R    MOAXX.KL=MIN(MORXX.JK,MODXX.JK)                      ORDERS ACCEPTED  1201
1L     MOUXX.K=MOUXX.J+(DT)(MOAXX.JK-MGSXX.JK)              ORDERS UNFILLED  1202
8A     MA2XX.K=MA7XX.K+MA6XX.K+MA3XX.K                                       1203
58A    MA4XX.K=TABHL(MF2XX,MA2XX.K,0,8.5,.5)                                 1204
1L     MA1XX.K=MA1XX.J+(DT)(MA21X.J-M0000)                                   1205
58A    MPXXX.K=TABHL(MF1XX,MA1XX.K,0,100,10)           PRICE                 1206
58A    MA8XX.K=TABHL(MF4XX,MA1XX.K,30,110,10)                                1207
12A    MA9XX.K=(MA8XX.K)(MA21X.K)                                            1208
3L     MPRXX.K=MPRXX.J+(DT)(1/MK7XX)(MA9XX.J-MPRXX.J) PRICE RATE             1209
58A    MPDMX.K=TABHL(MF3XX,MA19X.K,56,78,2)                 PROD DESIRED/M   1210
8A     MA10X.K=MIMXX-MIAXX.K-MGPXX.K                                         1211
51A    MPFMX.K=CLIP(MA23X.K,MOMMX.K,MA20X.K,M0000)          PROD FEAS/M      1212
12R    MPOXX.KL=(MPFMX.K)(MNXXX)                            PROD ORDERED     1213
1L     MOCXX.K=MOCXX.J+(DT)(MPOXX.JK-MPSXX.JK)              ORDS IN CLER     1214
39R    MPSXX.KL=DELAY3(MPOXX.JK,MK5XX)                      PROD STARTED     1215
1L     MGPXX.K=MGPXX.J+(DT)(MPSXX.JK-MGIXX.JK)              GOODS IN PROD    1216
39R    MGIXX.KL=DELAY3(MPSXX.JK,MK6XX)                      GOODS TO INV     1217
1L     MIAXX.K=MIAXX.J+(DT)(MGIXX.JK-MGSXX.JK)              INV ACTUAL       1218
7A     MITXX.K=MIAXX.K+MGPXX.K                              INV TOTAL        1219
7A     MA11X.K=MITXX.K-MIDXX.K                                               1220
14A    MIDXX.K=MGPXX.K+(MGIXX.JK)(MK12X)                    INV DESRD        1221
20A    MA12X.K=MA11X.K/MK9XX                                                 1222
7A     MTSXX.K=MGIXX.JK+MA12X.K                             TRIAL SHIPMENT   1223
51R    MGSXX.KL=CLIP(MTSXX.K,M0000,MOUXX.K,M0000)           GOODS SHIPPED    1224
44A    MA3XX.K=(MA10X.K)(1)/MGIXX.JK                                         1225
44A    MA6XX.K=(MOUXX.K)(1)/MGIXX.JK                                         1226
3L     MFRXX.K=MFRXX.J+(DT)(1/MK3XX)(MA18X.JK-MFRXX.J) FACTOR RATE           1227
44A    MA7XX.K=(MFRXX.K)(MK2XX)/MGIXX.JK                                     1228
21A    MA13X.K=(1/MK11X)(MOUXX.K-MUDXX.K)                                    1229
12A    MUDXX.K=(MGIXX.JK)(MK13X)                            UNFORDS DESRD    1230
20A    MA14X.K=MA11X.K/MK11X                                                 1231
12A    MA15X.K=(MPRXX.K)(MK10X)                                              1232
9R     MODXX.KL=MPDXX.K+MA14X.K-MA15X.K-MA13X.K                              1233
7A     MA16X.K=MOAXX.JK-MGSXX.JK                                             1234
7A     MA17X.K=MORXX.JK-MGSXX.JK                                             1235
51R    MA18X.KL=CLIP(MA17X.K,MA16X.K,MORXX.JK,MODXX.JK)                      1236
12A    MCFXX.K=(MCFMX)(MNXXX)                               COST FIXED       1237
58R    MCVMX.KL=TABHL(MF5XX,MGIMX.JK,0,1.4,.2)             COST VAR          1238
20R    MGIMX.KL=MGIXX.JK/MNXXX                              GOODS TO INV/M   1239
12R    MCVXX.KL=(MCVMX.JK)(MNXXX)                           COST VAR         1240
7R     MCTXX.KL=MCVXX.JK+MCFXX.K                            COST TOT         1241
12R    MRSXX.KL=(MGSXX.JK)(MPXXX.K)                         REV PTS          1242
1L     MENSX.K=MENSX.J+(DT)(MRSXX.JK-MCTXX.JK)              EARNINGS NET PTS 1243
12R    MROXX.KL=(MOAXX.JK)(MPXXX.K)                         REV PTO          1244
1L     MENOX.K=MENOX.J+(DT)(MROXX.JK-MCTXX.JK)              EARNINGS NET PTO 1245
44R    MGSCX.KL=(MOUCX.K)(MGSXX.JK)/MOUXX.K                 GOODS SHPD C     1246
44R    MGSWX.KL=(MOUWX.K)(MGSXX.JK)/MOUXX.K                 GOODS SHPD W     1247
44R    MGSOX.KL=(MOUOX.K)(MGSXX.JK)/MOUXX.K                 GOODS SHPD O     1248
44R    MOACX.KL=(MORCX.JK)(MOAXX.JK)/MORXX.JK               ORDS ACC C       1245
44R    MOAWX.KL=(MORWX.JK)(MOAXX.JK)/MORXX.JK               ORDS ACC W       1250
44R    MOAOX.KL=(MOROX.JK)(MOAXX.JK)/MORXX.JK               ORDS ACC O       1251
1L     MOUCX.K=MOUCX.J+(DT)(MOACX.JK-MGSCX.JK)              ORDS UNFD C      1252
1L     MOUWX.K=MOUWX.J+(DT)(MOAWX.JK-MGSWX.JK)              ORDS UNFD W      1253
1L     MOUOX.K=MOUOX.J+(DT)(MOAOX.JK-MGSOX.JK)              ORDS UNFD O      1254
3L     MOMXX.K=MOMXX.J+(DT)(1/MK4XX)(MOAXX.JK-MOMXX.J) ORDS S M THD          1255
3L     MPMXX.K=MPMXX.J+(DT)(1/MK14X)(MPXXX.J-MPMXX.J)  PRICE S M THD         1256
14A    MA19X.K=MPXXX.K+(MK15X)(MPRXX.K)                                      1257
12A    MPDXX.K=(MNXXX)(MA23X.K)                             PROD DSD         1258
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20A   MOMMX.K=MOMXX.K/MNXXX                                  SMOOTHED ORDERS/M1259
7A    MA20X.K=MA10X.K+MOUXX.K                                TOTAL LEEWAY MMSQFT
12A   MA21X.K=(MK1XX)(MA4XX.K)                                               1261
35B   MBOX1=BOXCYC(13,4)                                                     1262
12A   MA22X.K=(MK16X)(MPDMX.K)                    VAC ADJ DSD PROD/M         1263
49A   MA23X.K=SWITCH(MPDMX.K,MA22X.K,MBOX1*13.K)                             1264
1L    WOULX.K=WOULX.J+(DT)(WOALX.JK-WGSLX.JK)                                2100
1L    WIAXX.K=WIAXX.J+(DT)(WGRMX.JK-WGSLX.JK)                                2101
20A   WTSLX.K=WOULX.K/WDFLX.K                                                2102
20A   WRNLX.K=WIAXX.K/DT                                                     2103
54R   WGSLX.KL=MIN(WTSLX.K,WRNLX.K)                                          2104
14A   WDFLX.K=WDMXX+(WDAXX)(WA2XX.K)                                         2105
12A   WIDXX.K=(WSSLX.K)(WK1XX)                                               2106
3L    WSSLX.K=WSSLX.J+(DT)(1/WK8XX)(WGSLX.JK-WSSLX.J)                        2107
20A   WA2XX.K=WIDXX.K/WIAXX.K                                                2108
6R    WOALX.KL=WORLX.JK                                                      2109
1L    WGIMX.K=WGIMX.J+(DT)(MGSWX.JK-WGRMX.JK)                                2113
39R   WGRMX.KL=DELAY3(MGSWX.JK,WK2XX)                                        2111
24A   WA3XX.K=(1/WK3XX)(WIFXX.K-WIAXX.K+WPDMX.K-WPAMX.K+WOULX.K-WONLX.K)
X1                                                                           2112
18A   WA4XX.K=(WK7XX)(DEXXX-SEXXX)                                           2113
12A   WA5XX.K=(WK4XX)(MPRXX.K)                                               2114
9A    WA6XX.K=WOALX.K+WA4XX.K+WA5XX.K+WA3XX.K                                2115
14A   WA1XX.K=WA6XX.K+(WK5XX)(-WA7XX.K)                                      2116
7A    WA7XX.K=MPXXX.K-MPMXX.K                                                2117
58R   WOIMX.KL=TABHL(WF1XX,WA1XX.K,0,200,50)                                 2118
1L    WOPMX.K=WOPMX.J+(DT)(WOIMX.JK-WOSMX.JK)                                2119
39R   WOSMX.KL=DELAY3(WOIMX.JK,WK6XX)                                        2120
6R    MORWX.KL=WOSMX.JK                                                      2121
7A    WPAMX.K=WGIMX.K+WOPMX.K                            ------              2122
6A    WDFMX.K=0                                                              2123
8A    WA8XX.K=WK6XX+WK2XX+WDFMX.K                                            2124
12A   WPDMX.K=(WSFLX.K)(WA8XX.K)                                             2125
6A    WSFLX.K=WSF1X.K                                        SALES FCS       2126
18A   WONLX.K=(WSSLX.K)(WDMXX+WDAXX)                                         2127
12A   WIFXX.K=(WK1XX)(WSFLX.K)                               INV FCST        2128
35B   WSAVB=BOXCYC(13,4)                          SEAS AVG BXCR CYC          2129
3L    WSAVB*13.K=WSAVB*13.J+(DT)(1/WK9XX)(WOALX.JK-WSAVB*13.J)               2130
37B   WTLSB=BOXLIN(1,4)                           TIME SIN LST SHFT          2131
1L    WTLSB*1.K=WTLSB*1.J+(DT)(1-0)                                          2132
8A    WTFBC.K=WTFXX+WTLSB*1.K-2                   TIME FR CEN BOT CAR        2133
7A    WINTD.K=48-WTFBC.K                          INTERP DIST FR TOP TRN     2134
59A   WSF1X.K=TABLE(WSAVB,WINTD.K,0,48,4)  FCST SALES 1ST APP                2135
21A   WA9XX.K=(1/WSSLX.K)(WSSLX.K-WSAVB*12)                                  2136
12A   WTFCX.K=(WK10X)(WA9XX.K)                       TREND FORECAST          2137
6R    WORLX.KL=LOSWX.JK                                                      2138
58A   PA1XX.K=TABHL(PF1XX,MPXXX.K,56,78,2)                                   1100
12A   PA2XX.K=(PK1XX)(PA1XX.K)                                               1101
35B   PBOX1=BOXCYC(13,4)                                                     1102
49R   PPDMX.KL=SWITCH(PA1XX.K,PA2XX.K,PBOX1*13.K)  PROD DSD/M                1103
12R   PPDXX.KL=(PNXXX)(PPDMX.JK)                           PROD DSD          1104
1L    POPXX.K=POPXX.J+(DT)(PPDXX.JK-PPSXX.JK)              ORDS IN PROC      1105
39R   PPSXX.KL=DELAY3(PPDXX.JK,PK5XX)                      PROD STD          1106
1L    PGPXX.K=PGPXX.J+(DT)(PPSXX.JK-PGIXX.JK)              GDS IN PROD       1107
39R   PGIXX.KL=DELAY3(PPSXX.JK,PK6XX)                      GDS TO INV        1108
3L    PGISX.K=PGISX.J+(DT)(1/PK2XX)(PGIXX.JK-PGISX.J)            GI SMTHD 1109
20R   PGIMX.KL=PGIXX.JK/PNXXX                              GDS TO INV/M      1110
13R   PLCRX.KL=(PGIMX.JK)(PRRXX)(PLCXX)        LOG COST RATE/M               1111
12R   PGCRX.KL=(PGIMX.JK)(PGCXX)              GLUE COST RATE/M               1112
54A   PA3XX.K=MIN(PGIMX.JK,PSCMX)                                            1113
12R   PSCRX.KL=(PA3XX.K)(PSCXX)               ST TIME MP CST RATE            1114
7A    PA4XX.K=PGIMX.JK-PSCMX                                                 1115
51A   PA5XX.K=CLIP(PA4XX.K,0,PA4XX.K,0)                                      1116
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12R   POCRX.KL=(PA5XX.K)(POCXX)                OV TIME MP CST RATE      1117
10R   PCMXX.KL=POCRX.JK+PSCRX.JK+PGCRX.JK+PLCRX.JK+PCFMX+0             1118
12R   PCXXX.KL=(PCMXX.JK)(PNXXX)               TOT CST                  1119
1L    PIAXX.K=PIAXX.J+(DT)(PGIXX.JK-PGSXX.J)         INV ACT            1120
12A   PIDXX.K=(PK3XX)(PGIXX.JK)                      INV DSD            1121
21A   PA7XX.K=(1/PK4XX)(PIAXX.K-PIDXX.K)                                1122
7A    PTSXX.K=PGIXX.K+PA7XX.K                        TRIAL SHMTS        1123
51A   PGSXX.K=CLIP(PTSXX.K,0,POUXX.K,0)              GDS SHPD           1124
44R   PGSCX.KL=(POUCX.K)(PGSXX.K)/POUXX.K            GDS SHPD C         1125
44R   PGSDX.KL=(POUDX.K)(PGSXX.K)/POUXX.K            GDS SHPD D         1126
1L    POUCX.K=POUCX.J+(DT)(PORCX.JK-PGSCX.JK)        ORDS UNF C         1127
1L    POUDX.K=POUDX.J+(DT)(PORDX.JK-PGSDX.JK)        ORDS UNF D         1128
7A    POUXX.K=POUCX.K+POUDX.K                        ORDS UNF TOT       1129
9A    PA8XX.K=POUXX.K+PIMXX-PIAXX.K-PGPXX.K                             1130
20A   PLTXX.K=PA8XX.K/PGIXX.JK                       LEEWAY TOT         1131
18A   PA6XX.K=(PGIXX.K)(PLDXX-PLTXX.K)                                  1132
1L    PENXX.K=PENXX.J+(DT)(PREXX.JK-PCXXX.JK)   EGS NET MDOLS           1134
12R   PREXX.KL=(MPXXX.K)(PGSXX.K)             REN MDOLS/WK              1135
14A   CODLX.K=CORLX.JK+(CK1XX)(-MPRXX.K)       ORDS DSD                 2200
54R   COALX.KL=MIN(CODLX.K,CORLX.JK)           ORDS ACC                 2201
1L    COULX.K=COULX.J+(DT)(COALX.JK-CGSLX.JK)  ORDS UNF                 2202
7A    CA1XX.K=MGSCX.JK+PGSCX.JK                                         2203
1L    CGIXX.K=CGIXX.J+(DT)(CA1XX.J-CGRXX.JK)   GDS INTRANSIT            2204
39R   CGRXX.KL=DELAY3(CA1XX.K,CK2XX)           GDS RCVD                 2205
1L    CIAXX.K=CIAXX.J+(DT)(CGRXX.JK-CGSLX.JK)  INV ACT                  2206
20A   CRNLX.K=CIAXX.K/DT                       MAX SHIP.RATE            2207
12A   CIDXX.K=(CSSLX.K)(CK3XX)                 INV DSD MMSQFT           2208
44A   CDVLX.K=(CDAXX)(CIDXX.K)/CIAXX.K         VAR SHIP DEL             2209
7A    CDFLX.K=CDMXX+CDVLX.K                    ORD FIL DEL              2210
20A   CA2XX.K=COULX.K/CDFLX.K                                           2211
54R   CGSLX.KL=MIN(CA2XX.K,CRNLX.K)                                     2212
3L    CSSLX.K=CSSLX.J+(DT)(1/CK4XX)(CGSLX.JK-CSSLX.J)  SM SALES         2213
12A   CIFXX.K=(CK3XX)(CSFLX.K)                 INV FORCST MMSQFT        2214
8A    CPAXX.K=CGIXX.K+COPPX.K+COPMX.K          PIPE ACT                 2215
44A   CA3XX.K=(MOUXX.K)(MOUCX.K)/MGIXX.JK                               2216
44A   CA4XX.K=(POUXX.K)(POUCX.K)/PGIXX.JK                               2217
6A    CA5XX.K=0                                                         2218
8A    CA6XX.K=CK2XX+CK10X+CA5XX.K                                       2219
12A   CPDXX.K=(CSFLX.K)(CA6XX.K)               PIPE INV DSD             2220
18A   CONLX.K=(CSFLX.K)(CDMXX+CDAXX)           ORDS UNF NOR             2221
24A   CA7XX.K=(1/CK5XX)(CIFXX.K-CIAXX.K+CPDXX.K-CPAXX.K+COULX.K-CONLX.K)
X1                                                                      2223
35B   CSAVB=BOXCYC(13,4)                       SEAS AVG BXCR CYC        2224
3L    CSAVB*13.K=CSAVB*13.J+(DT)(1/CK7XX)(COALX.JK-CSAVB*13.J)          2225
37B   CTLSB=BOXLIN(1,4)                        TIME SIN LSTSHFT         2226
1L    CTLSB*1.K=CTLSB*1.J+(DT)(1-0)                                     2227
8A    CTFBC.K=CTFXX+CTLSB*1.K-TWO     TIME FROM CNTR BOT CAR            2228
7A    CINTD.K=48-CTFBC.K              INTERP DIST FRM TOP TRAIN         2229
59A   CSF1X.K=TABLE(CSAVB,CINTD.K,0,48,4)      FCST SALES 1ST APP       2230
21A   CA8XX.K=(1/CSSLX.K)(CSSLX.K-CSAVB*12.K)                           2231
12A   CTFCX.K=(CA8XX.K)(CK8XX)        TREND FORECAST CORRECTION         2232
12A   CSFLX.K=(CSF1X.K)(1)            SALES,FORECAST                    2233
20A   CA9XX.K=PA6XX.K/CK9XX                                             2234
9A    CA10X.K=CA9XX.K+PGIXX.JK-DOAKX.K+COMMX                            2235
9A    CA11X.K=CONXX.K+DOAKX.K-PGIXX.JK-CA9XX.K                          2236
51A   COAXX.K=CLIP(CONXX.K,CA10X.K,CA11X.K,COMMX)                       2237
7A    CONXX.K=CA7XX.K+CSF1X.K         ORDS NORMAL                       2238
8A    COIPX.K=PGIXX.JK+CA9XX.K-DOAKX.K         ORDS IMP TO P            2239
9A    CA12X.K=COAXX.K+CA13X.K-COIPX.K+CA14X.K                           2240
51A   COIMX.K=CLIP(CA12X.K,COMMX,CA12X.K,COMMX)
1L    COPMX.K=COPMX.J+(DT)(COIMX.J-COSMX.JK)   ORDS IN PROC TO M        2241
39R   COSMX.KL=DELAY3(COIMX.K,CK10X)           ORDS SENT TO M           2242
1L    DOPPX.K=DOPPX.J+(DT)(DOAKX.J-DOSPX.JK)   ORDS IN PROC TO P        2243
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39R   DOSPX.KL=DELAY3(DOAKX.K,CK10X)            ORDS SENT TO P         2244
1L    COPPX.K=COPPX.J+(DT)(COIPX.J-COSPX.JK)    ORDS IN PROC TO P      2245
39R   COSPX.KL=DELAY3(COIPX.K,CK10X)            ORDS SENT TO P         2246
54A   DOAKX.K=MIN(DORKX.JK,DODKX.K)             ORDS ACC               2247
6A    DODKX.K=DORKX.JK                          ORDS DSD               2248
6R    PORDX.KL=DOSPX.JK                         ORDS RCVD              2249
6R    PORCX.KL=COSPX.JK                         ORDS RCVD              2250
6R    MORCX.KL=COSMX.JK                         ORDS REVD              2251
12A   CA13X.K=(MPRXX.K)(CK11X)                  SPEC FACTOR            2252
18A   CA14X.K=(CK12X)(MPMXX.K-MPXXX.K)          SPEC FACTOR            2253
6R    DGRPX.KL=PGSDX.JK                         D GDS RCVD             2254
6R    DGSKX.KL=DGRPX.JK                         GDS SHIPPED K          2255
6R    DORKX.KL=KOSDX.JK                         ORDS RCVD  K           2256
6R    CORLX.KL=LOSCX.JK                         ORDS RCVD  L           2257
7A    LA1XX.K=CGSLX.JK+WGSLX.JK                                        3100
1L    LGIXX.K=LGIXX.J+(DT)(LA1XX.J-LGRXX.JK)          GDS IN TRANSIT   3101
39R   LGRXX.KL=DELAY3(LA1XX.K,LK1XX)                  GDS REVD         3102
1L    LIAXX.K=LIAXX.J+(DT)(LGRXX.JK-LGSXX.JK)         INV ACT          3103
1L    LOUXX.K=LOUXX.J+(DT)(LOAXX.JK-LGSXX.JK)         UNF ORDS         3104
20A   LA2XX.K=LOUXX.K/LK2XX                                            3105
20A   LA3XX.K=LIAXX.K/DT                                               3106
54R   LGSXX.KL=MIN(LA2XX.K,LA3XX.K)                   GDS SHIPPED      3107
3L    LOSMX.K=LOSMX.J+(DT)(1/LK3XX)(LOAXX.JK-LOSMX.J) ORDS SMTHD       3108
12A   LIDXX.K=(LSFXX.K)(LK4XX)                        INV DSD          3109
51A   LA6XX.K=CLIP(0,MPRXX.K,MPRXX.K,0)                                3111
51A   LA7XX.K=CLIP(MPRXX.K,0,MPRXX.K,0)                                3112
12A   LSGKX.K=(LA6XX.K)(LK6XX)                        SALES GAINED     3113
12A   LSLKX.K=(LA7XX.K)(LK7XX)                        SALES LOST       3114
12A   LA8XX.K=(LK8XX)(MPRXX.K)                                         3115
18A   LA9XX.K=(LK9XX)(LPSXX.K-LPXXX.K)                                 3116
10A   LOIXX.K=LA4XX.K+LOSMX.K+LA8XX.K+LSGKX.K-LSLKX.K+LA9XX.K          3117
1L    LOPXX.K=LOPXX.J+(DT)(LOIXX.J-LOSXX.JK)          ORDS IN PROC     3118
39R   LOSXX.KL=DELAY3(LOIXX.K,LK10X)                  ORDS SENT        3119
50A   LOFWX.K=(LOSXX.JK)(WSXXX)/(CSXXX+WSXXX) ORDS FEAS TO W           3120
50A   LOFCX.K=(LOSXX.JK)(CSXXX)/(CSXXX+WSXXX) ORDS FEAS TO C           3121
34A   LN1XX.K=(LK19X)NORMRN(0,LN1SX.K)        NOISE                    3122
12A   LN1SX.K=(LK11X)(LOSXX.JK)               STD DEV                  3123
7A    LA10X.K=LOFCX.K+LN1XX.K                                          3124
7A    LA11X.K=LOFWX.K-LN1XX.K                                          3125
28A   LA12X.K=(1)EXP(-LA14X.K)                                         3126
28A   LA13X.K=(1)EXP(-LA15X.K)                                         3127
44A   LA14X.K=(LK12X)(CIAXX.K)/LA10X.K                                 3128
44A   LA15X.K=(LK13X)(WIAXX.K)/LA11X.K                                 3129
12A   CSLWX.K=(LA10X.K)(LA12X.K)              SALES LOST               3130
12A   WSLCX.K=(LA11X.K)(LA13X.K)              SALES LOST               3131
8R    LOSCX.KL=LA10X.K+WSLCX.K-CSLWX.K        ORDS SENT                3132
8R    LOSWX.KL=LA11X.K+CSLWX.K-WSLCX.K        ORDS SENT                3133
12A   LA16X.K=(MPXXX.K)(LK14X)                                         3134
3L    LPXXX.K=LPXXX.J+(DT)(1/LK15X)(LA16X.J-LPXXX.J) LCL PRICE         3135
3L    LPSXX.K=LPSXX.J+(DT)(1/LK16X)(LPXXX.J-LPSXX.J) LCL PRICE SM      3136
7A    LPAXX.K=LOPXX.K+LGIXX.K                 PIPE INV ACTUAL          3137
6A    LA19X.K=0
19A   LPDXX.K=(LSFXX.K)(LA19X.K+LK1XX+LK10X+0) PIPE INV DSD            3141
12A   LONXX.K=(LSFXX.K)(LK2XX)                      ORDS UNF NORMAL    3142
24A   LA4XX.K=(1/LK5XX)(LIDXX.K-LIAXX.K+LOUXX.K-LONXX.K+LPDXX.K-LPAXX.K)
X1                                                                     3142A
6R    LOAXX.KL=LORXX.JK                             ORDS ACCEPTED      3143
35B   LSAVB=BOXCYC(13,4)                   SEAS AVG BOXCAR CYCLE       3144
37B   LTLSB=BOXLIN(1,4)                    TIME SINCE LAST SHIFT       3145
1L    LTLSB*1.K=LTLSB*1.J+(DT)(1-0)                                    3146
8A    LTFBC.K=LTFXX+LTLSB*1.K-TWO          TIME FROM CNTR BOT CAR      3147
7A    LINTD.K=48-LTFBC.K                   INTERP DIST FROM TOP TRN    3148
59A   LSF1X.K=TABLE(LSAVB,LINTD.K,0,48,4)  FCST SALES 1ST APPROX       3149
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3L     LSAVP*13.K=LSAVB*13.J+(DT)(1/LK18X)(LOAXX.JK-LSAVP*13.J)     3150
18A    LA20X.K=(LK17X)(LOSMX.K-LSAVB*12.K) TREND ADJ FACTOR         3151
12A    LSFXX.K=(LSF1X.K)(1)                    SALES FCST           3152
NOTE   INITIAL CONDITIONS W SECTOR                                  IC1
NOTE                                                                IC2
18N    WOULX=(WORLX)(WDMXX+WDAXX)                                   IC3
12N    WIAXX=(WORLX)(WK1XX)                                         IC4
6N     WSSLX=WORLX                                                  IC5
12N    WGIMX=(WORLX)(WK2XX)                                         IC6
6N     MGSWX=WORLX                                                  IC7
12N    WOPMX=(WORLX)(WK6XX)                                         IC8
6N     WOIMX=WORLX                                                  IC9
NOTE   INITIAL CONDITIONS M SECTOR                                  IC12
NOTE                                                                IC13
6N     MORXX=WORLX                                                  IC13
6N     MOUXX=150  MMSQFT                                            IC15
6N     MAIXX=64 DOLLARS                                             IC16
6N     MPRXX=0                                                      IC17
12N    MOCXX=(WORLX)(MK5XX)                                         IC18
12N    MGPXX=(WORLX)(MK6XX)                                         IC20
6N     MIAXX=42  MM SQ FT                                           IC22
6N     MFRXX=0                                                      IC23
6N     MGSXX=WORLX                                                  IC24
6N     MODXX=WORLX                                                  IC25
20N    MGIMX=WORLX/MNXXX                                            IC26
12N    MCVXX=(MCVMX)(MNXXX)                                         IC27
6N     MENSX=0                                                      IC28
6N     MOAXX=WORLX                                                  IC29
6N     MENOX=0                                                      IC30
6N     MOUCX=0                                                      IC31
6N     MOUOX=0                                                      IC32
6N     MOUWX=MUDXX                                                  IC33
6N     MOMXX=WORLX                                                  IC34
6N     MPMXX=MPXXX                                                  IC35
12N    POPXX=(PPDXX)(PK5XX)                    EQH1105              IC40
12N    PGPXX=(PPDXX)(PK6XX)                    EQH1107              IC41
6N     PGISX=PGIXX                             EQN1109              IC42
12N    PIAXX=(PK3XX)(PGIXX)                    EQN1120              IC43
12N    POUCX=(3)(PGIXX)                        EQH1127              IC44
6N     POUDX=0                                 EQN1128              IC45
6N     PENXX=0                                 EQN1134              IC46
C      PROX1*=0/0/0/0/0/0/1/1/0/0/0/0/0/0
C      PLCXX=60 DOLS/MBDFT
C      LTLSB*=0
18N    COULX=(CORLX)(CDMXX+CDAXX)              EQN2102              IC50
12N    CGIXX=(CORLX)(CK2XX)                    EQN2104              IC51
12N    CIAXX=(CORLX)(CK3XX)                    EQN2106              IC52
6N     CSSLX=CORLX                             EQN2113              IC53
12N    COPPX=(CORLX)(CK10X)                    EQN2145              IC54
6N     DOPPX=0                                 EQN2143              IC55
6N     COPMX=0                                 EQN2141              IC56
12N    LGIXX=(LK1XX)(LORXX)                    EQN3101              IC65
12N    LIAXX=(LORXX)(LK4XX)                    EQN3103              IC66
12N    LOUXX=(LORXX)(LK2XX)                    EQN3104              IC67
6N     LOSMK=LORXX                             EQN3108              IC68
12N    LOPXX=(LORXX)(LK10X)                    EQN3118              IC69
6N     LPXXX=LA16X                                                  IC70
6N     LPSXX=LPXXX                                                  IC71
6N     LOSMX=93                                                     IC72
50N    CORLX=(LORXX)(CSXXX)/(CSXXX+WSXXX)                           IC73
50N    WORLX=(LORXX)(WSXXX)/(CSXXX+WSXXX)                           IC74
7N     LTEBC=LTEXX-2                                                IC75
7N     CTEBC=CTEXX-2                                                IC76
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NOT:                                                                    INP1
NOTE    INPUT                                                           INP2
NOTE                                                                    INP3
7R      LORXX.KL=93+LSEAS.K                                             INP4
32A     LSEAS.K=(-INK1X)COS((2PI)(TIME)/52)                             INP5
6R      MOROX.KL=0                                                      INP7
6R      KOSDX.KL=0                                                      INP8
NOTE                                                                    CON1
NOTE    CONSTANTS                                                       CON2
C       MCFMX=6 MDOLS/WKPER MILL                                        CON3
C       MF5XX*=0/10.8/21.6/32.4/43.2/54/66.8/79.6                       CON4
C       MK15X=2                                                         CON5
C       MNXXX=63                                                        CON6
C       MK1XX=1                                                         CON7
C       MK2XX=4                                                         CON8
C       MK3XX=.4 WK                    TIME TO SM UFO RATE              CON9
C       MK5XX=1.0 WK                   ADMIN LAG                        CON10
C       MK6XX=.20 WK                   PROD LAG                         CON11
C       MK7XX=.40 WK                   TIME TO SM PRICE RATE            CON12
C       MK9XX=4.0 WK                   TIME TO ADJ MILL INV             CON13
C       MK10X=2.4 MMSQFT/WK/DOL/WK     MILL SPEC FACTOR                 CON14
C       MK11X=4.0 WK                   TIME TO ADJ UFO                  CON15
C       MK12X=.5  WK                   WKS MILL INV DSD                 CON16
C       MK13X=2.5                                WKS UFO DSD            CON17
C       MK14X=100 WK                   TIME TO SM PRICE                 CON18
C       MK4XX=2.0 WK                   TIME TO SM ORDS ACC              CON19
C       M0000=0                        ZERO                             CON20
C       MIMXX=60 MMSQFT                MAX MILL INV                     CON21
C       MF1XX*=56/56/56/56/56/58/62/70/80/90/100                        CON23
C       MF4XX*=0/.1/.3/.65/.95/1/1/1/0                                  CON24
C       MF2XX*=-2.5/-2/-1/-.2/0/0/.1/.8/1.5/2/2.5/3/3.5/4/4.5/5/5.5/6     25
C       MF3XX*=.6/.85/.98/1/1/1.02/1.06/1.12/1.16/1.18/1.195/1.2        CON26
C       WK1XX=6.5 WK                   WKS INV DSD                      CON27
C       WK2XX=1.5 WK                   SHIPPING LAG                     CON28
C       WK3XX=8.0 WK                   WKS TO CORRECT INV               CON29
C       WK4XX=2.4 MMSQFT/WK/DOL/WK     WHSE SPEC FACTOR                 CON30
C       WK5XX=4    MMSQFT/WK/DOL       DEMAND ELAS                      CON31
C       WK6XX=.5 WK                    ORD PROC LAG                     CON32
C       WK7XX=0                                                         CON33
C       WK8XX=2 WK                     TIME TO SM SALES                 CON34
C       WDMXX=.2 WK                    MIN ORD FIL DEL                  CON35
C       WDAXX=.2 WK                    AVG ORD FIL DEL                  CON36
C       DEXXX=60 MMSQFT/WK             EST DEMAND                       CON37
C       SEXXX=60 MMSQFT/WK             EST SUPPLY                       CON38
C       WF1XX*=0/50/100/150/200                                         CON39
C       WK9XX=8 YR(4X2)              TIME TO AVG SEAS SALES             CON42
C       WTFXX=8 WKS                    FCST TIME                        CON43
C       WK10X=1                        TREND CONSTANT                   CON44
C       WSAVB*=43.5/47.5/54/62/69.5/75/76.8/75/69.5/62/54/47.5/43.5     CON45
C       WTLSB*=0                                                        CON46
C       INK1X=25                       MAG SEAS VARIATION               CON47
C       MK16X=.8                       VAC ADJ TO PROD                  CON48
C       MBOX1*=0/0/0/0/0/0/1/1/0/0/0/0/0/0                              CON49
C       PK1XX=.8                       VAC ADJ FACTOR                   CON50
C       PK2XX=2 WKS                    TIME TO SM PGIXX                 CON51
C       PK3XX=1 WK                     WKS INV DSD                      CON52
C       PK4XX=4 WKS                    WKS TO CORRECT INV               CON53
C       PK5XX=2 WKS                    PROD ORD PROC LAG                CON54
C       PK6XX=.4 WK                    PROD LAG                         CON55
C       PF1XX*=1/1/1/1/1/1.02/1.06/1.12/1.16/1.18/1.195/1.2             CON57
C       PNXXX=30                       NO. OF MILLS                     CON57
C       PRRXX=.455 BDFT/SQFT           REC RATIO                        CON58
C       PGCXX=4 DOL/MBDFT              GLUE COST                        CON59
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C      PSCXX=24 DOL/MBDFT                  ST LABOR COST            CON60
C      PSCMX=1 MMSQFT/WK                   ST TIME CAP/M            CON61
C      POCXX=36 DOL/MBDFT                  OT LABOR COST            CON62
C      PCFMX=6 MDOLS/WK/M                  FIXED COST               CON63
C      PIMXX=60 MMSQFT                     INV MAX                  CON64
C      PLDXX=4 WKS                         LEEWAY DSD               CON65
C      CK1XX=0                             SPEC CON                 CON66
C      CK2XX=2 WKS                         SHIP DELAY               CON67
C      CK3XX=7 WKS                         INV DSD                  CON68
C      CK4XX=4 WKS                         TIME TO SM SALES         CON69
C      CK5XX=8 WKS                         TIME TO ADJ INV          CON70
C      CK7XX=8 (4X2)                       TIME TO SM SEAS SALES    CON71
C      CK8XX=1                             TREND FCST CON           CON72
C      CK9XX=4 WKS                         TIME TO ADJ P LEEWAY     CON73
C      CK10X=.5 WK                         TIME TO PROC ORDS        CON74
C      CK11X=0                             RATE SPEC FACTOR         CON75
C      CK12X=0    MMSQFT/WK/DOL            DEMAND CONSTANT          CON76
C      CDAXX=.2 WK                         DELAY AVG                CON77
C      CDMXX=.2 WK                         DELAY MIN                CON78
C      CTFXX=8 WKS                         FCST TIME                CON79
C      COMMX=1 MMSQFT/WK                   MIN ORDS TO M            CON80
C      LK1XX=1  WK                         SHPG DEL W,P-L           CON81
C      LK2XX=.2 WK                         SHPG DEL L-END USE       CON82
C      LK3XX=2 WK                          TIME TO SM ORDS          CON83
C      LK4XX=4 WK                          INV DSD                  CON84
C      LK5XX=4 WK                          WKS TO COR INV           CON85
C      LK6XX=0                             LSGK FACTOR              CON86
C      LK7XX=0                             LSLK FACTOR              CON87
C      LK8XX=0                             PRICE RATE CON           CON88
C      LK9XX=0                             PRICE CON                CON89
C      LK10X=.5 WK                         ORD PROC LAG             CON90
C      LK11X=.1                            EQN 3123                 CON91
C      LK12X=100                           EQN 3128                 CON92
C      LK13X=100                           EQN 3129                 CON93
C      LK14X=1.15                          LCL PRICE MARKUP         CON94
C      LK15X=.5                            DEL MP TO LP             CON95
C      LK16X=100 WK                        TIME TO SM LCL PRICE     CON96
C      LK17X=1                             TREND CON                CON97
C      LK18X=8                             TIME TO SM SEAS SALES    CON98
C      LK19X=0                             NOISE CON                CON99
C      LTFXX=2 WKS                              FCST TIME           CON100
C      CSXXX=33                            C SALES EFFORT           CON101
C      WSXXX=60                            W SALES EFFORT           CON102
C      LSAVB*=67/73/83/95/106/114/117/114/106/95/83/73/67
C      CSAVB*=23.8/25.8/29/33/37/39/40/39/37/33/29/25.8/23.8
C      CTLSB*=0
C      TWO=2
NOTE                                                                R1
PRINT  1)WORLX,WGSLX/2)WOULX/3)WIAXX,WIDXX/4)MORXX,MODXX,MOAXX/5)MOUXX,MO
X1     UWX,MUDXX/6)MPXXX,MPMXX/7)MPRXX/8)MA7XX,MA2XX/9)MPDMX,MPOXX/10)MGI
X2     XX,MGSCX,MGSWX/11)MIDXX,MIAXX/12)MENOX,MENSX/13)MA16X,MA17X,MA18X/
X3     14)WTFCX                                                     R5
PRINT  1)PGIXX/2)PIAXX/3)PGSXX,PGSCX,PGSDX/4)POUCX,POUDX,POUXX,MOUCX/5)PL
X1     TXX,PENXX/6)CIAXX,CIDXX,COULX,LIAXX,LIDXX/7)CSF1X,CGSLX/8)COSMX,CO
X2     SPX,DOSPX/9)CORLX,DOAKX/10)CA10X,CA11X,COAXX,CONXX/11)COIPX,CA12X,
X3     COIMX/13)LOSXX,LOSWX,LOSCX/14)LSGKX,LSLKX,CSLWX,WSLCX,LGRXX
PLOT   MPXXX=P/MGIXX=Q,WORLX=D,WSAVB*13=X,WSF1X=F/MOUXX=U/MIAXX=I/WIAXX=S
X1     /WOULX=B                                                     R7
PLOT   PGIXX=Q/PIAXX=I/POUXX=U/COULX=B/CIAXX=S/CSAVB*13=X/LIAXX=S/LOUXX=B
X1     /LORXX=D/COSMX=C
SPEC   DT=.050/LENGTH=500/PRTPER=4/PLTPER=2
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*      2061-1,DYN,RUN3,14,15
RUN    3A
NOTE   MODEL OF PLYWOOD INDUSTRY SECTORS M W CD P L O K
NOTE
8R     MORXX.KL=MORCX.JK+MORWX.JK+MOROX.JK                 ORDERS RECEIVED   1200
54R    MOAXX.KL=MIN(MORXX.JK,MODXX.JK)                     ORDERS ACCEPTED   1201
1L     MOUXX.K=MOUXX.J+(DT)(MOAXX.JK-MGSXX.JK)             ORDERS UNFILLED   1202
8A     MA2XX.K=MA7XX.K+MA6XX.K+MA3XX.K                                       1203
58A    MA4XX.K=TABHL(MF2XX,MA2XX.K,0,8.5,.5)                                 1204
1L     MA1XX.K=MA1XX.J+(DT)(MA21X.J-M0000)                                   1205
58A    MPXXX.K=TABHL(MF1XX,MA1XX.K,0,100,10)             PRICE               1206
58A    MA8XX.K=TABHL(MF4XX,MA1XX.K,30,110,10)                                1207
12A    MA9XX.K=(MA8XX.K)(MA21X.K)                                            1208
3L     MPRXX.K=MPRXX.J+(DT)(1/MK7XX)(MA9XX.J-MPRXX.J) PRICE RATE             1209
58A    MPDMX.K=TABHL(MF3XX,MA19X.K,56,78,2)                PROD DESIRED/M    1210
8A     MA10X.K=MIMXX-MIAXX.K-MGPXX.K                                         1211
51A    MPFMX.K=CLIP(MA23X.K,MOMMX.K,MA20X.K,M0000)         PROD FEAS/M       1212
12R    MPOXX.KL=(MPFMX.K)(MNXXX)                           PROD ORDERED      1213
1L     MOCXX.K=MOCXX.J+(DT)(MPOXX.JK-MPSXX.JK)             ORDS IN CLER      1214
39R    MPSXX.KL=DELAY3(MPOXX.JK,MK5XX)                     PROD STARTED      1215
1L     MGPXX.K=MGPXX.J+(DT)(MPSXX.JK-MGIXX.JK)             GOODS IN PROD     1216
39R    MGIXX.KL=DELAY3(MPSXX.JK,MK6XX)                     GOODS TO INV      1217
1L     MIAXX.K=MIAXX.J+(DT)(MGIXX.JK-MGSXX.JK)             INV ACTUAL        1218
7A     MITXX.K=MIAXX.K+MGPXX.K                             INV TOTAL         1219
7A     MA11X.K=MITXX.K-MIDXX.K                                               1220
14A    MIDXX.K=MGPXX.K+(MGIXX.JK)(MK12X)                   INV DESRD         1221
20A    MA12X.K=MA11X.K/MK9XX                                                 1222
7A     MTSXX.K=MGIXX.JK+MA12X.K                            TRIAL SHIPMENT    1223
51R    MGSXX.KL=CLIP(MTSXX.K,M0000,MOUXX.K,M0000)          GOODS SHIPPED     1224
44A    MA3XX.K=(MA10X.K)(1)/MGIXX.JK                                         1225
44A    MA6XX.K=(MOUXX.K)(1)/MGIXX.JK                                         1226
3L     MFRXX.K=MFRXX.J+(DT)(1/MK3XX)(MA18X.JK-MFRXX.J) FACTOR RATE           1227
44A    MA7XX.K=(MFRXX.K)(MK2XX)/MGIXX.JK                                     1228
21A    MA13X.K=(1/MK11X)(MOUXX.K-MUDXX.K)                                    1229
12A    MUDXX.K=(MGIXX.JK)(MK13X)                           UNFORDS DESRD     1230
20A    MA14X.K=MA11X.K/MK11X                                                 1231
12A    MA15X.K=(MPRXX.K)(MK10X)                                              1232
9R     MODXX.KL=MPDXX.K+MA14X.K-MA15X.K-MA13X.K                              1233
7A     MA16X.K=MOAXX.JK-MGSXX.JK                                             1234
7A     MA17X.K=MORXX.JK-MGSXX.JK                                             1235
51R    MA18X.KL=CLIP(MA17X.K,MA16X.K,MORXX.JK,MODXX.JK)                      1236
12A    MCFXX.K=(MCFMX)(MNXXX)                              COST FIXED        1237
58R    MCVMX.KL=TABHL(MF5XX,MGIMX.JK,0,1.4,.2)           COST VAR            1238
20R    MGIMX.KL=MGIXX.JK/MNXXX                             GOODS TO INV/M    1239
12R    MCVXX.KL=(MCVMX.JK)(MNXXX)                          COST VAR          1240
7R     MCTXX.KL=MCVXX.JK+MCFXX.K                           COST TOT          1241
12R    MRSXX.KL=(MGSXX.JK)(MPXXX.K)                        REV PTS           1242
1L     MENSX.K=MENSX.J+(DT)(MRSXX.JK-MCTXX.JK)             EARNINGS NET PTS  1243
12R    MROXX.KL=(MOAXX.JK)(MPXXX.K)                        REV PTO           1244
1L     MENOX.K=MENOX.J+(DT)(MROXX.JK-MCTXX.JK)             EARNINGS NET PTO  1245
44R    MGSCX.KL=(MOUCX.K)(MGSXX.JK)/MOUXX.K                GOODS SHPD C      1246
44R    MGSWX.KL=(MOUWX.K)(MGSXX.JK)/MOUXX.K                GOODS SHPD W      1247
44R    MGSOX.KL=(MOUOX.K)(MGSXX.JK)/MOUXX.K                GOODS SHPD O      1248
44R    MOACX.KL=(MORCX.JK)(MOAXX.JK)/MORXX.JK              ORDS ACC C        1245
44R    MOAWX.KL=(MORWX.JK)(MOAXX.JK)/MORXX.JK              ORDS ACC W        1250
44R    MOAOX.KL=(MOROX.JK)(MOAXX.JK)/MORXX.JK              ORDS ACC O        1251
1L     MOUCX.K=MOUCX.J+(DT)(MOACX.JK-MGSCX.JK)             ORDS UNFD C       1252
1L     MOUWX.K=MOUWX.J+(DT)(MOAWX.JK-MGSWX.JK)             ORDS UNFD W       1253
1L     MOUOX.K=MOUOX.J+(DT)(MOAOX.JK-MGSOX.JK)             ORDS UNFD O       1254
3L     MOMXX.K=MOMXX.J+(DT)(1/MK4XX)(MOAXX.JK-MOMXX.J) ORDS S M THD          1255
3L     MPMXX.K=MPMXX.J+(DT)(1/MK14X)(MPXXX.J-MPMXX.J)   PRICE S M THD        1256
14A    MA19X.K=MPXXX.K+(MK15X)(MPRXX.K)                                      1257
12A    MPDXX.K=(MNXXX)(MA23X.K)                            PROD DSD          1258
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20A   MOMMX.K=MOMXX.K/MNXXX                          SMOOTHED ORDERS/M1259
7A    MA20X.K=MA10X.K+MOUXX.K                        TOTAL LEEWAY MMSQFT
12A   MA21X.K=(MK1XX)(MA4XX.K)                                        1261
35B   MBOX1=BOXCYC(13,4)                                              1262
12A   MA22X.K=(MK16X)(MPDMX.K)              VAC ADJ DSD PROD/M        1263
49A   MA23X.K=SWITCH(MPDMX.K,MA22X.K,MBOX1*13.K)                      1264
6R    MOROX.KL=OOSMX.JK                                               1265
1L    WOULX.K=WOULX.J+(DT)(WOALX.JK-WGSLX.JK)                         2100
1L    WIAXX.K=WIAXX.J+(DT)(WGRMX.JK-WGSLX.JK)                         2101
20A   WTSLX.K=WOULX.K/WDFLX.K                                         2102
20A   WRNLX.K=WIAXX.K/DT                                              2103
54R   WGSLX.KL=MIN(WTSLX.K,WRNLX.K)                                   2104
14A   WDFLX.K=WDMXX+(WDAXX)(WA2XX.K)                                  2105
12A   WIDXX.K=(WSSLX.K)(WK1XX)                                        2106
3L    WSSLX.K=WSSLX.J+(DT)(1/WK8XX)(WGSLX.JK-WSSLX.J)                 2107
20A   WA2XX.K=WIDXX.K/WIAXX.K                                         2108
6R    WOALX.KL=WORLX.JK                                               2109
1L    WGIMX.K=WGIMX.J+(DT)(MGSWX.JK-WGRMX.JK)                         2113
39R   WGRMX.KL=DELAY3(MGSWX.JK,WK2XX)                                 2111
24A   WA3XX.K=(1/WK3XX)(WIFXX.K-WIAXX.K+WPDMX.K-WPAMX.K+WOULX.K-WONLX.K)
X1                                                                    2112
18A   WA4XX.K=(WK7XX)(DEXXX-SEXXX)
12A   WA5XX.K=(WK4XX)(MPRXX.K)                                        2114
9A    WA6XX.K=WOALX.K+WA4XX.K+WA5XX.K+WA3XX.K                         2115
14A   WA1XX.K=WA6XX.K+(WK5XX)(-WA7XX.K)                               2116
7A    WA7XX.K=MPXXX.K-MPMXX.K                                         2117
58R   WOIMX.KL=TABHL(WF1XX,WA1XX.K,0,200,50)                          2118
1L    WOPMX.K=WOPMX.J+(DT)(WOIMX.JK-WOSMX.JK)                         2119
39R   WOSMX.KL=DELAY3(WOIMX.JK,WK6XX)                                 2120
6R    MORWX.KL=WOSMX.JK                                               2121
7A    WPAMX.K=WGIMX.K+WOPMX.K                    ------               2122
6A    WDFMX.K=0                                                       2123
8A    WA8XX.K=WK6XX+WK2XX+WDFMX.K                                     2124
12A   WPDMX.K=(WSFLX.K)(WA8XX.K)                                      2125
6A    WSFLX.K=WSF1X.K                                SALES FCST L     2126
18A   WONLX.K=(WSSLX.K)(WDMXX+WDAXX)                                  2127
12A   WIFXX.K=(WK1XX)(WSFLX.K)                       INV FCST         2128
35B   WSAVB=BOXCYC(13,4)                    SEAS AVG BXCR CYC         2129
3L    WSAVB*13.K=WSAVB*13.J+(DT)(1/WK9XX)(WOALX.JK-WSAVB*13.J)        2130
37B   WTLSB=BOXLIN(1,4)                     TIME SIN LST SHFT         2131
1L    WTLSB*1.K=WTLSB*1.J+(DT)(1-0)                                   2132
8A    WTFBC.K=WTFXX+WTLSB*1.K-2             TIME FR CEN BOT CAR       2133
7A    WINTD.K=48-WTFBC.K                    INTERP DIST FR TOP TRN    2134
59A   WSF1X.K=TABLE(WSAVB,WINTD.K,0,48,4)  FCST SALES 1ST APP         2135
21A   WA9XX.K=(1/WSSLX.K)(WSSLX.K-WSAVB*12)                           2136
12A   WTFCX.K=(WK10X)(WA9XX.K)                 TREND FORECAST         2137
6R    WORLX.KL=LOSWX.JK                                               2138
58A   PA1XX.K=TABHL(PF1XX,MPXXX.K,56,78,2)                            1100
12A   PA2XX.K=(PK1XX)(PA1XX.K)                                        1101
35B   PBOX1=BOXCYC(13,4)                                              1102
49R   PPDMX.KL=SWITCH(PA1XX.K,PA2XX.K,PBOX1*13.K)    PROD DSD/M       1103
12R   PPDXX.KL=(PNXXX)(PPDMX.JK)                     PROD DSD         1104
1L    POPXX.K=POPXX.J+(DT)(PPDXX.JK-PPSXX.JK)        ORDS IN PROC     1105
39R   PPSXX.KL=DELAY3(PPDXX.JK,PK5XX)                PROD STD         1106
1L    PGPXX.K=PGPXX.J+(DT)(PPSXX.JK-PGIXX.JK)        GDS IN PROD      1107
39R   PGIXX.KL=DELAY3(PPSXX.JK,PK6XX)                GDS TO INV       1108
3L    PGISX.K=PGISX.J+(DT)(1/PK2XX)(PGIXX.JK-PGISX.J)      GI SMTHD 09
20R   PGIMX.KL=PGIXX.JK/PNXXX                        GDS TO INV/M     1110
13R   PLCRX.KL=(PGIMX.JK)(PRRXX)(PLCXX)      LOG COST RATE/M          1111
12R   PGCRX.KL=(PGIMX.JK)(PGCXX)            GLUE COST RATE/M          1112
54A   PA3XX.K=MIN(PGIMX.JK,PSCMX)                                     1113
12R   PSCRX.KL=(PA3XX.K)(PSCXX)             ST TIME MP CST RATE       1114
7A    PA4XX.K=PGIMX.JK-PSCMX                                          1115
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51A   PA5XX.K=CLIP(PA4XX.K,0,PA4XX.K,0)                                  1116
12R   POCRX.KL=(PA5XX.K)(POCXX)            OV TIME MP CST RATE           1117
10R   PCMXX.KL=POCRX.JK+PSCRX.JK+PGCRX.JK+PLCRX.JK+PCFMX+0               1118
12R   PCXXX.KL=(PCMXX.JK)(PNXXX)            TOT CST                      1119
1L    PIAXX.K=PIAXX.J+(DT)(PGIXX.JK-PGSXX.J)          INV ACT            1120
12A   PIDXX.K=(PK3XX)(PGIXX.JK)                       INV DSD            1121
21A   PA7XX.K=(1/PK4XX)(PIAXX.K-PIDXX.K)                                 1122
7A    PTSXX.K=PGIXX.K+PA7XX.K                         TRIAL SHMTS        1123
51A   PGSXX.K=CLIP(PTSXX.K,0,POUXX.K,0)               GDS SHPD           1124
44R   PGSCX.KL=(POUCX.K)(PGSXX.K)/POUXX.K             GDS SHPD C         1125
44R   PGSDX.KL=(POUDX.K)(PGSXX.K)/POUXX.K             GDS SHPD D         1126
1L    POUCX.K=POUCX.J+(DT)(PORCX.JK-PGSCX.JK)         ORDS UNF C         1127
1L    POUDX.K=POUDX.J+(DT)(PORDX.JK-PGSDX.JK)         ORDS UNF D         1128
7A    POUXX.K=POUCX.K+POUDX.K                         ORDS UNF TOT       1129
9A    PA8XX.K=POUXX.K+PIMXX-PIAXX.K-PGPXX.K                              1130
20A   PLTXX.K=PA8XX.K/PGIXX.JK                        LEEWAY TOT         1131
18A   PA6XX.K=(PGIXX.K)(PLDXX-PLTXX.K)                                   1132
1L    PENXX.K=PENXX.J+(DT)(PREXX.JK-PCXXX.JK)   EGS NET MDOLS            1134
12R   PREXX.KL=(MPXXX.K)(PGSXX.K,           REN MDOLS/WK                 1135
14A   CODLX.K=CORLX.JK+(CK1XX)(-MPRXX.K)         ORDS DSD                2200
54R   COALX.KL=MIN(CODLX.K,CORLX.JK)             ORDS ACC                2201
1L    COULX.K=COULX.J+(DT)(COALX.JK-CGSLX.JK)    ORDS UNF                2202
7A    CA1XX.K=MGSCX.JK+PGSCX.JK                                          2203
1L    CGIXX.K=CGIXX.J+(DT)(CA1XX.J-CGRXX.JK)     GDS INTRANSIT           2204
39R   CGRXX.KL=DELAY3(CA1XX.K,CK2XX)             GDS RCVD                2205
1L    CIAXX.K=CIAXX.J+(DT)(CGRXX.JK-CGSLX.JK)    INV ACT                 2206
20A   CRNLX.K=CIAXX.K/DT                         MAX SHIP.RATE           2207
12A   CIDXX.K=(CSSLX.K)(CK3XX)                   INV DSD MMSQFT          2208
44A   CDVLX.K=(CDAXX)(CIDXX.K)/CIAXX.K           VAR SHIP DEL            2209
7A    CDFLX.K=CDMXX+CDVLX.K                      ORD FIL DEL             2210
20A   CA2XX.K=COULX.K/CDFLX.K                                            2211
54R   CGSLX.KL=MIN(CA2XX.K,CRNLX.K)                                      2212
3L    CSSLX.K=CSSLX.J+(DT)(1/CK4XX)(CGSLX.JK-CSSLX.J) SM SALES           2213
12A   CIFXX.K=(CK3XX)(CSFLX.K)                   INV FORCST MMSQFT       2214
10A   CPAXX.K=CGIXX.K+COPPX.K+COPMX.K+POUCX.K+MOUCX.K+0 PIPE ACT         2215
44A   CA3XX.K=(MOUXX.K)(MOUCX.K)/MGIXX.JK                                2216
44A   CA4XX.K=(POUXX.K)(POUCX.K)/PGIXX.JK                                2217
26A   CA5XX.K=(CA3XX.K+CA4XX.K+0)/(POUXX.K+MOUXX.K+0)                    2218
8A    CA6XX.K=CK2XX+CK10X+CA5XX.K                                        2219
12A   CPDXX.K=(CSFLX.K)(CA6XX.K)                 PIPE INV DSD            2220
18A   CONLX.K=(CSFLX.K)(CDMXX+CDAXX)             ORDS UNF NOR            2221
24A   CA7XX.K=(1/CK5XX)(CIFXX.K-CIAXX.K+CPDXX.K-CPAXX.K+COULX.K-CONLX.K)
X1                                                                       2223
35B   CSAVB=BOXCYC(13,4)                         SEAS AVG BXCR CYC       2224
3L    CSAVB*13.K=CSAVB*13.J+(DT)(1/CK7XX)(COALX.JK-CSAVB*13.J)           2225
37B   CTLSB=BOXLIN(1,4)                          TIME SIN LSTSHFT        2226
1L    CTLSB*1.K=CTLSB*1.J+(DT)(1-0)                                      2227
8A    CTFBC.K=CTFXX+CTLSB*1.K-2        TIME FROM CNTR BOT CAR            2228
7A    CINTD.K=48-CTFBC.K               INTERP DIST FRM TOP TRAIN         2229
59A   CSF1X.K=TABLE(CSAVB,CINTD.K,0,48,4)        FCST SALES 1ST APP      2230
21A   CA8XX.K=(1/CSSLX.K)(CSSLX.K-CSAVB*12.K)                            2231
12A   CTFCX.K=(CA8XX.K)(CK8XX)         TREND FORECAST CORRECTION         2232
12A   CSFLX.K=(CSF1X.K)(CTFCX.K)       SALES,FORECAST                    2233
20A   CA9XX.K=PA6XX.K/CK9XX                                              2234
9A    CA10X.K=CA9XX.K+PGIXX.JK-DOAKX.K+COMMX                             2235
9A    CA11X.K=CONXX.K+DOAKX.K-PGIXX.JK-CA9XX.K                           2236
51A   COAXX.K=CLIP(CONXX.K,CA10X.K,CA11X.K,COMMX)                        2237
7A    CONXX.K=CA7XX.K+COALX.JK         ORDS NORMAL                       2238
8A    COIPX.K=PGIXX.JK+CA9XX.K-DOAKX.K           ORDS IMP TO P           2239
9A    CA12X.K=COAXX.K-COIPX.K+CA13X.K+CA14X.K                            2240
56A   COIMX.K=MAX(CA12X.K,COMMX)
1L    COPMX.K=COPMX.J+(DT)(COIMX.J-COSMX.JK)     ORDS IN PROC TO M       2241
39R   COSMX.KL=DELAY3(COIMX.K,CK10X)             ORDS SENT TO M          2242
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1L    DOPPX.K=DOPPX.J+(DT)(DOAKX.J-DOSPX.JK)      ORDS IN PROC TO P    2243
39R   DOSPX.KL=DELAY3(DOAKX.K,CK10X)              ORDS SENT TO P       2244
1L    COPPX.K=COPPX.J+(DT)(COIPX.J-COSPX.JK)      ORDS IN PROC TO P    2245
39R   COSPX.KL=DELAY3(COIPX.K,CK10X)              ORDS SENT TO P       2246
54A   DOAKX.K=MIN(DORKX.JK,DODKX.K)               ORDS ACC             2247
6A    DODKX.K=DORKX.JK                            ORDS DSD             2248
6R    PORDX.KL=DOSPX.JK                           ORDS RCVD            2249
6R    PORCX.KL=COSPX.JK                           ORDS RCVD            2250
6R    MORCX.KL=COSMX.JK                           ORDS REVD            2251
12A   CA13X.K=(MPRXX.K)(CK11X)                    SPEC FACTOR          2252
18A   CA14X.K=(CK12X)(MPMXX.K-MPXXX.K)            SPEC FACTOR          2253
6R    DGRPX.KL=PGSDX.JK                           D GDS RCVD           2254
6R    DGSKX.KL=DGRPX.JK                           GDS SHIPPED K        2255
6R    DORKX.KL=KOSDX.JK                           ORDS RCVD  K         2256
6R    CORLX.KL=LOSCX.JK                           ORDS RCVD  L         2257
7A    LA1XX.K=CGSLX.JK+WGSLX.JK                                        3100
1L    LGIXX.K=LGIXX.J+(DT)(LA1XX.J-LGRXX.JK)            GDS IN TRANSIT 3101
39R   LGRXX.KL=DELAY3(LA1XX.K,LK1XX)                    GDS REVD       3102
1L    LIAXX.K=LIAXX.J+(DT)(LGRXX.JK-LGSXX.JK)           INV ACT        3103
1L    LOUXX.K=LOUXX.J+(DT)(LOAXX.JK-LGSXX.JK)           UNF ORDS       3104
20A   LA2XX.K=LOUXX.K/LK2XX                                            3105
20A   LA3XX.K=LIAXX.K/DT                                               3106
54R   LGSXX.KL=MIN(LA2XX.K,LA3XX.K)                     GDS SHIPPED    3107
3L    LOSMX.K=LOSMX.J+(DT)(1/LK3XX)(LOAXX.JK-LOSMX.J) ORDS SMTHD       3108
12A   LIDXX.K=(LSFXX.K)(LK4XX)                          INV DSD        3109
51A   LA6XX.K=CLIP(0,MPRXX.K,MPRXX.K,0)                                3111
51A   LA7XX.K=CLIP(MPRXX.K,0,MPRXX.K,0)                                3112
12A   LSGKX.K=(LA6XX.K)(LK6XX)                          SALES GAINED   3113
12A   LSLKX.K=(LA7XX.K)(LK7XX)                          SALES LOST     3114
12A   LA8XX.K=(LK8XX)(MPRXX.K)                                         3115
18A   LA9XX.K=(LK9XX)(LPSXX.K-LPXXX.K)                                 3116
10A   LOIXX.K=LA4XX.K+LORXX.JK+LA8XX.K+LSGKX.K-LSLKX.K+LA9XX.K         3117
1L    LOPXX.K=LOPXX.J+(DT)(LOIXX.J-LOSXX.JK)            ORDS IN PROC   3118
39R   LOSXX.KL=DELAY3(LOIXX.K,LK10X)                    ORDS SENT      3119
50A   LOFWX.K=(LOSXX.JK)(WSXXX)/(CSXXX+WSXXX) ORDS FEAS TO W           3120
50A   LOFCX.K=(LOSXX.JK)(CSXXX)/(CSXXX+WSXXX) ORDS FEAS TO C           3121
34A   LN1XX.K=(LK19X)NORMRN(0,LN1SX.K)        NOISE                    3122
12A   LN1SX.K=(LK11X)(LOSXX.JK)               STD DEV                  3123
7A    LA10X.K=LOFCX.K+LN1XX.K                                          3124
7A    LA11X.K=LOFWX.K-LN1XX.K                                          3125
28A   LA12X.K=(1)EXP(-LA14X.K)                                         3126
28A   LA13X.K=(1)EXP(-LA15X.K)                                         3127
44A   LA14X.K=(LK12X)(CIAXX.K)/LA10X.K                                 3128
44A   LA15X.K=(LK13X)(WIAXX.K)/LA11X.K                                 3129
12A   CSLWX.K=(LA10X.K)(LA12X.K)              SALES LOST               3130
12A   WSLCX.K=(LA11X.K)(LA13X.K)              SALES LOST               3131
8R    LOSCX.KL=LA10X.K+WSLCX.K-CSLWX.K        ORDS SENT                3132
8R    LOSWX.KL=LA11X.K+CSLWX.K-WSLCX.K        ORDS SENT                3133
12A   LA16X.K=(MPXXX.K)(LK14X)                                         3134
3L    LPXXX.K=LPXXX.J+(DT)(1/LK15X)(LA16X.J-LPXXX.J) LCL PRICE         3135
3L    LPSXX.K=LPSXX.J+(DT)(1/LK16X)(LPXXX.J-LPSXX.J) LCL PRICE SM      3136
7A    LPAXX.K=LOPXX.K+LGIXX.K                        INV ACT           3137
6A    LA19X.K=0                                                        3140
19A   LPDXX.K=(LSFXX.K)(LA19X.K+LK1XX+LK10X+0) PIPE INV DSD            3141
12A   LONXX.K=(LSFXX.K)(LK2XX)                     ORDS UNF NORMAL     3142
24A   LA4XX.K=(1/LK5XX)(LIDXX.K-LIAXX.K+LOUXX.K-LONXX.K+LPDXX.K-LPAXX.K)
X1                                                                     3142A
6R    LOAXX.KL=LORXX.JK                             ORDS ACCEPTED      3143
35B   LSAVB=BOXCYC(13,4)                      SEAS AVG BOXCAR CYCLE    3144
37B   LTLSB=BOXLIN(1,4)                       TIME SINCE LAST SHIFT    3145
1L    LTLSB*1.K=LTLSB*1.J+(DT)(1-0)                                    3146
8A    LTFBC.K=LTFXX+LTLSB*1.K-2               TIME FROM CNTR BOT CAR   3147
7A    LINTD.K=48-LTFBC.K                      INTERP DIST FROM TOP TRN 3148
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59A   LSF1X.K=TABLE(LSAVR,LINTD.K,0,48,4) FCST SALES 1ST APPROX   3149
3L    LSAVR*13.K=LSAVR*13.J+(DT)(1/LK18X)(LOAXX.JK-LSAVR*13.J)     3150
18A   LA20X.K=(LK17X)(LOSMX.K-LSAVR*12.K)  TREND ADJ FACTOR        3151
12A   LSFXX.K=(LSF1X.K)(1)                 SALES FCST              3152
1L    OGIXX.K=OGIXX.J+(DT)(MGSOX.JK-OGRMX.JK) GDS IN TRANSIT       2300
39R   OGRMX.KL=DELAY3(MGSOX.JK,OK1XX)         GDS RCVD             2301
40A   OA1XX.K=OGRMX.JK+(1/OK2XX)(OIAXX.K-OIDXX)                    2302
20A   OA2XX.K=OOUXX.K/DT                                           2303
54R   OGSKX.KL=MIN(OA1XX.K,OA2XX.K)           GDS SHIPPED          2304
1L    OIAXX.K=OIAXX.J+(DT)(OGRMX.JK-OGSKX.JK) INV ACTUAL           2305
1L    OOUXX.K=OOUXX.J+(DT)(OORKX.JK-OGSKX.JK) ORDS UNFLLD          2306
14A   OA3XX.K=OONXX.K+(OK3XX)(-OA9XX.K)                            2307
56A   OODXX.K=MAX(OA3XX.K,0)              ORDS DSD                 2308
18A   OA4XX.K=(OK4XX)(OODXX.K-OOUXX.K)                             2309
8R    OA5XX.KL=OORKX.JK+OA12X.K+OA13X.K                            2310
39R   OOSMX.KL=DELAY3(OA5XX.JK,OK6XX)         ORDS SENT M          2312
3L    OA7XX.K=OA7XX.J+(DT)(1/OK7XX)(OA4XX.J-OA7XX.J)               2313
6R    KGROX.KL=OGSKX.JK                       K GDS RCVD           2314
3L    OOSKX.K=OOSKX.J+(DT)(1/OK8XX)(OORKX.JK-OOSKX.J) ORDS SMTHD   2315
12A   OONXX.K=(OOSKX.K)(OK9XX)                ORDS NORMAL          2316
1L    OOPMX.K=OOPMX.J+(DT)(OA5XX.JK-OOSMX.JK) ORDS IN PROC         2317
6R    OORKX.KL=KOSOX.JK                       ORDS RCVD K          2318
12A   OOMXX.K=(OK10X)(OMSXX.K)                                     2319
56A   OA8XX.K=MAX(MPRXX.K,0)                                       2320
54A   OA9XX.K=MIN(MPRXX.K,0)                                       2321
7A    OA10X.K=OOUXX.K-OK11X                                        2322
56A   OA11X.K=MAX(OA10X.K,0)                                       2323
20A   OA12X.K=OA11X.K/OK12X                                        2324
12A   OA13X.K=(OA8XX.K)(OK5XX)                                     2325
1L    KOUXX.K=KOUXX.J+(DT)(KOAXX.JK-KGSXX.JK) ORDS UNFLLD          3200
20A   KA1XX.K=KOUXX.K/KK1XX                                        3201
20A   KA2XX.K=KIAXX.K/DT                                           3202
54R   KGSXX.KL=MIN(KA1XX.K,KA2XX.K)           GDS SHIPPED          3203
1L    KGIDX.K=KGIDX.J+(DT)(DGSKX.JK-KGRDX.JK) GDS INTRANSIT        3204
39R   KGRDX.KL=DELAY3(DGSKX.JK,KK2XX)         GDS RCVD             3205
52L   KIAXX.K=KIAXX.J+(DT)(KGROX.JK+KGRDX.JK-KGSXX.JK+0) INV ACT   3206
7A    KPAXX.K=KGIDX.K+OGIXX.K                                      3207
12A   KIFXX.K=(KSFXX.K)(KK3XX)                INV FCST             3208
20A   KONXX.K=KSFXX.K/KK1XX                                        3209
24A   KA3XX.K=(1/KK4XX)(KIFXX.K-KIAXX.K+KPDXX.K-KPAXX.K+KOUXX.K-KONXX.K)
X1                                                                 3211
3L    KPXXX.K=KPXXX.J+(DT)(1/KK5XX)(KA4XX.J-KPXXX.J) PRICE         3212
12A   KA4XX.K=(MPXXX)(KK6XX)                                       3213
3L    KPSXX.K=KPSXX.J+(DT)(1/KK7XX)(KPXXX.J-KPSXX.J) PRICE SMTHD   3214
18A   KA5XX.K=(KK8XX)(KPSXX.K-KPXXX.K)                             3215
3L    MPRSX.K=MPRSX.J+(DT)(1/KK9XX)(MPRXX.J-MPRSX.J)  PR RATE SM   3216
12A   KA6XX.K=(KK10X)(MPRSX.K)                                     3217
10A   KOIXX.K=KA3XX.K-LSGKX.K+LSLKX.K+KA5XX.K+KOAXX.JK+KA6XX.K     3218
1L    KOPXX.K=KOPXX.J+(DT)(KOIXX.J-KOSXX.JK)  ORDS IN PROC         3219
39R   KOSXX.KL=DELAY3(KOIXX.K,KK11X)          ORDS SENT            3220
50A   KA7XX.K=(KOSXX.JK)(OSXXX)/(OSXXX+DSXXX)                      3221
34A   KA8XX.K=(KK19X)NORMRN(0,KA9XX.K)        NOISE                3222
12A   KA9XX.K=(KK12X)(KA7XX.K)                STD DEV              3223
7A    OMSXX.K=KA7XX.K+KA8XX.K                 O MKT SHARE          3224
51A   KA13X.K=CLIP(OOMXX.K,OMSXX.K,OA7XX.K,KK14X)                  3228
1L    KA14X.K=KA14X.J+(DT)(KA13X.J-KOSOX.JK)                       3229
39R   KOSOX.KL=DELAY3(KA13X.K,KK15X)          ORDS SENT O          3230
7R    KOSDX.KL=KOSXX.JK-KOSOX.JK              ORDS SENT D          3231
6A    KOAXX.K=KORXX.JK                        ORDS ACC             3232
3L    KOSMX.K=KOSMX.J+(DT)(1/KK16X)(KOAXX.J-KOSMX.J)               3233
35R   KSAVR=BOXCYC(13,4)                      SEAS AVG BXCR CYC    3234
3L    KSAVR*13.K=KSAVR*13.J+(DT)(1/KK17X)(KOAXX.J-KSAVR*13.J)      3235
37R   KTLSR=BOXLIN(1,4)                                            3236
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1L     KTLSB*I.K=KTLSB*I.J+(DT)(I-0)                    TIME SNCE LST SHFT  3237
8A     KTFBC.K=KTFXX+KTLSB*1.K-2                  TIME FRM CEN BOT CAR      3238
7A     KINTD.K=48-KTFBC.K                         INTERP DIST FRM TOP TRN   3239
59A    KSF1X.K=TABLE(KSAVB,KINTD.K,0,48,4)           FCST SLS 1STAPPROX     3240
6A     KA18X.K=1                                                            3241
12A    KSFXX.K=(KSF1X.K)(KA18X.K)                 SALES FCST                3242
6A     KA17X.K=0                                                            3245
19A    KPDXX.K=(KSFXX.K)(KK2XX+KK11X+KA17X.K+0)        PIPE INV DSD         3246
NOTE   INITIAL CONDITIONS W SECTOR                                          IC1
NOTE                                                                        IC2
18N    WOULX=(WORLX)(WDMXX+WDAXX)                                           IC3
12N    WIAXX=(WORLX)(WK1XX)                                                 IC4
6N     WSSLX=WORLX                                                          IC5
12N    WGIMX=(WORLX)(WK2XX)                                                 IC6
6N     MGSWX=WORLX                                                          IC7
12N    WOPMX=(WORLX)(WK6XX)                                                 IC8
6N     WOIMX=WORLX                                                          IC9
C      WSAVB*=34/34/34/34/34/34/34/34/34/34/34/34/34
NOTE   INITIAL CONDITIONS M SECTOR                                          IC12
NOTE                                                                        IC13
6N     MORXX=WORLX                                                          IC13
6N     MOUXX=150  MMSQFT                                                    IC15
6N     MAIXX=64 DOLLARS                                                     IC16
6N     MPRXX=0                                                              IC17
12N    MOCXX=(WORLX)(MK5XX)                                                 IC18
12N    MGPXX=(WORLX)(MK6XX)                                                 IC20
6N     MIAXX=42  MM SQ FT                                                   IC22
6N     MFRXX=0                                                              IC23
6N     MGSXX=WORLX                                                          IC24
6N     MODXX=WORLX                                                          IC25
20N    MGIMX=WORLX/MNXXX                                                    IC26
12N    MCVXX=(MCVMX)(MNXXX)                                                 IC27
6N     MENSX=0                                                              IC28
6N     MOAXX=WORLX                                                          IC29
6N     MENOX=0                                                              IC30
6N     MOUCX=10                                                             IC31
6N     MOUOX=70                                                             IC32
6N     MOUWX=70                                                             IC33
6N     MOMXX=WORLX                                                          IC34
6N     MPMXX=MPXXX                                                          IC35
12N    POPXX=(PPDXX)(PK5XX)                       EQH1105                   IC40
12N    PGPXX=(PPDXX)(PK6XX)                       EQH1107                   IC41
6N     PGISX=PGIXX                                EQN1109                   IC42
12N    PIAXX=(PK3XX)(PGIXX)                       EQN1120                   IC43
12N    POUCX=(3)(PGIXX)                           EQH1127                   IC44
6N     POUDX=20                                   EQN1128                   IC45
6N     PENXX=0                                    EQN1134                   IC46
C      PBOX1*=0/0/0/0/0/0/1/1/0/0/0/0/0/0
C      PLCXX=60 DOLS/MBDFT
C      LTLSB*=0
18N    COULX=(CORLX)(CDMXX+CDAXX)                 EQN2102                   IC50
12N    CGIXX=(CORLX)(CK2XX)                       EQN2104                   IC51
12N    CIAXX=(CORLX)(CK3XX)                       EQN2106                   IC52
6N     CSSLX=CORLX                                EQN2113                   IC53
12N    COPPX=(CORLX)(CK10X)                       EQN2145                   IC54
C      CSAVB*=26/26/26/26/26/26/26/26/26/26/26/26/26
6N     DOPPX=0                                    EQN2143                   IC55
6N     COPMX=0                                    EQN2141                   IC56
12N    LGIXX=(LK1XX)(LORXX)                       EQN3101                   IC65
12N    LIAXX=(LORXX)(LK4XX)                       EQN3103                   IC66
12N    LOUXX=(LORXX)(LK2XX)                       EQN3104                   IC67
6N     LOSMK=LORXX                                EQN3108                   IC68
12N    LOPXX=(LORXX)(LK10X)                       EQN3118                   IC69
```

```
6N     LPXXX=LA16X
6N     LPSXX=LPXXX
6N     LOSMX=93                                                                IC
C      LSAVB*=56/56/56/56/56/56/56/56/56/56/56/56/56                           IC
50N    CORLX=(LORXX)(CSXXX)/(CSXXX+WSXXX)                                      IC
50N    WORLX=(LORXX)(WSXXX)/(CSXXX+WSXXX)                                      IC
6N     OGIXX=60
6N     OIAXX=0
6N     OOUXX=60
6N     OA7XX=0                                 XXXXX
6N     OOSKX=30
6N     OOPMX=30
6N     KOUXX=28
6N     KGIDX=10
6N     KIAXX=300
12N    KPXXX=(MPXXX)(KK6XX)
12N    KPSXX=(MPXXX)(KK6XX)
6N     MPRSX=MPRXX
6N     KOPXX=22
6N     KA14X=6.8
C      KSAVB*=44/44/44/44/44/44/44/44/44/44/44/44/44                           IC
6N     KOSMX=0
7N     CTFBC=CTFXX-2                                                           IC
7N     LTFBC=LTFXX-2                                                           IC
7N     KTFBC=KTFXX-2                                                           IC
NOTE                                                                         INP1
NOTE   INPUT                                                                 INP2
NOTE                                                                         INP3
7R     LORXX.KL=LORAX+LSEAS.K                                                INP4
32A    LSEAS.K=(-INK1X)COS((2PI)(TIME)/52)                                   INP5
7R     KORXX.KL=KORAX+KSEAS.K                                                INP6
32A    KSEAS.K=(-INK2X)COS((2PI)(TIME)/52)                                   INP7
NOTE                                                                         CON1
NOTE   CONSTANTS                                                             CON2
C      MCFMX=6 MDOLS/WKPER MILL                                              CON3
C      MF5XX*=0/10.8/21.6/32.4/43.2/54/66.8/79.6                             CON4
C      MK15X=2                                                               CON5
C      MNXXX=67                                                              CON6
C      MK1XX=1                                                               CON7
C      MK2XX=4                                                               CON8
C      MK3XX=.4 WK                             TIME TO SM UFO RATE           CON9
C      MK5XX=1.0 WK                            ADMIN LAG                     CON10
C      MK6XX=.20 WK                            PROD LAG                      CON11
C      MK7XX=.40 WK                            TIME TO SM PRICE RATE         CON12
C      MK9XX=4.0 WK                            TIME TO ADJ MILL INV          CON13
C      MK10X=2.4 MMSQFT/WK/DOL/WK              MILL SPEC FACTOR              CON14
C      MK11X=4.0 WK                            TIME TO ADJ UFO               CON15
C      MK12X=.5  WK                            WKS MILL INV DSD              CON16
C      MK13X=2.5                                    WKS UFO DSD              CON17
C      MK14X=100 WK                            TIME TO SM PRICE              CON18
C      MK4XX=2.0 WK                            TIME TO SM ORDS ACC           CON19
C      M0000=0                                 ZERO                          CON20
C      MIMXX=60 MMSQFT                         MAX MILL INV                  CON21
C      MF1XX*=56/56/56/56/56/58/62/70/80/90/100                              CON23
C      MF4XX*=0/.1/.3/.65/.95/1/1/1/0                                        CON24
C      MF2XX*=-2.5/-2/-1/-.2/0/0/.1/.8/1.5/2/2.5/3/3.5/4/4.5/5/5.5/6  25
C      MF3XX*=.6/.85/.98/1/1/1.02/1.06/1.12/1.16/1.18/1.195/1.2              CON26
C      WK1XX=6.5 WK                            WKS INV DSD                   CON27
C      WK2XX=1.5 WK                            SHIPPING LAG                  CON28
C      WK3XX=8.0 WK                            WKS TO CORRECT INV            CON29
C      WK4XX=2.4 MMSQFT/WK/DOL/WK              WHSE SPEC FACTOR              CON30
C      WK5XX=4   MMSQFT/WK/DOL                 DEMAND ELAS                   CON31
C      WK6XX=.5 WK                             ORD PROC LAG                  CON32
```

```
C       WK7XX=0                                                                  CON33
C       WK8XX=2 WK                              TIME TO SM SALES                 CON34
C       WDMXX=.2 WK                             MIN ORD FIL DEL                  CON35
C       WDAXX=.2 WK                             AVG ORD FIL DEL                  CON36
C       DEXXX=60 MMSQFT/WK                      EST DEMAND                       CON37
C       SEXXX=60 MMSQFT/WK                      EST SUPPLY                       CON38
C       WF1XX*=0/50/100/150/200                                                  CON39
C       WK9XX=8 YR(4X2)                       TIME TO AVG SEAS SALES             CON42
C       WTFXX=8 WKS                             FCST TIME                        CON43
C       WK10X=1                                 TREND CONSTANT                   CON44
C       WTLSP*=0                                                                 CON46
C       INK1X=14                                MAG SEAS VARIATION               CON47
C       INK2X=11                            MAG SEAS VAR
C       MK16X=.9                                VAC ADJ TO PROD                  CON48
C       MBOX1*=0/0/0/0/0/1/1/0/0/0/0/0                                           CON49
C       PK1XX=.8                                VAC ADJ FACTOR                   CON50
C       PK2XX=2 WKS                             TIME TO SM PGIXX                 CON51
C       PK3XX=1 WK                              WKS INV DSD                      CON52
C       PK4XX=4 WKS                             WKS TO CORRECT INV               CON53
C       PK5XX=2 WKS                             PROD ORD PROC LAG                CON54
C       PK6XX=.4 WK                             PROD LAG                         CON55
C       PF1XX*=1/1/1/1/1/1.02/1.06/1.12/1.16/1.18/1.195/1.2                      CON56
C       PNXXX=30                                NO. OF MILLS                     CON57
C       PRRXX=.455 BDFT/SQFT                    REC RATIO                        CON58
C       PGCXX=4 DOL/MBDFT                       GLUE COST                        CON59
C       PSCXX=24 DOL/MBDFT                      ST LABOR COST                    CON60
C       PSCMX=1 MMSQFT/WK                       ST TIME CAP/M                    CON61
C       POCXX=36 DOL/MBDFT                      OT LABOR COST                    CON62
C       PCFMX=6 MDOLS/WK/M                      FIXED COST                       CON63
C       PIMXX=60 MMSQFT                         INV MAX                          CON64
C       PLDXX=4 WKS                             LEEWAY DSD                       CON65
C       CK1XX=0                                 SPEC CON                         CON66
C       CK2XX=2 WKS                             SHIP DELAY                       CON67
C       CK3XX=7 WKS                             INV DSD                          CON68
C       CK4XX=4 WKS                             TIME TO SM SALES                 CON69
C       CK5XX=8 WKS                             TIME TO ADJ INV                  CON70
C       CK7XX=8 (4X2)                           TIME TO SM SEAS SALES            CON71
C       CK8XX=1                                 TREND FCST CON                   CON72
C       CK9XX=4 WKS                             TIME TO ADJ P LEEWAY             CON73
C       CK10X=.5 WK                             TIME TO PROC ORDS                CON74
C       CK11X=0                                 RATE SPEC FACTOR                 CON75
C       CK12X=0    MMSQFT/WK/DOL                DEMAND CONSTANT                  CON76
C       CDAXX=.2 WK                             DELAY AVG                        CON77
C       CDMXX=.2 WK                             DELAY MIN                        CON78
C       CTFXX=8 WKS                             FCST TIME                        CON79
C       COMMX=2 MMSQFT/WK                       MIN ORDS TO M                    CON80
C       LK1XX=.5 WK                             SHPG DEL W,P-L                   CON81
C       LK2XX=.2 WK                             SHPG DEL L-END USE               CON82
C       LK3XX=4 WK                              TIME TO SM ORDS                  CON83
C       LK4XX=6 WK                              INV DSD                          CON84
C       LK5XX=8 WK                              WKS TO COR INV                   CON85
C       LK6XX=0                                 LSGK FACTOR                      CON86
C       LK7XX=0                                 LSLK FACTOR                      CON87
C       LK8XX=0                                 PRICE RATE CON                   CON88
C       LK9XX=0                                 PRICE CON                        CON89
C       LK10X=.5 WK                             ORD PROC LAG                     CON90
C       LK11X=.1                                EQN 3123                         CON91
C       LK12X=100                               EQN 3128                         CON92
C       LK13X=100                               EQN 3129                         CON93
C       LK14X=1.15                              LCL PRICE MARKUP                 CON94
C       LK15X=.5                                DEL MP TO LP                     CON95
C       LK16X=100 WK                            TIME TO SM LCL PRICE             CON96
C       LK17X=1                                 TREND CON                        CON97
```

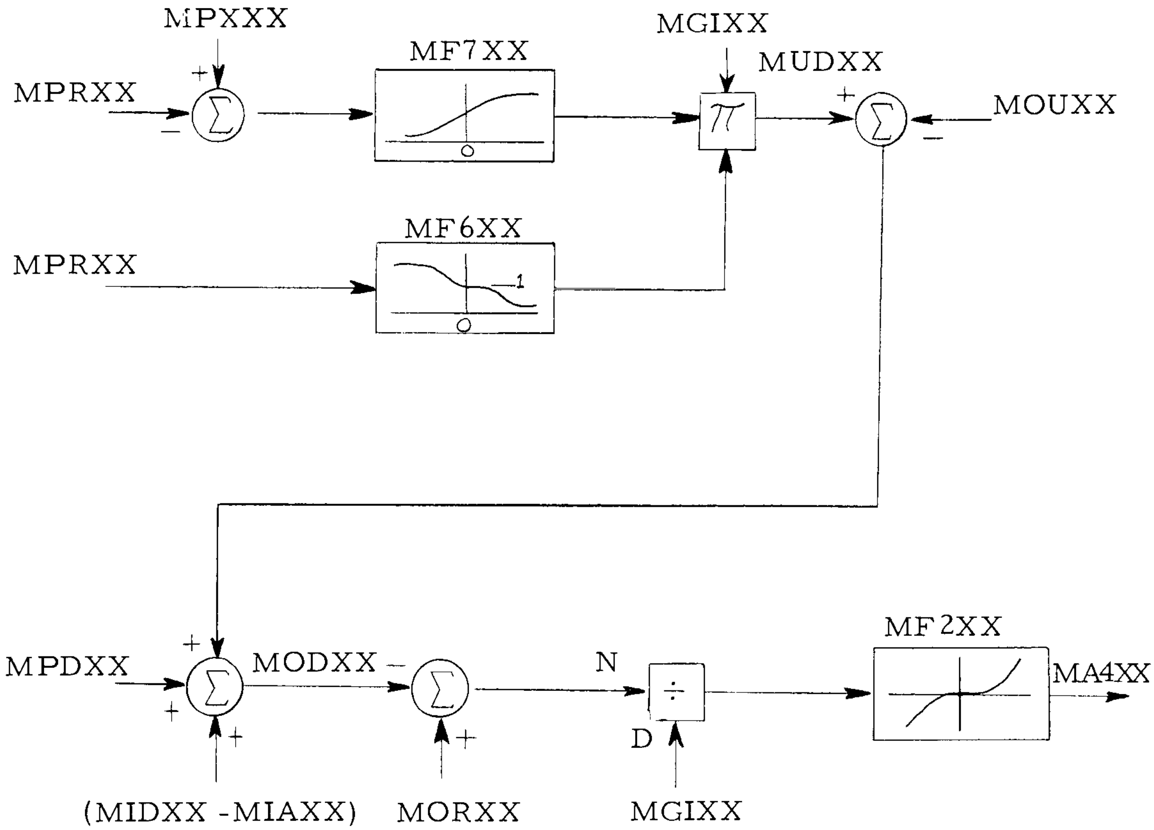
```
C     LK18X=8                                      TIME TO SM SEAS SALES   CON98
C     LK19X=0                                      NOISE CON               CON99
C     LTFXX=2 WKS                                  FCST TIME               CON99
C     CTLSB*=0                                                             CON100
C     OK1XX=1.5 WKS                                SHIP DEL M-K            CON110
C     OK2XX=1 WKS                                  WKS TO ADJ INV          CON111
C     OK3XX=120                                    PRICE RATE CON (SELL)   CON112
C     OK4XX=1                                      EQN2309 XXXXX           CON113
C     OK5XX=6                                      PRICE RATE CON (ORD)    CON114
C     OK6XX=.2 WK                                  ORD PROC DEL XXXXX      CON115
C     OK7XX=.2 WK                                  PRICE CUT DEL           CON116
C     OK8XX=52 WKS                                 TIME TO SM SALES        CON117
C     OK9XX=2 WK                                   UFO DSD                 CON118
C     OK10X=1.2                            MAX ORD FACTOR                  CON119
C     KK1XX=.5 WKS                                 SHIP DEL                CON120
C     KK2XX=1.5 WKS                                SHIP LAG D-K            CON121
C     KK3XX=6 WKS                                  INV SSD                 CON122
C     KK4XX=8  WK                                  TIME TO ADJ INV         CON123
C     KK5XX=.4 WKS                                 LAG MP TO CL PRICE      CON124
C     KK6XX=1.03                                   KPXXX/MPXXX             CON125
C     KK7XX=100                                    TIME TO SMOOTH KP       CON126
C     KK8XX=0                                      PRICE CON               CON127
C     KK9XX=.5                                     TIME TO SM MPR          CON128
C     KK10X=0                                      PRICE RATE CON          CON129
C     KK11X=.5 WK                                  ORD PROC LAG            CON130
C     KK12X=.1                                     EQN3223                 CON131
C     KK14X=30                                                             CON133
C     KK15X=.2                                     TIME TO SM ORD-O        CON134
C     KK16X=4 WKS                                  TIME TO SM INCMG ORDS   CON135
C     KK17X=8 (4X2)                                TIME TO SM SEAS SALES   CON136
C     KK19X=0                                      NOISE COEFF             CON138
C     KTLSB*=0                                                             CON139
C     KORAX=44                                                             CON140
C     KTFXX=8                                                              CON141
C     OIDXX=0                                                              CON142
C     OSXXX=15                                                             CON143
C     CSXXX=11                                                             CON144
C     WSXXX=17                                                             CON145
C     LORAX=56                                                             CON146
C     DSXXX=7                                                              CON147
C     OK11X=100                                                            CON148
C     OK12X=4                                                              CON149
NOTE                                                                          R1
PRINT 1)WORLX,WGSLX/2)WOULX/3)WIAXX,WIDXX/4)MORXX,MODXX,MOAXX/5)MOUXX,MO
X1    UWX,MUDXX/6)MPXXX,MPMXX/7)MPRXX/8)MA7XX,MA2XX/9)MPDMX,MPOXX/10)MGI
X2    XX,MGSXX,MGSWX/11)MIDXX,MIAXX/12)MENOX,MENSX/13)MA16X,MA17X,MA18X/
X3    14)WTFCX                                                             R5
PLOT  MPXXX=P/KIAXX=S/KOUXX=B/OIAXX=O/OOUXX=U/OA7XX=7/KOSOX=R/KOSDX=K/KO
X1    RXX=D
PLOT  MPXXX=P/MGIXX=Q,WORLX=D,WSAVB*13=X,WSF1X=F/MOUXX=U/MIAXX=I/WIAXX=S
X1    /WOULX=B                                                             R7
PLOT  MPXXX=P/PGIXX=Q/COULX=B/CIAXX=S/LIAXX=L/COSMX=C/LORXX=D/LOUXX=O
SPEC  DT=.050/LENGTH=250/PRTPER=32/PLTPER=2
```

APPENDIX II

MODIFICATIONS FOR A SECOND GENERATION SIMULATION MODEL

In this appendix, two possible modifications of the simulation model will be discussed. It is felt, on the basis of model tests, that a second generation model incorporating these changes would better represent the industry. The first of these changes deals with the industry market mechanism discussed in chapter four section 3.4 and the second with the W sector order rate decision rule of chapter four section 4.3.

As discussed in connection with the mill market mechanism (chapter four section 3.4), M sector Unfilled orders Desired, MUDXX, was assumed to be dependent only upon production rate. It was subsequently learned that MUDXX is also a function of market price MPXXX, and price rate, MPRXX. The first model modification to be discussed, then, introduces a functional dependence of MUDXX upon MPXXX and MPRXX. This additional dependence of MUDXX includes in the model the speculative behavior of independent mills that is possible if producers are willing to allow unfilled orders (MUDXX) to vary within limits as market price changes. As an example of this speculative behavior, mills desire a large order backlog when prices are high and falling and a small order backlog when prices are low and rising. One possible means of incorporating the foregoing discussion into the mill market mechanism is shown in the block diagram of Figure (A2-1):



Modified Market Mechanism

Figure (A2-1)

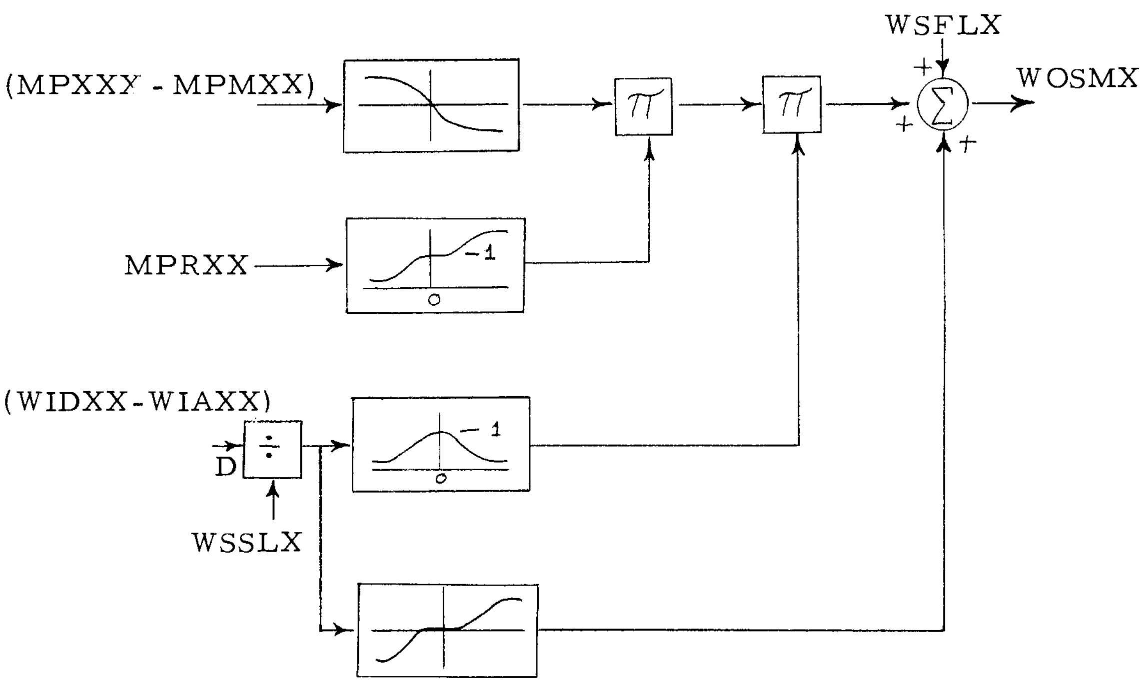
Variables appearing in the figure are defined as follows:

MPXXX = Mill market Price ($/ ft^2)
MPMXX = Mill market Price sMoothed ($/ ft^2)
MGIXX = M sector Goods to Inventory (ft^2/ wk)
MUDXX = M sector Unfilled orders Desired (ft^2)
MOUXX = M sector Orders Unfilled (ft^2)
MPRXX = Mill market Price Rate ($/ ft^2)/ wk
MIDXX = M sector Inventory Desired (ft^2)

MIAXX = M sector Inventory Actual (ft^2)
MPDXX = M sector Production Desired (ft^2/ wk)
MODXX = M sector Orders Desired (ft^2/ wk)
MORXX = M sector Orders Received (ft^2/ wk)
MA4XX = Approximately price rate, MPRXX, as discussed in chapter four.

The second possible simulation model modification to be discussed relates to the W sector order rate decision rule. As discussed in section 4.3 of chapter four, the decision rule initially incorporated in the model was a linearized rule. As a result of model tests, insight was gained into the structure of a nonlinear decision rule which better represents reality.

It was learned in the course of model tests that over a "normal" range of inventory levels W sector purchasing was dominately determined by market price. It is also known that for inventory levels considerably more or less than this normal range sector order rate is essentially that necessary to return inventory level to the normal range with market conditions playing a relatively minor role. The nonlinear decision rule illustrated in Figure (A2-2) is a possible means of simulating the W sector ordering behavior described above.



Modified Order Rate Decision Rule

Figure (A2-2)

Variables included in the figure are defined as follows:

MPXXX	=	Mill market Price ($\$/ft^2$)
MPMXX	=	Mill market Price, sMoothed ($\$/ft^2$)
MPRXX	=	Mill market Price Rate ($\$/ft^2$)/wk
WIDXX	=	W sector Inventory Desired (including pipeline inventory) ft^2
WIAXX	=	W sector Inventory Actual (including pipeline inventory) ft^2
WSSLX	=	W sector Sales Smoothed to L sector (ft^2/wk)
WOSMX	=	W sector Orders Sent to M sector (ft^2/wk)