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MANAGING PRODUCT LINES THAT SHARE

A COMMON CAPACITY BASE

by

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WP1331-82

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ABSTRACT

This paper examines the difficulties of managing the
competitive profile of product lines which share a common capacity
base. The analysis is derived from a case study of a manufacturing
firm that produces finished product and service parts at a single
plant. Finished product and service parts are treated as a special
case of two product lines. A system dynamics simulation model is used
to represent production and ordering policies within the firm and its
distribution network. Simulation analysis shows that these policies
cause demand volatility in the finished product to be converted into
supply volatility of service parts, leading to loss of service parts
market share. To improve the performance of the service parts
business, the production of finished product and parts should be
decoupled, so the supply of the two product lines becomes independent.
The results are discussed for the general multiproduct-line case. A
brief report of implementation results is included.

MANAGING PRODUCT LINES THAT SHARE

A COMMON CAPACITY BASE

1. INTRODUCTION

In many manufacturing firms, product lines with different
market characteristics share a common capacity base. When a single
manufacturing facility must cater for a variety of product lines, it
becomes increasingly difficult to devise manufacturing policies that
will satisfy the diverse marketing needs of all product lines. Some
product lines may be very price-sensitive or delivery-sensitive.
Others may have inherently volatile and unpredictable demand patterns.
The result can be conflicting priorities in production, complexity of
production planning, and competitive weakness of one or more product
lines.

In this paper we draw on a case study of a manufacturing firm
which produces finished product and service parts at a single plant.
We treat finished product and service parts as a special case of two
product lines, where the product lines have clearly differentiated
market characteristics. A system dynamics simulation model is used to
represent production and ordering policies within the firm and its
distribution network. Simulation analysis shows that these policies
cause demand volatility in finished product to be converted into
supply volatility of service parts. Since the major need of service
parts is reliable and short delivery time, loss of service parts

market share results. Under the prevailing set of operating policies,
the service parts business finds itself in a weak competitive
position, pincered between volatile capacity constraints and a
delivery-sensitive market.

Simulation runs of the model are used to explain how the
competitive weakness of the service parts business results directly
from the operating policies of the firm and why those policies are
able to persist despite their damaging effect. The simulation model
is also used to explore policy changes that will strengthen the
service parts business. The major policy recommendation is to
decouple finished product and service parts production, so that the
supply of the two product lines becomes independent.

Although the analysis is based on a specific case study of
service parts, it has general implications for multiproduct-line
manufacturing, which are developed at the end of the paper. In
addition a brief report is provided of the implementation of policy
recommendations arising from the case.

2. A PERSPECTIVE ON THE NATURE OF THE ANALYSIS

This paper treats an area that has been the focus of much
work in operations management. It deals with issues of aggregate
production planning in a setting where two demand streams (assumed to
be highly correlated) share a common capacity base. The early work of

Holt, Modigliani, Muth and Simon (HMMS) [6] and the more recent

hierarchical production planning methods described by Bitran and Hax

[2] and Hax and Meal [5] have shed much light on optimal scheduling of

such a system. However, this paper should not be regarded as an

attempt to cover the same ground. Its purpose is fundamentally

different. Rather than examining how an efficient schedule should be

set, it examines why, in a complex organization, inefficient schedules

are likely to exist and to be sustained over time. In particular it

shows how an organizational structure composed of many reasonable and

rational policies can lead to a form of inefficiency that causes

loss of market share in a product line.

The system dynamics model used in the analysis is primarily a

descriptive model of organizational process, much more closely related

to the behavioral models of Cyert and March [3] and the Carnegie

school than to normative optimizing models of the HMMS kind.[1] The

model portrays a considerable breadth of decision making from the

ordering decision of a retail network through to aggregate production

planning, capacity planning, and capacity allocation decisions of the

original equipment manufacturer, OEM. Decision functions are

descriptive of the actual decision-making processes that have evolved

in the real system. Simulation is used to understand how these

decision functions interact over time. Only when an understanding of

the system behavior has been acquired through careful scrutiny of

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[1] For a discussion of the organizational and behavioral aspects of
system dynamics models see Morecroft [12].

simulation runs, is the model then used in a normative sense to devise better policies than those which currently prevail in the system.

The interpretation given to the analysis has been greatly aided by the manufacturing strategy concepts of writers such as Skinner and Miller. Skinner [14] talks about the concept of a focused factory in which products with different marketing needs are completely separated in production by the creation of a "plant within a plant," or PWP. This kind of manufacturing strategy has marked parallels to the policy of separation proposed later in the paper.

Miller [10] also talks about the concept of focus as one element of strategic choice in designing manufacturing systems that are consistent with marketing strategy. In addition, in joint work with Van Dierdonck [15] he indicates that focus can be increased by the introduction of slack resources. The relation between focus and manufacturing slack (in the form of inventory) is central to the detailed design of the policy of separation described later.

3. BACKGROUND TO THE CASE AND MODEL OVERVIEW

The case involves a manufacturer of consumer durables operating in a highly seasonal market. The manufacturer supplies a network of retail outlets with both finished product (also referred to as primary product) and sercive parts (also referred to as secondary product). The retail outlets are independent businesses responsible

for selling the product to the final customer and for stocking and ordering product and parts. At the time the project was undertaken, the manufacturer had become concerned about loss of service parts market share and high manufacturing costs. It was to these two problems that analysis was directed.

Figure 1 shows the arrangement of subunits within the overall manufacturing and distribution organization. Although the focus is on manufacturing policy within the OEM (original equipment manufacturer), it seemed essential to consider the retail network because of its importance in defining the differing characteristics of the primary and secondary product markets.

Subunits 1 and 2 on the left of the figure represent a standard two-stage production and distribution network involving the primary business of retailers and OEMs. Subunits 3, 4, and 5 on the right of the figure represent the production and distribution network of the secondary business, which is similar to the primary network but includes alternative secondary sources with which retailers can place orders. Subunit 6 in the lower center of the figure represents capacity management and allocation within the original equipment manufacturer. The subunit couples the primary and secondary businesses according to their common dependence on capacity. In the paragraphs that follow, there will be a brief description of the major policies within each subunit. The reader is assumed to have some familiarity with the typical structure of production and distribution
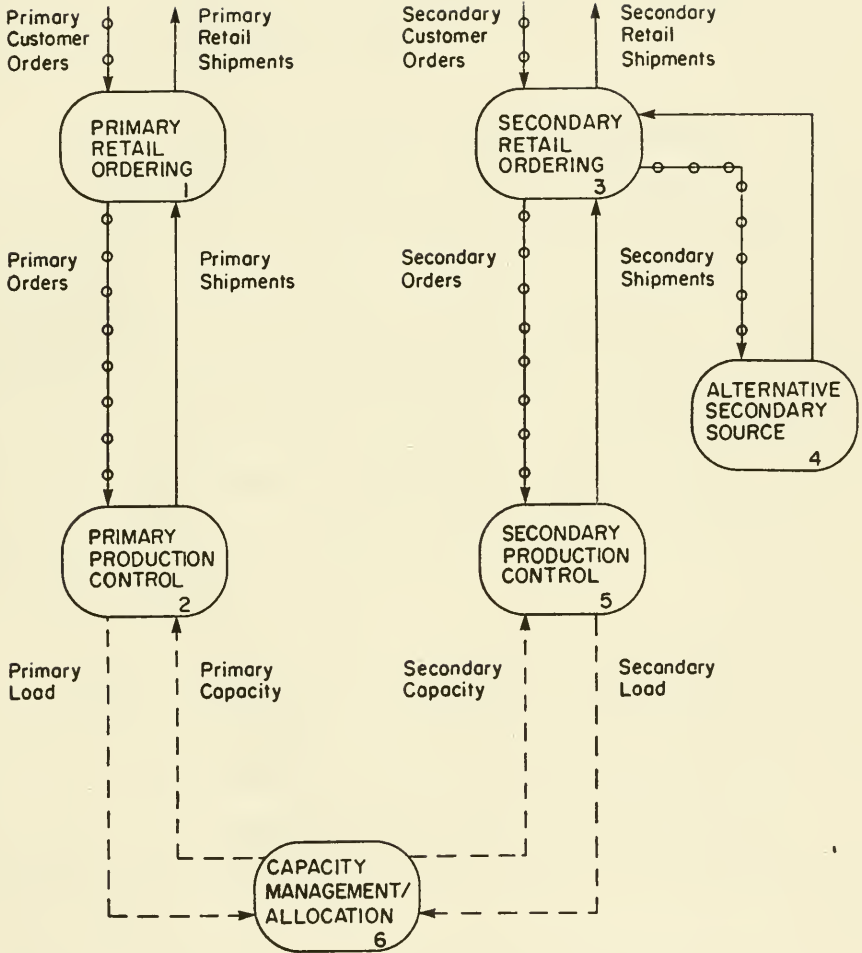
Figure 1. Overview of Coupled Primary and Secondary Businesses

networks and their portrayal in system dynamics.[2] Policy structure

diagrams and full equation listings for each subunit are provided in

the appendices. The reader with some business experience need not be

familiar with the detail of the appendices to follow the arguments

that are developed later in the paper.

       Consider first the operation of subunit 1, primary retail

ordering. Orders are received from the customer, and shipments of

finished product are made in return. Within the subunit are located

the forecasting and inventory control policies that guide retail

ordering and encompass the inventory and service objectives of

retailers. As a whole, the retail network prefers to sell from

inventory and consequently carries a large stock of finished product,

between two and three months' coverage of sales. Retailers order

aggressively in the event of supply shortages, tending to overorder to

ensure adequate supplies.

       Subunit 2 contains production planning and control within the

original equipment manufacturer. The subunit receives orders from

retailers and makes shipments in return. Within production control

are located the OEM's aggregate production planning, encompassing

forecasting, inventory control, and backlog control. The OEM follows

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[2] For further information see Forrester [4] amd Lyneis [8, pp.
143-210].

a produce and ship-to-order policy, carrying only small quantities of finished inventory (historical records showed that the company rarely carried more than two weeks' finished product, despite strongly seasonal demand) and adjusting production plans quickly in response to unexpected changes in demand.

Subunits 3 and 5 of the secondary network are closely analogous in internal structure to primary subunits 1 and 2. The only notable difference is that the OEM tries to follow a ship-from-stock policy for service parts, rather than the ship-to-order policy used in the primary business. In addition, however, the secondary network contains subunit 4 representing alternative secondary sources. The alternative secondary sources are small suppliers that specialize in the service parts business. They produce parts that can be used interchangeably with the parts of the original equipment manufacturer. Alternative suppliers are an important feature of the competitive environment in secondary sales. They ensure their existence by providing prompt delivery, which is a major competitive variable in the secondary market.

It was found from discussion that retailers will order from an alternative source only if OEM delivery times are noticeably worse than times quoted by the small specialist suppliers. Faced with equal delivery times from OEM and an alternative source, retailers will prefer to order from the OEM.

Subunit 6 in the lower center of the figure represents capacity management and allocation within the OEM. Capacity is adjusted to support the production needs of the primary and secondary businesses. If either primary or secondary demand rises, the capacity management subunit will acquire additional capacity, usually by expanding the workforce. Capacity is allocated between primary and secondary production, giving preference to primary production when capacity shortages develop.

The rationale for a biased capacity allocation policy seemed to revolve around both the political weight of the primary business and consideration of revenue loss. The primary business is a much larger part of the company, accounting for more than 70% of revenues. There are many more people within its ranks who carry more influence. Consequently, when a capacity shortage develops, primary production receives more of the scarce capacity resource. A shortfall in primary production is a more visible problem than in secondary production and has a more immediate and obvious effect on sales. Furthermore, the threat of revenue loss from primary production cutbacks is at first sight much greater than from secondary production cutbacks, despite the well-known high margin on secondary sales. Secondary production tends to operate from a weak bargaining base when it comes to capacity allocation.

With this picture of the system in place, several structural features can be identified that should be borne in mind in the later analysis. The model is basically a pair of production and

distribution networks that are coupled through a common capacity base
deep within the manufacturing process. The relative size of the
networks is rather skewed, since the primary network is about eight
times the size of the secondary network in terms of capacity needs.
The secondary business operates in a very sensitive and constraining
capacity environment in which small primary capacity shortages can be
translated into relatively large secondary capacity shortages by the
allocation policies. Furthermore, the secondary business operates in
a market environment in which the competition is composed of
specialist parts producers that do not face such restrictive and
volatile capacity constraints. The simulation experiments of the next
two sections explore the repercussions of this scenario in more
detail.

3. EXPERIMENTAL DESIGN

        The objective of the simulation experiments is to expose the
difficulties of managing the secondary business within the
constraining capacity environment that results from sharing capacity
with the primary business. Of course, it does not take much
imagination to realize that a capacity allocation policy biased in
favor of primary production is likely to be detrimental to the
secondary business. What is more difficult to realize is just how
detrimental even a mild allocation bias can be within the setting of
coupled production and distribution networks.

Two simulation experiments are used to develop understanding
of the reasons for competitive weakness of the secondary business.
First we use the complete model to show that volatility of demand,
arising in the structure of the primary production distribution
network, causes unreliable supply of service parts. Then we use a
simplified model to explain the persistence of the existing operating
policies. We argue that the source of problems for the secondary
business is invisible within individual subunits of the organization.
Without a broad perspective on manufacturing and distribution, the
existing policies seem reasonable and will stay in place.

4. COMPETITIVE WEAKNESS OF SECONDARY SALES--AN ORGANIZATIONAL PROBLEM

In this section we examine the response of the entire
manufacturing and distribution organization to a simultaneous 20% step
increase[3] in primary and secondary customer orders.[4] We examine the
situation as it unfolds in different parts of the organization: in

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[3] A simultaneous primary and secondary increase can be interpreted to
represent a market in which primary and secondary demand are highly
correlated. Such correlation is common in products for which there
is strongly seasonal demand. The reader should bear in mind that
the demand increase is unexpected and cannot be anticipated in its
timing or shape.

[4] Secondary customer orders are expressed in "finished unit
equivalents." Initially, secondary customer order rate is assumed
to be the equivalent (in capacity terms) of 125 finished units per
week. Primary customer order rate is initially set at 1,000
finished units per week.
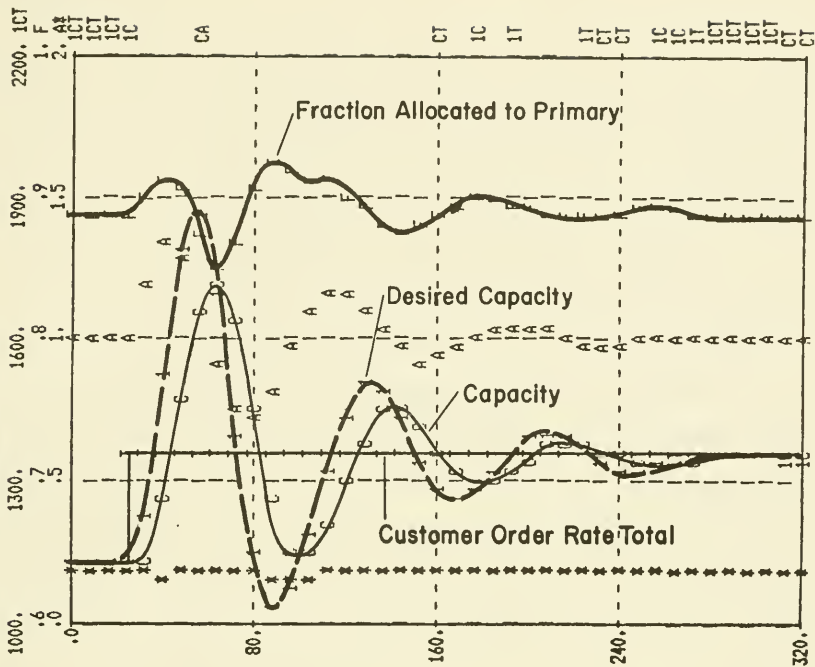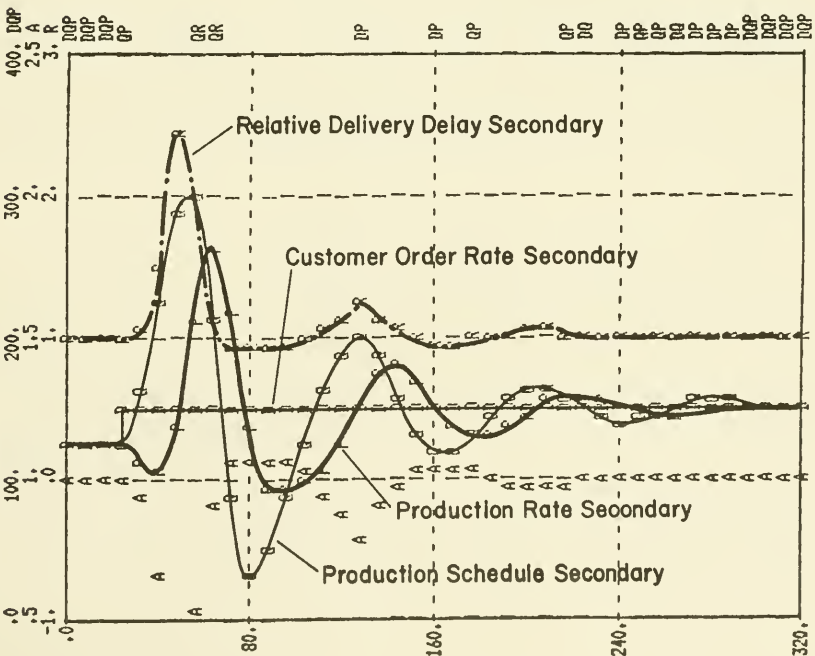
Figure 2.   Capacity Adjustment and Secondary Production

capacity management, in production control, and in the retail network. The upper half of Figure 2 shows behavior in the capacity management subsystem. The 20% step increase in customer orders is translated into a volatile and fluctuating requirement for manufacturing capacity as indicated by the trajectory of desired capacity. Capacity requirements do not simply follow the change in customer order rate. Inventory and forecast adjustments made in retail ordering and production scheduling amplify the base-customer requirements. Capacity is seen to fluctuate around the equilibrium customer order rate with a period of about 120 weeks. (A detailed explanation of the causes of demand amplification and fluctuation is beyond the scope of this paper. Readers should note that such behavior of production and distribution systems had been observed empirically in the work of Mack [9] and is believed by many economists, such as Abramovitz [1] and Klein and Popkin [7], to be the source of short-term business cycles in industrial economies. Readers who would like to see a detailed explanation of this behavior using system dynamics modeling are referred to Forrester [2] and Morecroft [11].)

The figure also shows the allocation of capacity to the primary business. The allocation starts off in equilibrium at .89, commensurate with the large volume of primary business. Soon after the demand increase the primary allocation begins to rise, as primary production takes priority in the use of available capacity. As additional capacity comes on line, the fraction of capacity allocated to primary production begins to fall. Thereafter the allocation curve

mirrors the trajectory for capacity. Whenever there is excess
capacity, primary production takes less than its "equitable" share of
capacity. Whenever there is a shortage of capacity, primary
production takes more than its "equitable" share of capacity.

The lower half of Figure 2 shows behavior in the secondary
production control subunit. Secondary customer order rate increases
in a 20% step. In response, the secondary production rate actually
falls initially. The fall occurs because capacity is being allocated
to primary production. For a period of about twenty weeks, secondary
production remains below the customer order rate, leading to a
substantial rise in delivery delay for the secondary product (to a
peak of approximately 2 1/2 times the normal delay). The shortage of
secondary production is followed by a period of catch-up and
overshoot, in which secondary production greatly exceeds customer
demand. Delivery delay quickly returns to normal. Secondary
production rate continues to be volatile as it is pushed and pulled by
the capacity needs of the primary business.

Suppose we now trace events as they are seen in the secondary
portion of the retail subunit. Figure 3 shows the variables of
particular interest to retail decision making. Customer orders, which
are directly observable by the retailer, are shown increasing by 20%.
Soon after the increase, the retailers experience an increase in
secondary delivery delay from the manufacturer. Delivery delay rises
to a peak of 2.5 times normal and remains more than twice normal for
around sixteen weeks, or four months. The rapid rise in delivery

delay is, of course, directly attributable to the allocation policy in
capacity management.
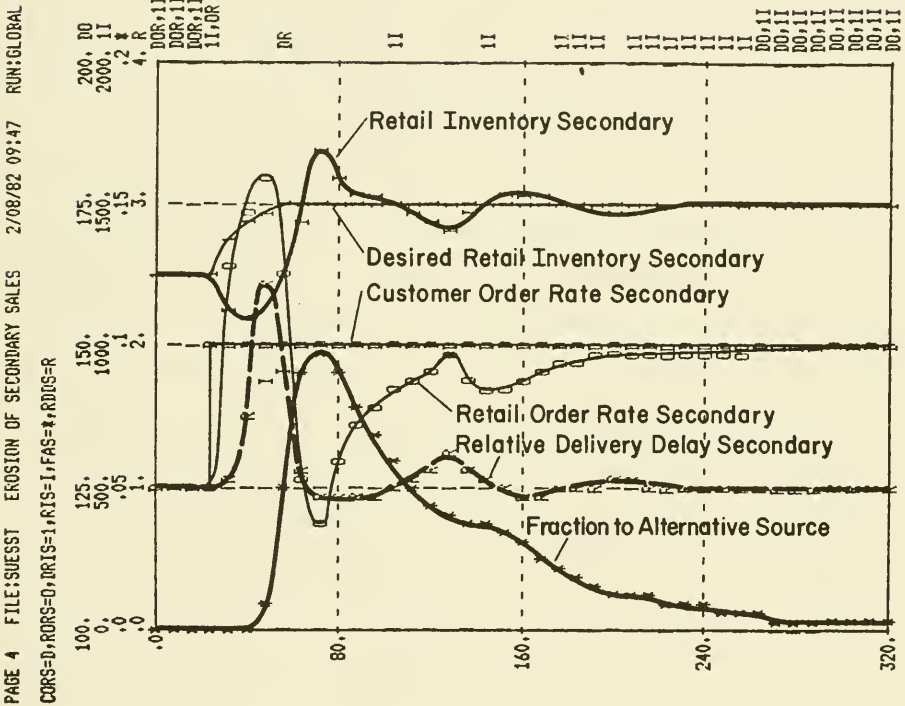
Figure 3.   Secondary Retail Ordering and Allocation

But the retailer is not concerned with the rationale for the increase.
From the retail perspective, secondary lead times become intolerably
high.   The percentage of secondary orders going to alternative sources
increases to a peak of 10% by week 72.   Thereafter the OEMs slowly

regain lost sales as they once again establish competitive secondary
delivery times.

It should be pointed out that alternative sources are assumed
to maintain constant delivery times in the face of the demand
increase. It is this assumption that causes retailers to allocate
orders in their favor. However, it is important to realize that the
assumption is not lightly adopted, but reflects a very important
aspect of the competitive character of the secondary market.
Alternative sources are dedicated to parts manufacture and are not
faced with difficult capacity allocation decisions. In such a
dedicated manufacturing environment, the first response to an increase
in secondary demand is an increase in secondary production. By
contrast, in the OEM the first response to an increase in secondary
demand (when it is accompanied by an increase in primary demand) is a
decrease in secondary production. As a result, the OEM's secondary
lead times are likely to be much more volatile. Furthermore, the
secondary market is very sensitive to delivery. Delivery is the
primary competitive variable. The entire system therefore tends to
produce a delivery scenario in the retail subsystem that encourages
alternative sourcing. The differences in organizational character of
OEMs and alternative sources, coupled with the delivery sensitivity of
the secondary market, conspire to cause loss of market share of the
secondary business.

The last set of runs in this section fills in the remaining
pieces of the organizational picture, showing the sources of schedule
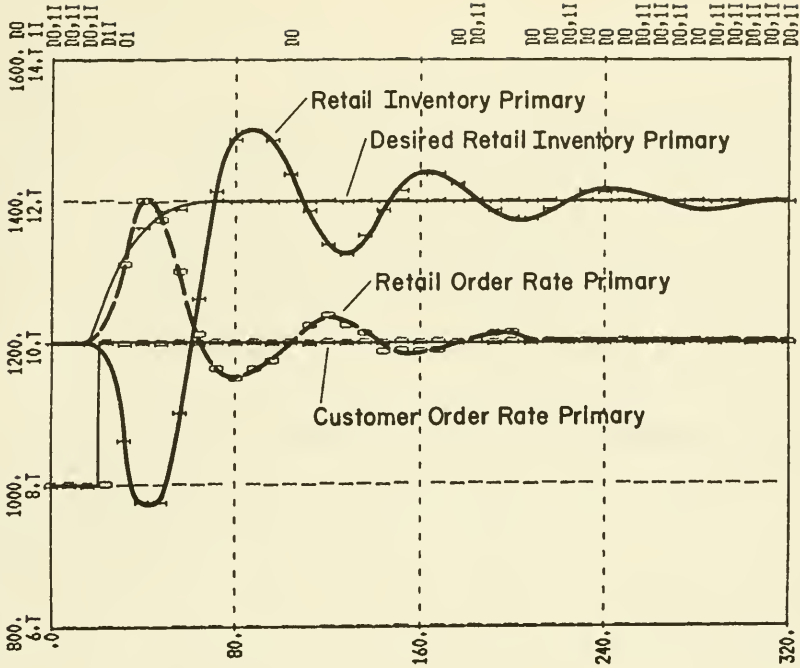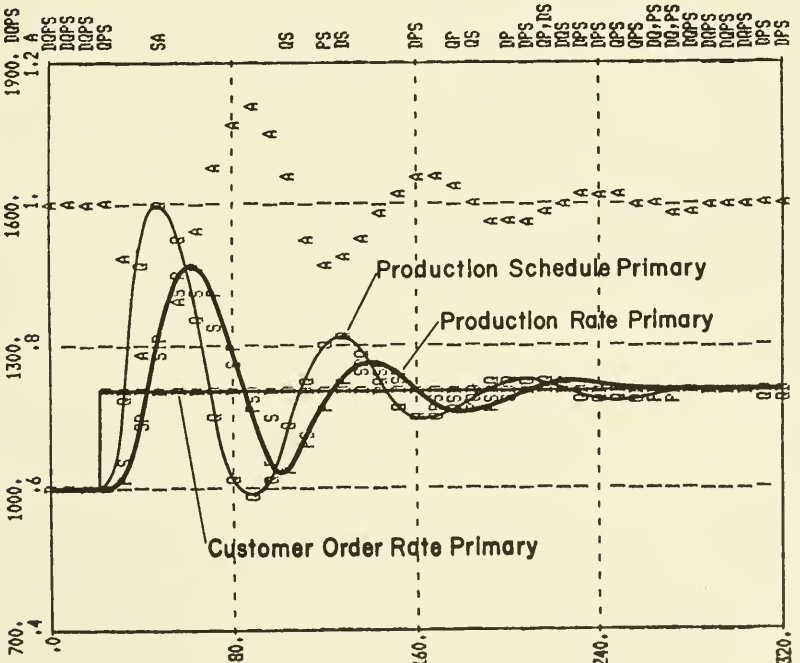
Figure 4.   Primary Retail Ordering and Primary Production

volatility in the primary business. Figure 4 shows the behavior of
variables in the primary retail and production control subsystems.
The retail subsystem, shown in the upper left of the figure, is the
direct recipient of the 20% step increase in customer orders. But
retail ordering is not a simple repeat of the customer order pattern.
Policies for retail inventory control, coupled with supply
constraints, cause retail ordering to follow a fluctuating path. The
ordering and inventory patterns display the well-known dynamics of
production and distribution referred to earlier.

In the lower half of the figure, primary production control
responds to the varying retail order stream with a still more variable
schedule. The greater schedule variability is again attributable to
policies for inventory and backlog control coupled with capacity
constraints. The primary production schedule increases to a peak of
almost 600 units per week above its initial equilibrium value, even
though customer orders increase by only 200 units per week. The
organization places a much greater load on manufacturing than might at
first seem necessary.

5. INVISIBILITY OF THE PROBLEM AT THE SUBUNIT LEVEL

The causes of competitive weakness of the secondary business
are not clearly visible at the level of an individual subunit in the
system. Supply volatility of secondary product does not arise from
any one subunit, but from the joint interaction of policies in all

subunits. Herein lies an explanation of why an inconsistent set of policies could have evolved in the organization. In the absence of any argument pointing out the policy inconsistencies, the existing policy set is likely to remain in place, with problems being blamed on external factors "beyond the control of management."

In this section we use a simplified version of the simulation model to demonstrate that policy inconsistency cannot be observed without a complete picture of organizational structure. In the simplified model, the dynamics of the retail network are excluded from the system. Of course, the simplified model is no longer representative of the real system, but it is likely to be representative of an incomplete perception or "mental model" of the system used to justify existing manufacturing policy.

Figure 5 shows a simulation run of the model subject to the same 20% increase in total customer order rate. The simulation run should be interpreted as the process of "thinking through" (with an incomplete mental model) the consequences of adjusting the manufacturing system to a sustained increase in demand. As we shall see, the adjustment of the simplified model is easier to interpret and more compatible with our intuition than the adjustment of the complete model.

Soon after the increase in customer orders, desired capacity begins to rise as capacity plans are adjusted to accommodate the higher volume of orders. The delay between the change in demand and

desired capacity reflects a natural caution in capacity planning.
There is a need to be persuaded that a demand increase is permanent
rather than transient before committing to capacity expansion. The
level of capacity in the system also rises, but some time later than
desired capacity, due to the delays in acquiring capacity once a
commitment to expansion has been made. Nevertheless, the simulation
run shows that capacity rises in a rational and timely way in response
to the load change.
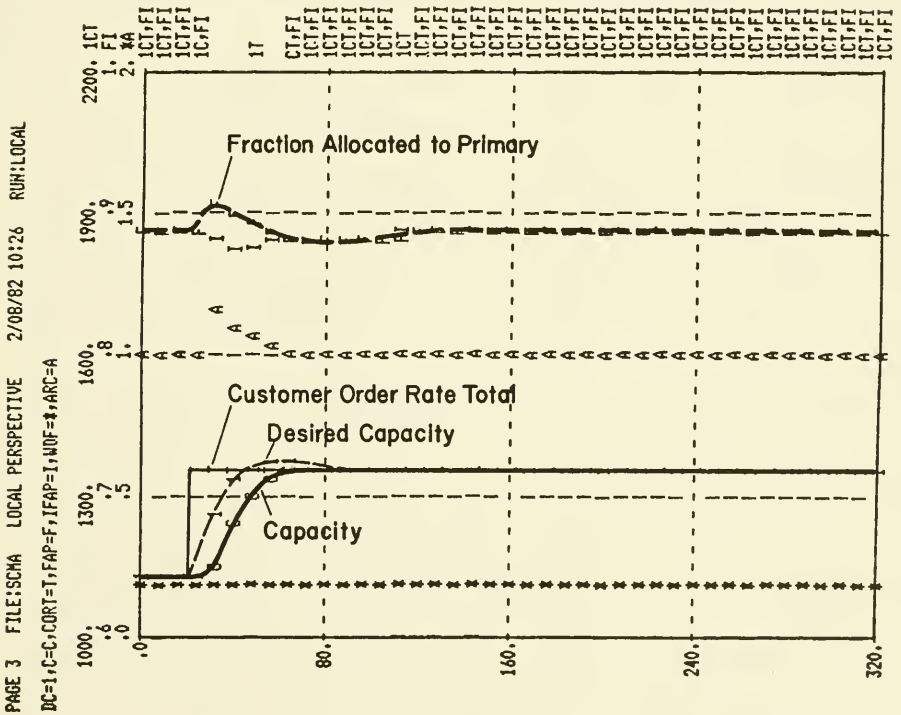
Figure 5.   Capacity Adjustment and Allocation From
Perspective of Surrogate Mental Model

During the interval between week 24 and week 80, there is a capacity shortage that activates the priority allocation process. In the upper half of the figure, the fraction (of capacity) allocated to primary production starts off from an equilibrium value of .89. Soon after week 24, the fraction increases above the equilibrium allocation as capacity shortage develops. The arrival of new capacity alleviates the capacity shortage, so that by week 72 capacity is once more "equitably" allocated between primary and secondary production. The allocation curves show a transient bias toward primary production, but not a bias that is likely to disrupt the secondary business.

The analysis so far suggests that large unexpected increases in market demand can be accommodated with only a minor, transient disturbance of production allocation. The analysis can be extended by imagining the consequences of the allocation bias as it affects secondary production and shipping. Again the argument is advanced from the incomplete perspective of our surrogate mental model.

In the lower half of Figure 6 are the trajectories for the secondary production schedule and production rate. As a reference, the secondary customer order rate is also plotted. At week 24, the customer order rate makes its 20% step increase. The secondary schedule increases soon after, as confidence builds that the demand increase is permanent. The secondary production rate, however, actually declines for a period of eight weeks, as the allocation policy draws secondary capacity for primary production. After week 32, the secondary business begins to regain its lost allocation, and secondary production recovers.

In the upper half of the figure a curve for relative delivery
delay is plotted. After the demand increase, relative delivery delay
rises from its initial value of one[5] until secondary production
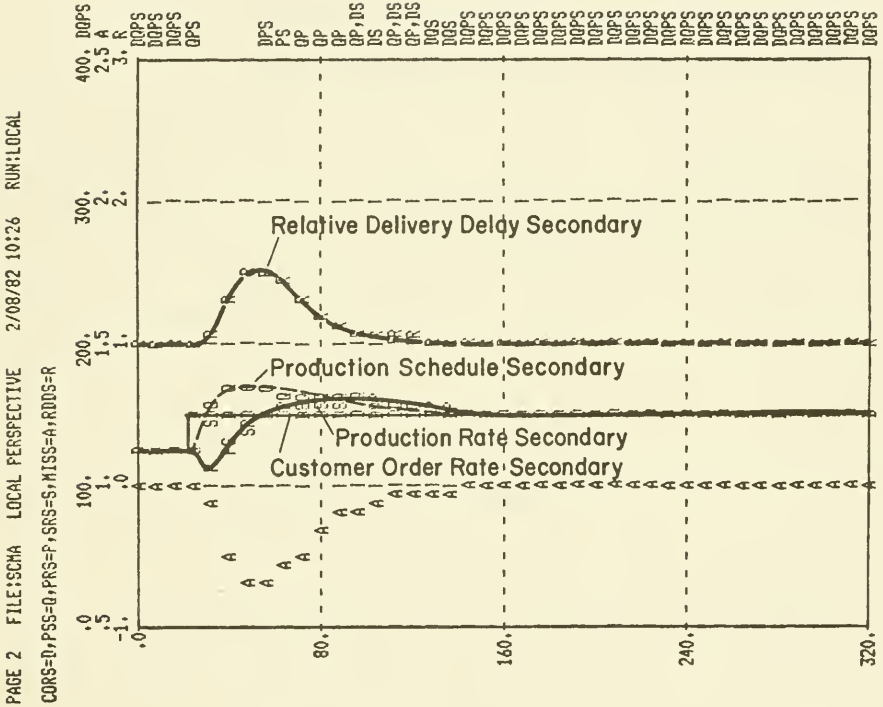
Figure 6.   Secondary Production and Delivery From
            Perspective of Surrogate Mental Model

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[5] Meaning that delivery delay on secondary sales is equal to the
    delivery delay of alternative secondary sources. In this situation,
    it is assumed that retailers will prefer to order from the OEM.

catches up with the new and higher rate of ordering in week 56. At

its peak, relative delivery reaches a value of 1.5, meaning that

secondary delivery times are 50% greater than the competitive norm.

The simulation run supports an opinion that the allocation

policy in capacity management is not greatly damaging to the secondary

business. A large change in primary and secondary demand results in a

small, transient rise in delivery times. While the rise is not

desirable, it is unlikely to encourage retailers to seek alternative

sources of supply. It is the plausibility of opinions like this than

can hold the existing policy structure in place--even though the

structure is manifestly inefficient when viewed from a total-system

perspective.

6. POLICIES TO OVERCOME COMPETITIVE WEAKNESS

To overcome competitive weakness of the secondary business,

it is necessary to ensure a stable supply of service parts. One way

to achieve this is to remove the allocation bias within capacity

management. Removal of the allocation bias is easily tested within

the model and can be shown to have beneficial effects. In reality,

however, the solution would be difficult to implement. It would face

strong organizational resistance because it runs counter to the

political weight and powerful revenue-generating potential of the

primary business. Even with a strong argument to support a neutral

allocation policy, when faced with a capacity shortage the needs of

the primary business would be likely to prevail.

An alternative method of ensuring a stable supply of service parts is through an organizational policy change that alleviates capacity allocation pressures. It is possible to think of a number of such policy changes. All involve decoupling the primary and secondary businesses so they can operate independently. For example, a policy of increasing secondary finished inventory would be an example of a decoupling policy. Additional inventory would be held not as a buffer against secondary demand variations, but rather as a buffer against variations in primary capacity needs. Alternatively, a policy of primary production smoothing, implemented entirely within the primary business, would relieve capacity shortages, thereby benefiting the secondary business.

Figure 7 shows the results of implementing a production smoothing policy in primary production control, seen from the perspective of secondary retailing.[6] The results are a great improvement on the original behavior seen in Figure 3. After the step increase in demand, relative delivery delay rises to a peak of around 1.5 by week 48. The rise in delivery delay causes a small fraction of retail orders to go to alternative sources, but the peak fraction is only 3%, by comparison with almost 10% in the system without the

[6] The policy involves the following changes: Primary finished inventory target is increased from two weeks of shipments to eight weeks of shipments. Correction times in the linear control rules for inventory and backlog are doubled from sixteen to thirty-two weeks. The smoothing time in the exponential average used to represent forecasting is doubled from ten to twenty weeks.

primary production smoothing policy. The secondary business becomes
less volatile and more able to compete with specialist parts
producers.
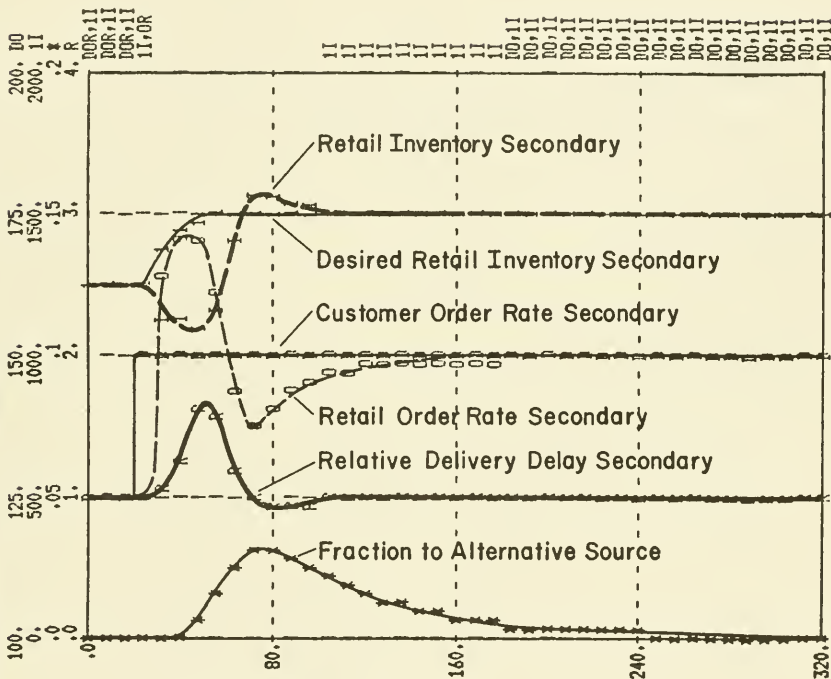
Figure 7. Secondary Retail Behavior When
Primary Production is Smoothed

7. SUMMARY AND CONCLUSIONS

Manufacturing policy cannot be set in isolation from a
careful consideration of the nature and needs of the different markets

in which a manufactured product is sold. To ignore the linkage between manufacturing policy and marketing strategy is to significantly increase the probability of competitive weakness in one or more product lines.

In this paper we have taken a specific case study showing the difficulties of supporting primary product and service parts sales from a shared capacity base. The competitive posture of the service parts business was the focus of the analysis. Using a system dynamics simulation model of the manufacturing firm, we were able to identify two features of the policy structure of the organization that caused the secondary business to be a weak and ineffective competitor in the secondary market. First, since the primary business was much larger in terms of revenue and personnel, it tended to have priority of allocation during periods of capacity shortage. Second, capacity shortages could readily occur in the system because of high demand amplification in the policies of the primary production and distribution network. The combination of these two features caused the supply of service parts to be very volatile in a market where quick and reliable delivery is an important competitive variable.

To overcome this inherent weakness, policy changes should be adopted that create more independence for secondary production. Theoretically, removing allocation bias within capacity management would be effective but would likely run into a great deal of organizational resistance.

A more practical policy is to deliberately invest in the separation of primary and secondary production. The paper illustrates one example of such a policy. Primary finished inventory investment is increased as a means of stabilizing the primary production schedule and thereby alleviating load variations on capacity from the primary business. With fewer capacity shortages, secondary production can be made more responsive to market variations, even without the elimination of capacity allocation bias.

Although the analysis was based on a specific case study, it has a number of general features that are of broad applicability. Most manufacturers sell through a distribution network, which tends to amplify demand variations of the customer. If the demands of many distribution networks are focused on a single manufacturing facility, production priority conflicts are likely to occur.

The analysis would suggest that careful thought be given to grouping products according to the characteristics of the markets they serve. The fewer the similarities of market characteristics, the more the supply of different product lines should be insulated (through the use of buffering inventories or independent plants-within-a-plant, PWPs). In addition, the analysis suggests that particular attention be paid to the situation where one product line, small in terms of volume (but perhaps highly profitable, as in the case of service parts), competes with much larger volume product lines. Then small adjustments of capacity in favor of the large volume product can have a greatly magnified effect on the small volume product. Such a

situation would suggest that relative volume is a market

characteristic to be considered in grouping product lines.

8. IMPLEMENTATION RESULTS

        The policy recommendations described above were the basis for

an implementation effort in the company. Using the arguments of

strengthening the secondary business and simultaneously lowering

manufacturing cost in the primary business, authorization was obtained

from the parent company for a $15-million investment in primary

finished inventory[7]--a substantial investment in relation to the

subsidiary company's annual revenues of approximately $200 million.

The model predicted a return on policy investment of not less than 20%

per year.

        A detailed implementation report was prepared for the company

(Morecroft and Stephens [13]) showing how the new policy could be

integrated into the existing informal production planning procedures

of the organization. During the period of overlap between policy

implementation and the end of the project, a marked smoothing of

primary production was noted, accompanied by fewer instances of

capacity shortages.

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[7] $15 million was the maximum investment authorized to cover inventory
  buildup during the slow winter selling season. The average
  investment over the year was approximately $8 million.

        The project did not extend for a sufficiently long period
after implementation to observe its full impact on the secondary
business. (Simulation runs suggest a one-to-two-year time lag before
more reliable supply would clearly win back service parts market
share.) Nevertheless, the project did have a considerable impact
within the organization. It supplied a plausible rationale for
manufacturing policy change and a rationale that was convincing enough
to bring about a real commitment of resources to implement the change.

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APPENDIX: MODEL DOCUMENTATION

Note: Numbers correspond to equations in model listing. When two
sets of numbers appear in a symbol, the upper numbers
correspond to primary business and the lower to secondary
business. When an "*" appears, there are no equations in the
primary business corresponding to the symbol.

Figure A1. Policy Structure Diagram of Retail Ordering Subunits

```
NOTE                                                                    00000001
*    EROSION OF SECONDARY SALES                                         00000002
NOTE   MODEL TO ANALYSE STRUCTURES UNDERLYING                           00000003
NOTE   EROSION OF SECONDARY SALES IN THE PRODUCTION                     00000004
NOTE   AND RETAILING OF CONSUMER DURABLES (SUESS)                       00000005
NOTE   BY JOHN D.W. MORECROFT JANUARY 1981                              00000006
NOTE                                                                    00000007
NOTE *** RETAIL ORDERING SUBSYSTEM PRIMARY ***                          00000008
NOTE                                                                    00000009
L    RIP.K=RIP.J+(DT)(SRP.JK-RSRP.JK)                                   00000010
N    RIP=CORP*NRICP                                                     00000011
R    RSRP.KL=CORP.K                                                     00000020
A    CORP.K=IDP*(1+STEP(SDP,TSDP))                                      00000030
C    IDP=1000                          UNITS/WEEK                       00000031
C    SDP=0/TSDP=24                      WEEKS                           00000032
NOTE                                                                    00000033
NOTE   CONTROL POLICIES IN PRIMARY ORDERING                            00000034
R    RORP.KL=ACORP.K+(CRIP.K+CSLP.K)                                    00000040
L    ACORP.K=ACORP.J+(DT/TACORP)(CORP.J-ACORP.J)                        00000050
N    ACORP=IDP                                                          00000051
C    TACORP=10                          WEEKS                           00000052
A    CRIP.K=(DRIP.K-RIP.K)/TCRIP                                        00000060
C    TCRIP=12                           WEEKS                           00000061
A    DRIP.K=ACORP.K*NRICP                                               00000070
C    NRICP=10                           WEEKS                           00000071
A    CSLP.K=((DSLP.K-SLP.K)/TCSLP)*WSLP                                 00000080
C    TCSLP=12                           WEEKS                           00000081
C    WSLP=.5                                                            00000082
A    DSLP.K=ACORP.K*NDDP                                                00000090
C    NDDP=8                             WEEKS                           00000091
A    SLP.K=BP.K                                                         00000100
NOTE                                                                    00000101
NOTE *** RETAIL ORDERING SUBSYSTEM SECONDARY ***                       00000102
NOTE                                                                    00000103
L    RIS.K=RIS.J+(DT)(SRS.JK+SRAS.JK-RSRS.JK)                           00000110
N    RIS=CORS*NRICS                                                     00000111
R    RSRS.KL=CORS.K                                                     00000120
A    CORS.K=IDS*(1+STEP(SDS,TSDS))                                      00000130
C    IDS=125                            UNITS/WEEK                       00000131
C    SDS=0/TSDS=24                      WEEKS                           00000132
NOTE                                                                    00000133
NOTE   CONTROL POLICIES IN SECONDARY ORDERING                          00000134
R    RORS.KL=TRORS.K*(1-FAS.K)                                          00000140
A    TRORS.K=ACORS.K+(CRIS.K+CSLS.K)                                    00000150
L    ACORS.K=ACORS.J+(DT/TACORS)(CORS.J-ACORS.J)                        00000160
N    ACORS=IDS                                                          00000161
C    TACORS=10                          WEEKS                           00000162
A    CRIS.K=(DRIS.K-RIS.K)/TCRIS                                        00000170
C    TCRIS=10                           WEEKS                           00000171
A    DRIS.K=ACORS.K*NRICS                                               00000180
C    NRICS=10                           WEEKS                           00000181
A    CSLS.K=((DSLS.K-SLS.K)/TCSLS)*WSLS                                 00000190
C    TCSLS=12                           WEEKS                           00000191
C    WSLS=.5                                                            00000192
A    DSLS.K=ACORS.K*NDDS*(1-FAS.K)                                      00000200
C    NDDS=4                             WEEKS                           00000201
A    SLS.K=BS.K                                                         00000210
NOTE                                                                    00000211
NOTE   ALLOCATION OF SECONDARY RETAIL ORDERING                         00000212
L    FAS.K=FAS.J+(DT)(CFAS.JK)                                          00000220
N    FAS=0                                                              00000221
R    CFAS.KL=(DFAS.K-FAS.K)/TEAS                                        00000230
C    TEAS=50                            WEEKS                           00000231
A    DFAS.K=TABHL(TFAS,PRDDS.K,1,4,.5)                                  00000240
T    TFAS=0/.1/.4/.7/.9/.95/1                                           00000241
A    PRDDS.K=SMOOTH(RDDS.K,TPDD)                                        00000250
C    TPDD=12                            WEEKS                           00000251
A    RDDS.K=DDS.K/NDDS                                                  00000260
A    DDS.K=BS.K/SRS.JK                                                  00000270
NOTE                                                                    00000271
NOTE *** ALTERNATIVE SOURCE ***                                        00000272
NOTE                                                                    00000273
R    ORAS.KL=TRORS.K*FAS.K                                              00000280
R    SRAS.KL=DELAY1(ORAS.JK,NDDS)                                       00000290
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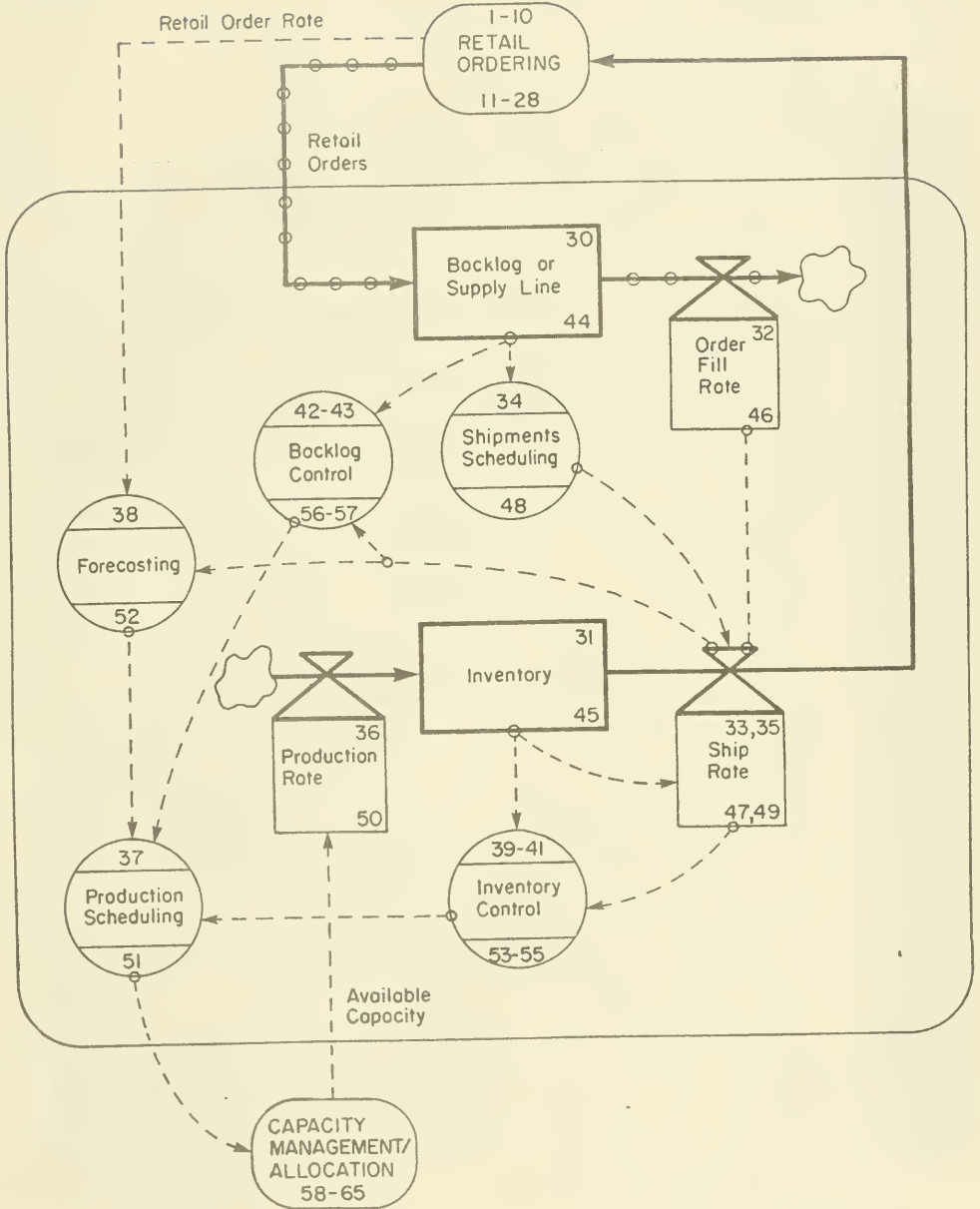
Figure A2. Policy Structure Diagram of Production Control Subunits

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NOTE
NOTE  *** PRODUCTION CONTROL PRIMARY ***
NOTE
L     BP.K=BP.J+(DT)(RORP.JK-OFRP.JK)
N     BP=NDDP*IDP
L     IP.K=IP.J+(DT)(PRP.JK-SRP.JK)
N     IP=NICP*IDP
R     OFRP.KL=SRP.JK
R     SRP.KL=DSBP.K*MISP.K
A     DSBP.K=BP.K/NDDP
A     MISP.K=TABHL(TMISP,(IP.K/(NICP*DSBP.K)),0,2,,25)
T     TMISP=0/.4/.7/.9/1/1.05/1.08/1.12/1.15
R     PRP.KL=C.K*FAP.K
NOTE
NOTE   CONTROL POLICIES IN PRIMARY PRODUCTION PLANNING
A     PSP.K=ARORP.K+(CIP.K+CBP.K)
L     ARORP.K=ARORP.J+(DT/TARORP)(RORP.JK-ARORP.J)
N     ARORP=IDP
C     TARORP=10                        WEEKS
A     CIP.K=(DIP.K-IP.K)/TCIP          WEEKS
C     TCIP=16
A     DIP.K=ASRP.K*NICP                WEEKS
C     NICP=2
L     ASRP.K=ASRP.J+(DT/TASRP)(SRP.JK-ASRP.J)
N     ASRP=IDP
C     TASRP=10                         WEEKS
A     CBP.K=(BP.K-DBP.K)/TCBP          WEEKS
C     TCBP=16
A     DBP.K=NDDP*ASRP.K
NOTE
NOTE  *** PRODUCTION CONTROL SECONDARY ***
NOTE
L     BS.K=BS.J+(DT)(RORS.JK-OFRS.JK)
N     BS=NDDS*IDS
L     IS.K=IS.J+(DT)(PRS.JK-SRS.JK)
N     IS=NICS*IDS
R     OFRS.KL=SRS.JK
R     SRS.KL=DSBS.K*MISS.K
A     DSBS.K=BS.K/NDDS
A     MISS.K=TABHL(TMISS,(IS.K/(NICS*DSBS.K)),0,2,,25)
T     TMISS=0/.6/.9/.95/1/1.03/1.05/1.05/1.05
R     PRS.KL=C.K*(1-FAP.K)
NOTE
NOTE   CONTROL POLICIES IN PRODUCTION PLANNING
A     PSS.K=ARORS.K+(CIS.K+CBS.K)
L     ARORS.K=ARORS.J+(DT/TARORS)(RORS.JK-ARORS.J)
N     ARORS=IDS
C     TARORS=10                        WEEKS
A     CIS.K=(DIS.K-IS.K)/TCIS          WEEKS
C     TCIS=10
A     DIS.K=ASRS.K*NICS                WEEKS
C     NICS=6
L     ASRS.K=ASRS.J+(DT/TASRS)(SRS.JK-ASRS.J)
N     ASRS=IDS
C     TASRS=10                         WEEKS
A     CBS.K=(BS.K-DBS.K)/TCBS          WEEKS
C     TCBS=10
A     DBS.K=NDDS*ASRS.K
```
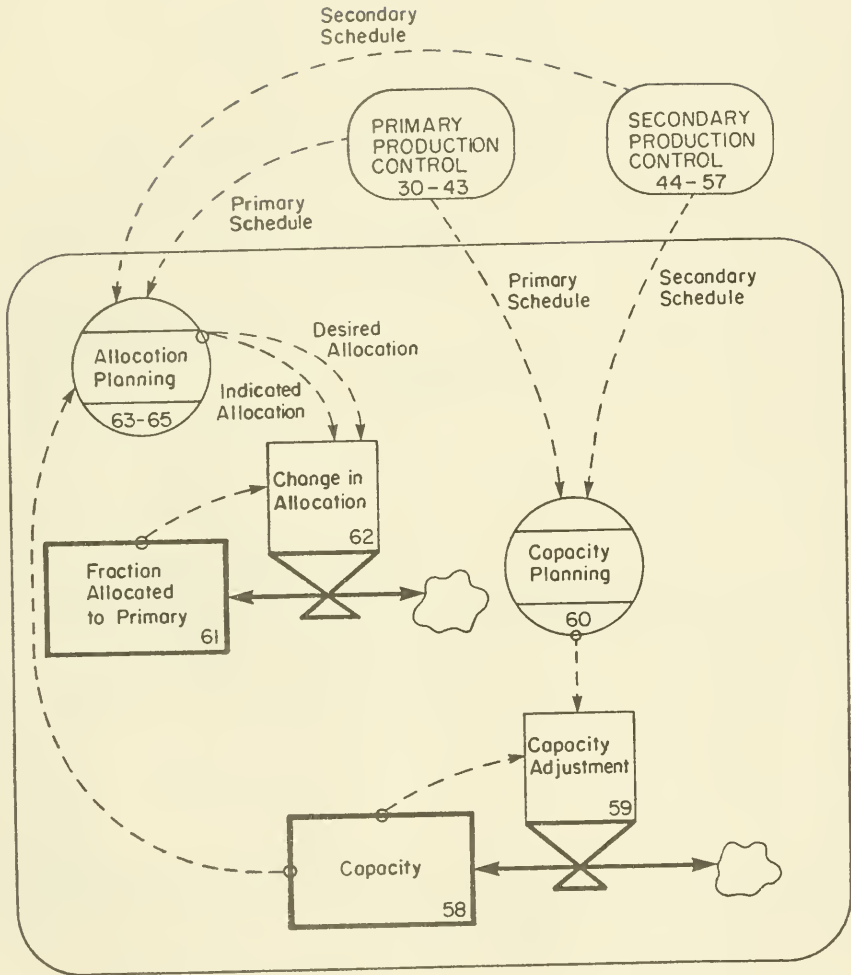
Figure A3.   Policy Structure Diagram of Capacity
              Management and Allocation Subunit

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NOTE                                                              00000571
NOTE *** CAPACITY MANAGEMENT AND ALLOCATION ***                   00000572
NOTE                                                              00000573
L    C.K=C.J+(DT)(CAR.JK)                                         00000580
N    C=IDP+IDS                                                    00000581
R    CAR.KL=(DC.K-C.K)/TAC                                        00000590
C    TAC=12                          WEEKS                        00000591
A    DC.K=SMOOTH((PSP.K+PSS.K),TPC)                               00000600
C    TPC=4                           WEEKS                        00000601
NOTE                                                              00000602
NOTE   ALLOCATION POLICY                                          00000603
L    FAP.K=FAP.J+(DT)(CFAP.JK)                                    00000610
N    FAP=IDP/(IDP+IDS)                                            00000611
R    CFAP.KL=(DFAP.K*WDF.K+IFAP.K*(1-WDF.K)-FAP.K)/TACP           00000620
C    TACP=4                          WEEKS                        00000621
A    DFAP.K=PSP.K/C.K                                             00000630
A    IFAP.K=PSP.K/(PSP.K+PSS.K)                                   00000640
A    WDF.K=TABHL(TWDF,FAP.K,,S,1,,05)                             00000650
T    TWDF=.2/.2/.2/.1/0                                           00000651
NOTE                                                              00000652
S    ARC.K=DFAP.K/IFAP.K                                          00000660
S    CORT.K=CORP.K+CORS.K                                         00000670
NOTE                                                              00000671
NOTE *** CONTROL STATEMENTS ***                                  00000672
SPEC DT=,5/LENGTH=0/PLTPER=8/PRTPER=0                             00000680
PLOT DC=1,C=C,CORT=T(1000,2200)/FAP=F(,6,1)/ARC=A,WDF=*(0,2)      00000690
PLOT CORS=D,PSS=Q,PRS=P(0,400)/MISS=A(.5,2.5)/RDDS=R(-1,3)        00000700
PLOT CORS=D,RORS=0(100,200)/DRIS=1,RIS=I(0,2000)/FAS=*(0,.2)/RDDS=R(0, 00000710
X   4)                                                           00000711
PLOT CORP=D,RORP=0(800,1600)/DRIP=1,RIP=I                        00000720
PLOT CORP=D,PSP=Q,PRP=P,SRP=S(700,1900)/MISP=A(.4,1.2)           00000730
RUN COMPILE                                                      00000740
CP LENGTH=320                                                    00000741
CP SDP=,2                                                        00000742
CP SDS=,2                                                        00000743
RUN GLOBAL                                                       00000750
C    WSLP=1                                                      00000751
C    NICP=8                                                      00000752
C    TCIP=32                                                     00000753
C    TCRP=32                                                     00000754
C    TASRP=20                                                    00000755
C    TARORP=20                                                   00000756
PLOT CORS=D,RORS=0(100,200)/DRIS=1,RIS=I(0,2000)FAS=*(0,.2)/RDDS=R(0,4) 00000760
RUN GLOBAL,                        PRIMARY SMOOTH                 00000770
-EOF-
```

```
*   LOCAL PERSPECTIVE                                                        00000001
NOTE  MODEL TO ILLUSTRATE LOCAL PERSPECTIVE                                  00000002
NOTE  IN CAPACITY MANAGEMENT AND ALLOCATION (SCMA)                          00000003
NOTE                                                                         00000004
NOTE *** SKETCH OF RETAIL ORDERING ***                                       00000005
R   RORP.KL=CORP.K                                                          00000010
A   CORP.K=IDP*(1+STEP(SDP,TSDP))                                           00000020
C   IDP=1000                           UNITS/WEEK                           00000021
C   SDP=0/TSDP=24                       WEEKS                               00000022
R   RORS.KL=CORS.K                                                          00000030
A   CORS.K=IDS*(1+STEP(SDS,TSDS))                                           00000040
C   IDS=125                            UNITS/WEEK                           00000041
C   SDS=0/TSDS=24                       WEEKS                               00000042
NOTE                                                                         00000043
NOTE *** SKETCH OF PRIMARY PRODUCTION CONTROL. ***                          00000044
A   PSP.K=ARORP.K                                                          00000050
L   ARORP.K=ARORP.J+(DT/TARORP)(RORP.JK-ARORP.J)                           00000060
N   ARORP=IDP                           WEEKS                               00000061
C   TARORP=4                                                               00000062
NOTE                                                                         00000063
NOTE *** SKETCH OF SECONDARY SHIPMENTS AND PRODUCTION CONTROL. ***          00000064
L   BS.K=BS.J+(DT)(RORS.JK-OFRS.JK)                                        00000070
N   BS=NDDS*IDS                                                            00000071
C   NDDS=4                              WEEKS                               00000072
L   IS.K=IS.J+(DT)(PRS.JK-SRS.JK)                                          00000080
N   IS=NICS*IDS                                                            00000081
R   OFRS.KL=SRS.JK                                                         00000090
R   SRS.KL=DSBS.K*MISS.K                                                   00000100
A   DSBS.K=BS.K/NDDS                                                       00000110
A   MISS.K=TABHL(TMISS,(IS.K/(NICS*DSBS.K)),0,2,.25)                       00000120
T   TMISS=0/.6/.9/.95/1/1.03/1.05/1.05/1.05                               00000121
R   PRS.KL=C.K*(1-FAP.K)                                                   00000130
NOTE                                                                         00000131
A   PSS.K=ARORS.K+CIS.K                                                    00000140
L   ARORS.K=ARORS.J+(DT/TARORS)(RORS.JK-ARORS.J)                          00000150
N   ARORS=IDS                                                              00000151
C   TARORS=4                            WEEKS                               00000152
A   CIS.K=(DIS.K-IS.K)/TCIS                                               00000160
C   TCIS=30                             WEEKS                               00000161
A   DIS.K=ARORS.K*NICS                                                    00000170
C   NICS=6                              WEEKS                               00000171
NOTE                                                                         00000172
NOTE *** CAPACITY MANAGEMENT AND ALLOCATION ***                             00000173
NOTE                                                                         00000174
L   C.K=C.J+(DT)(CAR.JK)                                                  00000180
N   C=IDP+IDS                                                              00000181
R   CAR.KL=(DC.K-C.K)/TAC                                                  00000190
C   TAC=12                              WEEKS                               00000191
A   DC.K=SMOOTH((PSP.K+PSS.K),TPC)                                        00000200
C   TPC=4                               WEEKS                               00000201
NOTE                                                                         00000202
NOTE  ALLOCATION POLICY                                                     00000203
L   FAP.K=FAP.J+(DT)(CFAP.JK)                                             00000210
N   FAP=IDP/(IDP+IDS)                                                      00000211
R   CFAP.KL=(DFAP.K*WDF.K+IFAP.K*(1-WDF.K)-FAP.K)/TACP                    00000220
C   TACP=4                              WEEKS                               00000221
A   DFAP.K=PSP.K/C.K                                                      00000230
A   IFAP.K=PSP.K/(PSP.K+PSS.K)                                            00000240
A   WDF.K=TABHL(TWDF,FAP.K,.8,1,.05)                                      00000250
T   TWDF=.2/.2/.2/.1/0                                                    00000251
NOTE                                                                         00000252
S   ARC.K=DFAP.K/IFAP.K                                                   00000260
S   CORT.K=CORP.K+CORS.K                                                  00000270
S   RDDS.K=(BS.K/SRS.JK)/NDDS                                             00000280
NOTE                                                                         00000281
NOTE *** CONTROL STATEMENTS ***                                             00000282
SPEC DT=.5/LENGTH=0/PLTPER=8/PRTPER=0                                      00000290
PLOT CORS=D,PSS=Q,PRS=P,SRS=S(0,400)/MISS=A(.5,2.5)/RDDS=R(-1,3)          00000300
PLOT DC=1,C=C,CORT=T(1000,2200)/FAP=F,IFAP=I(.6,1)/WDF=*,ARC=A(0,2)       00000310
RUN COMPILE                                                                00000320
CP LENGTH=320                                                              00000321
CP PLTPER=8                                                                00000322
CP SDP=.2                                                                  00000323
CP SDS=.2                                                                  00000324
RUN LOCAL                                                                  00000330
```

LIST OF VARIABLES

SYMBOL	T	WHR-CMP	DEFINITION
ACORP	L	5	AVERAGE CUSTOMER ORDER RATE PRIMARY (UNITS/WEEK)
	N	5.1	<5>
ACORS	L	16	AVERAGE CUSTOMER ORDER RATE SECONDARY (UNITS/
	N	16.1	WEEK) <16>
ARC	S	66	ALLOCATION RATIO FOR CAPACITY (DIMENSIONLESS)
			<66>
ARORP	L	38	AVERAGE RETAIL ORDER RATE PRIMARY (UNITS/WEEK)
	N	38.1	<38>
ARORS	L	52	AVERAGE RETAIL ORDER RATE SECONDARY (UNITS/WEEK)
	N	52.1	<52>
ASRP	L	41	AVERAGE SHIP RATE PRIMARY (UNITS/WEEK) <41>
	N	41.1	
ASRS	L	55	AVERAGE SHIP RATE SECONDARY (UNITS/WEEK) <55>
	N	55.1	
BP	L	30	BACKLOG PRIMARY (UNITS) <30>
	N	30.1	
BS	L	44	BACKLOG SECONDARY (UNITS) <44>
	N	44.1	
C	L	58	CAPACITY (UNITS/WEEK) <58>
	N	58.1	
CAR	R	59	CAPACITY ARRIVAL RATE (UNITS/WEEK/WEEK) <59>
CBP	A	42	CORRECTION FOR BACKLOG PRIMARY (UNITS/WEEK) <42>
CBS	A	56	CORRECTION FOR BACKLOG SECONDARY (UNITS/WEEK)
			<56>
CFAP	R	62	CHANGE IN FRACTION ALLOCATED TO PRIMARY
			(FRACTION/WEEK) <62>
CFAS	R	23	CHANGE IN FRACTION TO ALTERNATIVE SOURCE
			(FRACTION/WEEK) <23>
CIP	A	39	CORRECTION FOR INVENTORY PRIMARY (UNITS/WEEK)
			<39>
CIS	A	53	CORRECTION FOR INVENTORY SECONDARY (UNITS/WEEK)
			<53>
CORP	A	3	CUSTOMER ORDER RATE PRIMARY (UNITS/WEEK) <3>
CORS	A	13	CUSTOMER ORDER RATE SECONDARY (UNITS/WEEK) <13>
CORT	S	67	CUSTOMER ORDER RATE TOTAL (UNITS/WEEK) <67>
CRIP	A	6	CORRECTION FOR RETAIL INVENTORY PRIMARY (UNITS/
			WEEK) <6>
CRIS	A	17	CORRECTION FOR RETAIL INVENTORY SECONDARY (UNITS/
			WEEK) <17>
CSLP	A	8	CORRECTION FOR SUPPLY LINE PRIMARY (UNITS/WEEK)
			<8>
CSLS	A	19	CORRECTION FOR SUPPLY LINE SECONDARY (UNITS/
			WEEK) <19>
DBP	A	43	DESIRED BACKLOG PRIMARY (UNITS) <43>
DBS	A	57	DESIRED BACKLOG SECONDARY (UNITS) <57>
DC	A	60	DESIRED CAPACITY (UNITS/WEEK) <60>
DDS	A	27	DELIVERY DELAY SECONDARY (WEEKS) <27>
DFAP	A	63	DESIRED FRACTION ALLOCATED TO PRIMARY
			(DIMENSIONLESS) <63>
DFAS	A	24	DESIRED FRACTION TO ALTERNATIVE SOURCE
			(DIMENSIONLESS) <24>
DIP	A	40	DESIRED INVENTORY PRIMARY (UNITS) <40>

BSRS	R	12	RETAIL SHIP RATE SECONDARY (UNITS/WEEK) <12>
SDP	C	3.2	STEP IN DEMAND PRIMARY (DIMENSIONLESS) <3>
SDS	C	13.2	STEP IN DEMAND SECONDARY (DIMENSIONLESS) <13>
SLP	A	10	SUPPLY LINE PRIMARY (WEEKS) <10>
SLS	A	21	SUPPLY LINE SECONDARY (UNITS) <21>
SRAS	R	29	SHIP RATE FROM ALTERNATIVE SOURCE (UNITS/WEEK) <29>
SRP	R	33	SHIP RATE PRIMARY (UNITS/WEEK) <33>
SRS	R	47	SHIP RATE SECONDARY (UNITS/WEEK) <47>
TAC	C	59.1	TIME TO ADJUST CAPACITY (WEEKS) <59>
TACORP	C	5.2	TIME TO AVERAGE CUSTOMER ORDER RATE PRIMARY (WEEKS) <5>
TACORS	C	16.2	TIME TO AVERAGE CUSTOMER ORDER RATE SECONDARY (WEEKS) <16>
TACP	C	62.1	TIME TO ALLOCATE CAPACITY TO PRIMARY (WEEKS) <62>
TARORP	C	36.2	TIME TO AVERAGE RETAIL ORDER RATE PRIMARY (WEEKS) <36>
TARORS	C	52.2	TIME TO AVERAGE RETAIL ORDER RATE SECONDARY (WEEKS) <52>
TASRP	C	41.2	TIME TO AVERAGE SHIP RATE PRIMARY (WEEKS) <41>
TASRS	C	55.2	TIME TO AVERAGE SHIP RATE SECONDARY (WEEKS) <55>
TCBP	C	42.1	TIME TO CORRECT BACKLOG PRIMARY (WEEKS) <42>
TCBS	C	56.1	TIME TO CORRECT BACKLOG SECONDARY (WEEKS) <56>
TCIP	C	39.1	TIME TO CORRECT INVENTORY PRIMARY (WEEKS) <39>
TCIS	C	53.1	TIME TO CORRECT INVENTORY SECONDARY (WEEKS) <53>
TCRIP	C	6.1	TIME TO CORRECT RETAIL INVENTORY PRIMARY (WEEKS) <6>
TCRIS	C	17.1	TIME TO CORRECT RETAIL INVENTORY SECONDARY (WEEKS) <17>
TCSLP	C	8.1	TIME TO CORRECT SUPPLY LINE PRIMARY (WEEKS) <8>
TCSLS	C	19.1	TIME TO CORRECT SUPPLY LINE SECONDARY (WEEKS) <19>
TEAS	C	23.1	TIME TO ESTABLISH ALTERNATIVE SOURCE (WEEKS) <23>
TFAS	T	24.1	TABLE FOR FRACTION TO ALTERNATIVE SOURCE (DIMENSIONLESS) <24>
TWDSP	T	35.1	TABLE FOR WDSP (DIMENSIONLESS) <35>
TWDSS	T	49.1	TABLE FOR WDSS (DIMENSIONLESS) <49>
TPC	C	60.1	TIME TO PLAN CAPACITY (WEEKS) <60>
TPDD	C	25.1	TIME TO PERCEIVE DELIVERY DELAY (WEEKS) <25>
TRORS	A	15	TOTAL RETAIL ORDER RATE SECONDARY (UNITS/WEEK) <15>
TSDP	C	3.2	TIME FOR STEP IN DEMAND PRIMARY (WEEKS) <3>
TSDS	C	13.2	TIME FOR STEP IN DEMAND SECONDARY (WEEKS) <13>
TWDF	T	65.1	TABLE FOR WEIGHT FOR DESIRED FRACTION (DIMENSIONLESS) <65>
WDF	A	65	WEIGHT FOR DESIRED FRACTION (DIMENSIONLESS) <65>
WSLP	C	8.2	WEIGHT FOR SUPPLY LINE PRIMARY (DIMENSIONLESS) <8>
WSLS	C	19.2	WEIGHT FOR SUPPLY LINE SECONDARY (DIMENSIONLESS) <19>

RSRS	R	12	RETAIL SHIP RATE SECONDARY (UNITS/WEEK) <12>
SDP	C	3.2	STEP IN DEMAND PRIMARY (DIMENSIONLESS) <3>
SDS	C	13.2	STEP IN DEMAND SECONDARY (DIMENSIONLESS) <13>
SLP	A	10	SUPPLY LINE PRIMARY (WEEKS) <10>
SLS	A	21	SUPPLY LINE SECONDARY (UNITS) <21>
SRAS	R	29	SHIP RATE FROM ALTERNATIVE SOURCE (UNITS/WEEK) <29>
SRP	R	33	SHIP RATE PRIMARY (UNITS/WEEK) <33>
SRS	R	47	SHIP RATE SECONDARY (UNITS/WEEK) <47>
TAC	C	59.1	TIME TO ADJUST CAPACITY (WEEKS) <59>
TACORP	C	5.2	TIME TO AVERAGE CUSTOMER ORDER RATE PRIMARY (WEEKS) <5>
TACORS	C	16.2	TIME TO AVERAGE CUSTOMER ORDER RATE SECONDARY (WEEKS) <16>
TACP	C	62.1	TIME TO ALLOCATE CAPACITY TO PRIMARY (WEEKS) <62>
TARORP	C	38.2	TIME TO AVERAGE RETAIL ORDER RATE PRIMARY (WEEKS) <38>
TARORS	C	52.2	TIME TO AVERAGE REETAIL ORDER RATE SECONDARY (WEEKS) <52>
TASRP	C	41.2	TIME TO AVERAGE SHIP RATE PRIMARY (WEEKS) <41>
TASRS	C	55.2	TIME TO AVERAGE SHIP RATE SECONDARY (WEEKS) <55>
TCBP	C	42.1	TIME TO CORRECT BACKLOG PRIMARY (WEEKS) <42>
TCBS	C	56.1	TIME TO CORRECT BACKLOG SECONDARY (WEEKS) <56>
TCIP	C	39.1	TIME TO CORRECT INVENTORY PRIMARY (WEEKS) <39>
TCIS	C	53.1	TIME TO CORRECT INVENTORY SECONDARY (WEEKS) <53>
TCRIP	C	6.1	TIME TO CORRECT RETAIL INVENTORY PRIMARY (WEEKS) <6>
TCRIS	C	17.1	TIME TO CORRECT RETAIL INVENTORY SECONDARY (WEEKS) <17>
TCSLP	C	8.1	TIME TO CORRECT SUPPLY LINE PRIMARY (WEEKS) <8>
TCSLS	C	19.1	TIME TO CORRECT SUPPLY LINE SECONDARY (WEEKS) <19>
TEAS	C	23.1	TIME TO ESTABLISH ALTERNATIVE SOURCE (WEEKS) <23>
TFAS	T	24.1	TABLE FOR FRACTION TO ALTERNATIVE SOURCE (DIMENSIONLESS) <24>
TMISP	T	35.1	TABLE FOR MISP (DIMENSIONLESS) <35>
TMISS	T	49.1	TABLE FOR MISS (DIMENSIONLESS) <49>
TPC	C	60.1	TIME TO PLAN CAPACITY (WEEKS) <60>
TPDD	C	25.1	TIME TO PERCEIVE DELIVERY DELAY (WEEKS) <25>
TRORS	A	15	TOTAL RETAIL ORDER RATE SECONDARY (UNITS/WEEK) <15>
TSDP	C	3.2	TIME FOR STEP IN DEMAND PRIMARY (WEEKS) <3>
TSDS	C	13.2	TIME FOR STEP IN DEMAND SECONDARY (WEEKS) <13>
TWDF	T	65.1	TABLE FOR WEIGHT FOR DESIRED FRACTION (DIMENSIONLESS) <65>
WDF	A	65	WEIGHT FOR DESIRED FRACTION (DIMENSIONLESS) <65>
WSLP	C	8.2	WEIGHT FOR SUPPLY LINE PRIMARY (DIMENSIONLESS) <8>
WSLS	C	19.2	WEIGHT FOR SUPPLY LINE SECONDARY (DIMENSIONLESS) <19>