Capacity Control Policies in a Material Requirements Planning Production Environment

by

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ABSTRACT

Two types of heuristic capacity control policies are evaluated with a SLAM simulation model of a materials requirements planning production system. The control policy decisions are based solely on the size of the queue, as measured in standard hours of work, at each work center in the production system. Several classes of product mixes and product structures are investigated, as well as several levels of the control parameters of each control policy. The results indicate that each control policy gives rise to a unique population of weekly labor, work in process, and inventory level. Product structure is also identified as a major variable in Materials Requirements Planning systems performance. Sensitivity analysis of the cost functions for each policy indicate the conditions under which it will minimize the sum of labor costs, work in process holding costs, and inventory holding costs. The simulation model, MRPSIM, is included with a user's guide.

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Chapter I

INTRODUCTION

1.1 CAPACITY PLANNING AND CONTROL OVERVIEW

Capacity planning and control methods for a production system vary considerably in their scope and usefulness. One of the earliest methods of planning capacity, the Gantt chart, has been in use since 1903. Since that time many improvements have been made. Beginning in the 1960's, the use of computers for production planning and control made significant inroads in many previously intractable or uneconomic problems.

Capacity planning is often divided into two categories of planning. Long term planning, also known as aggregate planning and more recently as resource requirements planning [47,64] usually involves a planning horizon of several years. Short term planning is concerned with the immediate future, usually a few weeks to several months . As the planning horizon for capacity planning is shortened, the methods tend to be more control oriented rather than planning oriented. In the short run, the capital equipment of a firm is generally fixed, so capacity must be adjusted by such methods as overtime, layoffs, extra shifts, schedule changes, and subcontracting.

1.2 MATERIALS REQUIREMENTS PLANNING SYSTEMS

Materials Requirements Planning (MRP) has changed the usual methods of production planning and control in a significant manner. Order-point methods previously were the standard for manufacturing inventory control [46,47,64]. This was mainly because there was no feasible way to process the large amounts of data involved with a method such as MRP until computers became widely available.

The basic function of MRP is to plan inventory for what are known as dependent demand items. A dependent demand item is one whose requirements are related in a known manner to some other item. The product structure defines the relationship of dependent demand items to an end-item. This is often referred to as an indented bill of materials [46,47,64].

An MRP system uses four inputs to determine material requirements. The master production schedule of end items defines what is to be produced when, and is the driving input to an MRP system. The MRP system also requires the product structure, the inventory and order status files as its other inputs.

Gross requirements are determined by running the master schedule against the bill of materials. The net requirements by planning period are then determined with the inventory and order status files. The planned lead time for each part is a key piece of information in this process, as the MRP system offsets the planned orders by the lead time through the product structure.

An important aspect of an MRP system is that it can generate and update priorities for all orders in the plant. Accurate work in proccess control is a prerequisite for this. The MRP system can also provide due date information for use in detailed scheduling [1,35].

The time-phasing of the material requirements makes the MRP system the useful tool that it is. However, there is a weak point in the rationale of the MRP system. An MRP system assumes that sufficient productive capacity exists to produce the items at the times they are required. If the master schedule is realistic, then this poses no major problem. If the master schedule places a strain on the existing capacity, perhaps requiring capacity above the stated norm, then some problems will arise on the shop floor. The most obvious result is growing backlogs (queues) at the work centers. The actual lead times will also increase.

The release of orders to production work centers and the capacity of those work centers need to be balanced in order have a smoothly operating production system.

1.3 CAPACITY REQUIREMENTS PLANNING/INFINITE LOADING

As an MRP system generates a time-phased material requirements plan, it can also process the materials requirements against the routing files for the materials to produce a time-phased Capacity Requirements Plan (CRP). The CRP states capacity requirements at the various work centers for each period of the planning horizon [50]. Implicit in this statement of requirements is the assumption that all work orders will be completed in their planned lead time.

The only difference between CRP and infinite loading is that infinite loading does not take into account planned orders, only released orders. While no plant can be loaded to infinite capacity, some idea of the capacity requirements is needed before loading the plant to a given capacity can begin [50].

1.4 FINITE LOADING

Finite loading is a method for loading orders into a plant in a priority order within the capacity constraints. The release of orders is rescheduled to accomodate the capacity constraint. The schedule of releases must be recalculated each time a priority change ocurrs. This problem is complicated by dependent priorities among components of higher level items. In practical applications the finite loading method may cycle endlessly, using vast amounts of computer time. Wight [50] refers to finite loading as "using 300 horsepower to blow the horn." Finite loading has some appeal since it apparently eliminates backlogs [64], but it really only postpones the release of some orders.

1.5 INPUT/OUTPUT CONTROL

Input/Output control (I/O control) is a capacity control method which is based on control of the queues at work centers. While there is a mathematical equivalence between I/O control and load/capacity analysis [63,32,33,34], the structure of I/O control is more amenable to practical implementations. The basic principle of I/O control is to adjust input and/or output of a work center based on the variations of the length (in standard hours) of the queue. An allowable range of the length of the queue is decided; when the queue exceeds the upper limit input is reduced or output is increased. When the queue falls below the lower limit input is increased or output is decreased.

Controlling input is generally more difficult than controlling output [50,28,29]. Input control is based on the order release process, but rescheduling lower level items may adversely impact the due date of parent items. Output control is more directly related to the actual capacity of the work center and is therefore easier to control by methods such as overtime, extra shifts, or layoffs.

Input/Output control is the only really useful tool available to shop floor managers for capacity control. It is already used on an informal basis by most managers; managers decide when to work overtime or pull orders early based on their observations of the backlog. The purpose of this research is to examine output control policies in an MRP shop.

1.6 SUMMARY

Capacity planning and control methods currently available are based on the master schedule and sales forecast. Knowledge of the work content of products by work center is used to perform long range capacity planning. Shorter range planning begins to address the time-phasing of capacity requirements, seeking to the answer question of when as well as how much capacity is required. A time-phased Capacity Requirements Plan can be produced with the help of an MRP system. As the planning interval is reduced to the immediate future capacity control methods take over. Machine load/capacity analysis and I/O control are the most often used methods in actual practice. Rescheduling orders to avoid apparent overloading is accomplished by finite loading procedures, but these procedures are costly in computer time and have the potential for endless iteration. I/O control methods seek to control the work in process levels within an acceptable range, and output as well as input (capacity and order release) are adjusted to achieve that objective.

Chapter II

REVIEW OF THE LITERATURE

2.1 INPUT/OUTPUT CONTROL

Input/Output control has received some attention in the literature recently. There is a distinction between Input/Output analysis as known in economics literature and Input/Output control as in production capacity control. In 1970 Wight [65] introduced the concept of I/O control to the production management world in his article in the Journal of Production and Inventory Management. Since that time several articles have appeared in the same journal on the subject.

Belt [5] suggests that work in process (WIP) be viewed as an investment subject to analysis by return on investment methods. Belt also recommends I/O control to manage WIP, but does not explicity define how this should be done. In a later article Belt [4] promotes I/O control but again fails to define any specifics of the method. Finally, Belt [3] supplies a trivial example, suggesting to his readers that they move marbles in and out of a matchbox to demonstrate how I/O control is "superior" to load/capacity analysis. Wemmerlov [63] rebukes Belt's matchbox theory by showing logical inconsistencies in Belt's definitions, and further shows mathematically the equivalence of I/O control and load/capacity analysis.

Irastorza and Deane [28,29] present a detailed order releasing scheme to balance workloads at a number of work centers. In an initial paper on the workload balancing method Deane [16] used a search procedure to select jobs within a time frame to route to a particular machine in order to balance the workloads in the period. A later development of this idea with Irastorza resulted in a mixed integer program formulation of the workload balance and job selection method. The objective was to minimize the deviation of work queue lengths from a specified value. The method was tested in a 10 machine job shop simulation. Job arrivals were a Poisson process with a varying rate. Due dates were assigned by summing operation times and adding a random slack. Two dispatching rules were also used, dynamic slack per remaining operations, and shortest processing time first. Significant reductions in work in process were observed, and a workload balance measure of merit was also improved. However, the experiment did not consider product structures as all jobs were one piece jobs. Capacity was also fixed so that the average utilization of the shop was 80 percent. This is an example of input control with fixed output.

The most detailed treatment of I/O plannning is given by Karni in three recent articles. Karni's first article [32] deals with the deterministic capacity requirements problem (CRP). Although the context of Karni's analysis is I/O control, he is really concerned with planning, not control. The planned input to a workcenter is given with an initial backlog and a minimum cost fixed capacity level over the planning horizon is determined by complete enumeration. An integer restriction is placed on the variables in the problem, so that an interminable search is not required. Karni's second article [33] discussed the case of variable capacity over the planning horizon. Tabular procedures are given for determining the minimum cost capacity plan with various constraints. Although the procedures are dynamic programming, they still require enumeration of solutions. Karni's third article [34] deals with a general CRP problem with numerous constraints. However, cost functions are not included in the analysis. The objective is to find feasible capacity plans that meet the constraints. Again, enumerative procedures are used to solve the problem. In all of these analyses, the planned input is considered as given. A single uncoupled workcenter is analyzed, and all variables in the problem (except lead time) are integer. It is important to note that Karni is examining planning rather than dynamic control policies. The constraints Karni deals with such as maximum queue size, minimum queue size, maximum capacity, minimum capacity, and so on, are given constraints of the problem rather than parameters of a dynamic control policy. Karni does not examine the sensitivity of his solutions to changing workloads on a dynamic basis. This shortcoming is similar in many respects to the Wagner-Whitin lotsize algorithm's sensitivity problems.

Buzacott [10] investigates a two machine job shop as a Markov process with limited storages (queues) and an order holding pool. The Jackson network assumptions are made except that release rules to the shop are independent of the number of operations and service times. The size of a queue is determined by the number of jobs in it rather than by the hours of work contained. Several central release rules are analyzed, with the highest utilization obtained with the idle machine rule. A close second was the balanced queue rule, which was optimal under certain conditions. The analysis was confined to two machines however, and it is shown that the results are completely general for any number of machines.

2.2 SHORT RANGE CAPACITY PLANNING

Caie and Maxwell [11] present a hierarchical machine load planning model that incorporates the bill of material, a bill of tool, work center information, lot sizing, and feasible machine-tool-part assignments. A combination of mathematical programming techniques are used to solve the model. Dynamic programming for consistent lot sizes across all levels is used with an embedded subgradient optimization method. The context of the model is the metal stamping industries and injection molding industries. The main focus is on the tool assignment problem. The model has been implemented in several factories using software systems developed specifically for that purpose.

Plossl [49] describes the basic production control functions of planning and controlling priorities and capacities. Plossl suggests increased use of computers for production problems. Plossl and Wight [50] provide one of the more detailed discussions of capacity. CRP (Infinite Loading), Finite Loading, and I/O control are compared as to their relative effectiveness and implementability. The basis for their discussion is experiential. Plossl indicates that finite loading is sophisticated but rather useless. Wight adds that finite loading techniques are far too costly in terms of computer time. Two finite loading programs from

IBM are discussed, CLASS, and the capacity planning module of PICS. Control of the master schedule is the only real way to avoid serious capacity problems they point out. Both Plossl and Wight recommend I/O control as the only really useable method for capacity planning and control.

Solberg's CAN-Q [55] is a stochastic flow model for analyzing capacity. The model is related to a deterministic counterpart, the bottleneck model. The shop is essentially a Jackson network with a material handler, also shown in [70]. Aspects of production that are neglected are blocked servers, limited storage, and costs. A simplifying assumption about the input process is that there is a constant number of units in the system.

2.3 AGGREGATE PRODUCTION PLANNING

A review of five approaches to aggregate planning is given by Eilon [19]. The approaches reviewed were: 1. HMMS (Holt,Modigliani,Muth,Simon) linear decision rule, 2. DE (Diezel,Eilon) rule for production with time lag, 3. management coefficients, 4. linear programming methods, 5. production switching method. All of these methods are forecast based and deal with the capacity problem on an aggregate level.

Fisk and Seagle [18] outline a long rang capacity planning method for evaluating master schedule feasibility. The linear decision rule is suggested for minimizing capacity change costs. Graziano [24] describes a long range capacity planning procedure. The procedure is essentially a look-ahead and look-back finite loading method.

Goodman [22] develops an aggregate planning model with six distinct costs: 1. basic production cost as function of rate, 2. production rate change costs, 3. work force level costs, 4. work force level change costs, 5. inventory holding costs, 6. shortage costs. The problem is formulated as a multi-stage decision problem with discrete opportunities for change of capacity and work force. A sectioning search method is used to minimize a cost based objective function.

A model incorporating stochastic capacity demands under a known fixed growth rate of aggregate demand is presented by Kalro [31]. Classes of capacity are identified with known probability distributions of their demands at each stage in the planning horizon. A stochastic linear program is formulated and results for three distributions of capacity demands are given.

Lunz [36] asserts that capacity requirements planning understates the requirements needed because of the omission of what he calls an Additional Planning Factor (APF). In essence, the APF acts like a performance rating for capacity. Lunz suggests modifying the APF to include things like holidays, absenteeism, and efficiency ratings in order to determine the "true" capacity.

Mather and Plossl [37] beleive that too much attention is focused on the priorities generated by MRP systems. Mather indicates that incorrect priorities will reduce effective capacity by loading the shop with unneeded orders. Plossl states that planned lead times do not need to coincide with actual experienced lead times, and that capacity control is the key to controlling lead times. Plossl also demonstrates a "vicious cycle" of lead time inflation for purchased parts from a capacitated vendor.

In the area of long range capacity requirements, Miller and Davis [39, 40] present a linear programming solution to the generalized machine requirements planning problem. The problem is analyzed as a resource allocation problem involving floor space, capital budget, and available overtime among various types of machines. The dynamic nature of the problem is included in the analysis, and a minimum cost plan of machine requirements by work center by year is produced by the model. An advantage of this model is generation of sensitivity information as a byproduct of the linear programming formulation.

Vollmann [59] cites a case study of a furniture manufacturer's capacity problems. The top management of the firm ignored consultants' advice to implement a capacity planning method. Later, one was installed and production performance improved. The point was made that smaller firms frequently ignore the capacity planning question.

2.4 MANUFACTURING LEAD TIMES

Actual manufacturing lead times are intimately related to work center backlogs and available capacity. Bellofatto [2] proposes three simple rules for reducing lead times. The rules act to keep work in process low and to keep the master schedule realistic. Belt [5] argues that lead time is a resource and must therefore be strictly controlled. Belt sees lead time as a thing that management gives to production personnel, much like a budget. Belt fails to suggest any definitive control methods.

Collier [13] presents one of the few quantitative analyses in the field of lead times. However, Collier deals specifically with statistical cum-sum methods to identify when a purchased part mean lead time has changed.

Diegel [17] presents a method for solving the perishable goods ordering problem (the classic newsboy problem). Diegel shows that uncertain lead times can be treated in a similar manner as uncertain demands. Diegel also shows the informational equivalence of different probability distributions.

Wolfmeyer [69] provides a generalized discussion of lead times and suggests I/O control methods for lead time management. The article reitirates Belt's previous ABC's of lead time management [5].

2.5 MASTER SCHEDULES

Civerolo [12] cites a case study of an overloaded plant. Discussion of how the problems were solved centers on the master schedule. Proud [52] gives a list of 12 ways to control the master schedule. His focus is on reconciling the sales forecast with the MRP and CRP systems through the master schedule.

Smolens [54] discusses problems in developing realistic master schedules. Smolens suggests load/capacity analysis to determine master schedule feasibility.

2.6 MRP AND MULTI-STAGE SYSTEMS

Articles on the MRP lot-size question abound. This is one of the most researchable areas of MRP systems from an academic point of view. The earliest work is the now well-known Wagner-Whitin dynamic lot size model [60]. Collier [14] presents a study of the interaction of various single-stage lot sizing models in an MRP system. The results are from a simulation experiment. Collier examines several product structures and makes recommendations based on his results. Orlicky [47] cites 22 references in his chapter on the MRP lot-size problem. Other aspects of MRP systems do not appear quite as frequently in the literature. However, Walker [61] presents a study of purchased parts planned lead times with lognormal distribution for three product structures. A simulation model was used to evaluate the cost performance of several policies and the results indicated that for certain parts the mean lead time may not be the most economic planned lead time.

Berry [7] indicates research needs in MRP decision making, bills of material coding, and MRP interaction with the informal production system. Orlicky [47] agrees that there are many areas open for research in the MRP field. Orlicky gives 12 areas in need of research in a section on research opportunities.

Huang [26] seeks to analyze an MRP/CRP system with a Q-GERT model. Two product structures of six total part numbers and three levels were modeled as a network with accumulating nodes. All component quantities per parent were one, with one exception of two per parent. Service times were normally distributed. The program did not perform bill of material processing and requirements explosion explicitly, rather this was imbedded in the particular network design. Also, no master schedule was used to drive the system. Components were generated exponentially and stored at acculumulate nodes until sufficient quantity existed for release of its parent order.

An investigation of a multi-stage production system and various operting rules is given by Goodwin and Goodwin [23]. A GPPS simulation model is used to evaluate three release date rules, six priority rules, and three priority update rules. The production system is modeled as a fixed converging branch network of 28 nodes. Hence, a product structure is defined by the lowest level operation node for each component. This constrains all product structures to be of four levels. The particular simulation experiment reported used three product structures. There is no explicitly maintained inventory, and components are assumed to exist plentifully. There is also no labor constraint. The service times at the next higher level in the production system/product structure are multiplied by a factor to balance the loads. This is required by the design of the production system. There is no master schedule for the system; instead, order arrivals are generated exponentially.

A feature of the model is that once an order has been released it remains in production node queues or in service until the finished end item leaves the system. One of the conclusions of the authors is that periodic updating of priorities in the system is not warranted. This process is referred to as "regeneration" even though in MRP systems that term typically refers to re-explosion of material requirements plans. The focus of the research is on scheduling rules. The model itself precludes any analysis of the capacity problem associated with MRP or in depth analysis of any other production shop configuraion or product structures.

A multi-stage production-inventory model by Jensen [30] attempts to define an optimal production schedule. The model is based on a known fixed rate of demand for one product that passes through multiple production stages and work in process inventories. Each stage produces at a fixed known rate greater than the demand rate so that it must be shut down and started up periodically. Different stages may produce at different rates. A procedure is developed to find a minimum cost startup/shutdown schedule for each stage using dynamic programming.

A formulation of an integrated material management system with many plants, many warehouses and intermediate warehouses is given by Uskup [56]. The problem is cast as a two-stage sequence problem similar to the traveling salesman problem but with due date and processing order constraints. Sufficient capacity is assumed and no late jobs are permitted. A branch and bound procedure is used to solve the two-stage formulation.

A dependent multi-product inventory model by Curry [15] is misleading. The definition of dependent in this case is joint-replenishment setup costs are less than independent replenishment costs. An [s,c,S] policy is analyzed. An [s,c,S] policy is applied to multiple items. If any item level drops below s, all items below c are ordered up to S.

Some unusual applications of MRP have been developed recently. Wilkerson [68] presents a manpower planning system for Air Force Minuteman missile maintenance. The model is based on component failure rates, repair actions, and total number of systems to maintain. The model produces a time phased requirements plan of varying skill groups of maintenance labor. Mitlevic [41] describes a financial application of MRP logic to inventory cash flow analysis and planning. Hershauer and Eck [25] discuss using MRP system logic for long range financial planning through an extended MRP system.

2.7 SUMMARY

The literature reviewed here has covered short range and long range capacity planning, MRP systems, and Input/Output control. Numerous articles on MRP systems have been published, mainly in the Journal of Production and Inventory Management. These articles are generally speculative, with few of them making any quantitative statements about MRP systems. As MRP becomes more widely used for manufacturing inventory and production control, the lack of quantitative information available about MRP systems will become more critical.

Input/Output control methods have received endorsement as the only practical way of handling backlogs. However, few studies have addressed the problems of deciding on a control policy and determining its operating parameters. This research will attempt to provide some useful definitions of Input/Output control policies available to the shop-floor manager, and give some guidance in the selection of parameters for those control policies.

Chapter III

EXPERIMENTAL METHOD

3.1 OBJECTIVES

The objectives of this investigation are as follows:

1. Develop an MRP/production system simulation model, and
2. Use the model to :
   a) Evaluate the effect of two output control policies on production system operating costs in an MRP production shop,
   b) Evaluate the effect of product structure on the operating characteristics of those policies, and
   c) Evaluate the effect of varying the control policy parameters.

From here on, frequent reference will be made to various mixes of product structure, so definition of terms used to describe product structures is given in table 1.

TABLE 1

Definition of Product Structure Terminology

FLAT - refers to product structures that have one or two levels of parts, and tend to spread out horizontally.

TALL - refers to product structures that have a relatively large number of levels and do not spread out horizontally, but rather extend vertically.

MIXED - refers to product structures that have the characteristics of both tallness and flatness within the one structure.

TALL & FLAT PRODUCT MIX - refers to several product structures, each of which is either flat or tall.

MIXED PRODUCT MIX - refers to several product structureseach of which may be classified as a mixed product structure.

3.2 OUTPUT CONTROL POLICIES

The objective of the experiment was to evaluate the effects two types of control policies and their associated parameters on the cost of production operations. Two general types of control policies were investigated, a simple production switching control [19] policy and a backlog reduction policy. The production switching (PS) policy operates as follows:

1. Two levels of production are specified, high and low; low may correspond to one shift per week, and high may correspond to two shifts per week.
2. A control limit (CL) is specified for the number of standard hours in the work center queue at the beginning of the work week.
3. If the number of standards hours in the work center queue at the beginning of the week exceeds the CL, the high production level is implemented for that week.
4. Otherwise, the low production level is implemented.

The parameters of this policy are the CL, and the low and high production levels (work week lengths).

The backlog reduction (BR) policy operates as follows:

1. A control limit is specified as for the production switching policy.

2. A reduction factor is specified, greater than zero.
3. A nominal (minimum) work week length is specified.
4. A maximum work week length is specified.
5. If the number of standard hours in the queue at the beginning of the work week is less than the CL the nominal work week length is implemented.
6. If the number of standard hours in the queue at the beginning of the work week exceeds the CL, the work week length is determined as follows: week length = nominal length + reduction factor x (queue length - CL). If the calculated week length exceeds the maximum length, then it is set to the maximum length.

The parameters of the backlog reduction policy are the CL, the reduction factor, and the work week lengths.

3.3 PRODUCTION COSTS

Although Goodman [22] lists six types of costs of production, previously noted in Chapter 2, only two types of costs were deemed pertinent for purposes of this investigation. Those costs were labor and inventory holding. Eilon [19] notes that work force level change, production level change, and shortage costs are difficult to assess. Labor and inventory costs were assessed by unit costs to permit sensitivity analysis of policy performance based on the ratio of labor to holding costs (R). Inventory costs were identified as the component inventory levels (finished components) and work in process level. Uniform holding cost for all parts was assumed. The average weekly total cost function was then as follows:

$$AWTC = C_1(AWL) + C_2(AI+AWIP) \qquad (3.1)$$

where

AWTC = Average Weekly Total Cost ($)

AWL = Average Weekly Labor Hours (hrs)

AI = Average Inventory Level (parts)

AWIP = Average Work In Process Level (parts)

C_1 = Hourly Labor and Burden Rate ($/hr)

C_2 = Weekly Holding Cost for Inventory and WIP ($/part wk)

Note: WIP is defined as all orders either being processed at a work center or waiting for processing in a work center queue.

Inventory is defined as the stock of components and subassemblies that have completed all processing on their routings.

By dividing the Equation (3.1) by C_1 the AWTC can be evaluated as a function of the ratio of labor costs to holding costs. This permits sensitivity analysis of the results to determine ranges of the ratio where one policy would dominate the others. The resulting cost function is then in terms of equivalent labor hours (ELH) per week :

$$ELH = AWL + (C_2/C_1)(AI + AWIP) \qquad (3.2)$$

$$ELH = AWL + R(AI + AWIP) \qquad (3.3)$$

where ELH = Equivalent Labor Hours per week

$R = C_2/C_1$

The result of Equation (3.3) is the average weekly cost of production in terms of equivalent labor hours. That is, the WIP and inventory holding costs have been converted to <u>labor hour equivalent units</u>. The AWTC for a specific value of C_1 is found by multiplying ELH by C_1. The Hotelling T^2 test will be used to determine significant differences in AWL, AI, and AWIP among the policies. The Hotelling test results are invariant under linear transformations of the data [42] so policies can be tested for significant differences before applying the cost coefficients to the results. Then only policies that are significantly different from each other need to be analyzed for sensitivity to the cost coefficients. Preliminary analysis of model results indicated that AWL, AI, and AWIP were correlated, so the Hotelling test was selected since it accounts for dependency in the data.

3.4 SIMULATION MODEL

A discrete event SLAM [51] simulation model was constructed to evaluate the control policies. Simulation was selected for two reasons: 1) detailed analysis of a complex MRP system is (relatively) easily accomplished, 2) simulation provides flexibility in experimental design.

3.4.1 Logic of the Model

The simulation model implements the standard MRP logic as shown in Figure 1. More detailed description of model logic is in Appendix A. While a simulation model, the model operates in essentially a deterministic manner. Since product structures and routings are fixed, the model processes entities in a known manner. The only source of variation in the model is from the master schedule. Using the same sequence of end item demands for each alternative reduced the variance of the estimators.

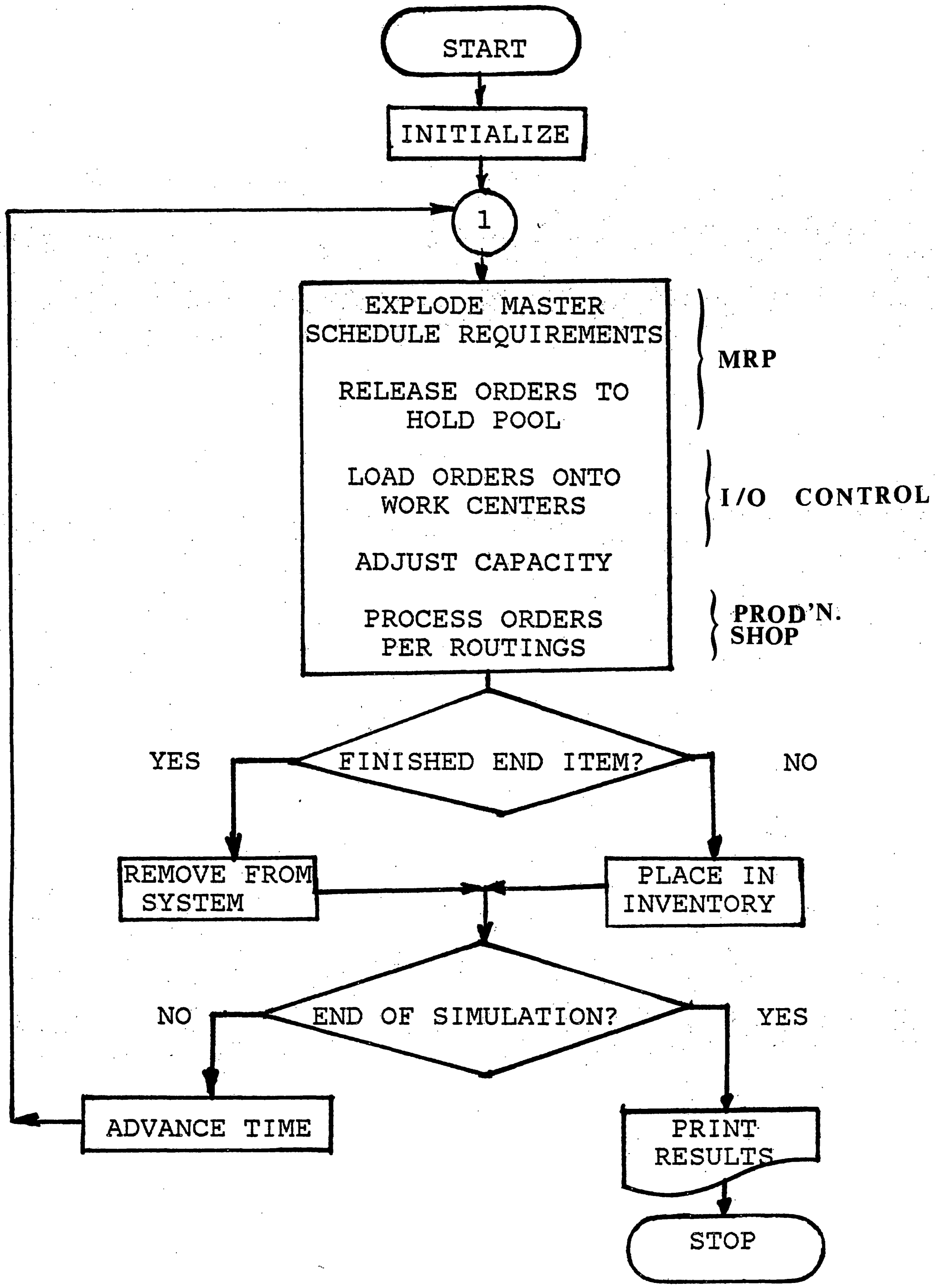

Figure 1: Logic of Simulation Model

3.4.2 Master Schedule

Pritsker [51] notes that trace driven models for comparing alternatives acheive variance reduction when the time series used affects both alternatives in a similar manner. The master schedule for the model is derived by exponentially smoothing a Poisson sequence of weekly demands for each end item. This is the only source of variation in the model, since in an MRP system only end items are of independent demand. Smoothing is applied to the time series to reflect the management practice of production leveling.

3.4.3 Bill of Material Processing

A simple method of product structure definition is used which requires only part number, quantity, parent record number, and level code for each node in the product structure tree. The bill of materials processor then determines component relationships and quantity requirements.

3.4.4 Explosion and Netting

At each MRP review the master schedule of end item requirements is exploded and component requirements are time phased according to their lead times. Net requirements are determined from gross requirements based on scheduled receipts and current inventory position. The net requirements are then converted to planned orders.

3.4.5 Order Release

Planned orders are released as they reach their planned release period. Released orders are placed into a holding pool. Since input control is not investigated here, all orders are released if possible. An order can be released if it requires no components. Assemblies can be released only if all the components are available in sufficient quantity. As an assembly is released its components are removed from stock. Released orders are loaded into the work center queue indicated by its first operation on its routing.

3.4.6 Production Shop

A standard shop simulator processes orders released to it from the holding pool. Routings are pre-defined for all parts and indicate the number of operations, the machine sequence, and standard and setup times for the operations.

As an order is completed, it is placed in inventory if it is a component, otherwise it is an end-item and is removed from the system.

3.4.7 Statistics Collection

The model automatically collects the following statistics:

1. Lead times for all parts,
2. Assembly and component blockage occurrences,
3. Starting backlogs by work center,
4. Work week lengths by work center,
5. Time in system for an order,
6. Time in shop for an order,
7. Time in holding pool for an order,
8. Order tardiness,
9. Total load in shop,
10. Total weekly labor,
11. Work center utilizations,
12. Component inventory levels,
13. Total inventory level,
14. Number of parts in shop (WIP),
15. Number of orders in shop, and
16. Queue statistics based on orders.

3.4.8 Model Validation

The validation process employed for the model was a logic verification procedure. The code was written in modules which performed specific functions in the model logic.

The bill of material (BOM) processor was the first module verified. Test data was developed so that complex structures would need to be processed. The results of the BOM module agreed with known solution derived manually. A second procedure in the BOM module phased the requirements into time buckets according to part lead times. This procedure also operated as designed.

Since the model was designed for lot for lot ordering the netting process is not required explicitly. That is, under lot for lot ordering the net requirements equal the gross requirements at any period in time.

The interface between the MRP modules and the production shop was designed to release all orders due for release to the shop. Traces of entity processing showed that this module also operated as designed.

The production shop modules used fairly standard job shop simulation logic. Again, these modules also were verified.

Since there are no analytical queueing models that describe a complex system such as modeled here, no validation of queueing parameters was possible. However, the extensive logic verification described above showed that the code indeed operated as designed.

3.5 EXPERIMENTAL DESIGN

As stated earlier, two types of control policy were the subject of investigation. Figure 2 shows the experimental production system. A factorial design with two control policies, two and three levels of policy parameters, and four types of product structure mixes was used. The nomenclature for referring to the individual experiments is shown in Table 2.

3.5.1 Product Structures

Since product structure could influence control policy performance four mixes of product structure were generated. The first mix was flat products only, with four different end items. A flat product is one whose structure consists of only the end item itself or one level of components below it. The second mix was four tall products. A tall product is one whose structure consists mainly of vertical relationships. The third mix was 3 flat products and 3 tall products. The fourth mix was 4 mixed product structures. A mixed product structure has both tall and flat characteristics. These specific product structures are shown graphically in Figures 3 - 9.

TABLE 2

Nomenclature for Experiment Reference

An experiment is referred to by a number and a letter code, such as 2B. The number portion refers to one of four product structures used:

1 : Flat Product Structures
2 : Tall Product Structures
3 : Tall & Flat Product Structures
4 : Mixed Product Structures

The letter portion of the reference indicates the control policy used for that experiment. These letter codes are shown below:

Letter	Policy	Control Limit	Reduction Factor
A	Production Switching	80 std. hrs.	Not used
B	Production Switching	120 std. hrs.	Not used
C	Backlog Reduction	80 std. hrs.	0.75
D	Backlog Reduction	120 std. hrs.	0.75
E	Backlog Reduction	80 std. hrs.	1.25
F	Backlog Reduction	120 std. hrs.	1.25

Example: 3C refers to the experimental set with the Tall&Flat product structures (3) with the Backlog Reduction policy (C) with a control limit of 80 std. hrs. and a reduction factor of 0.75 .

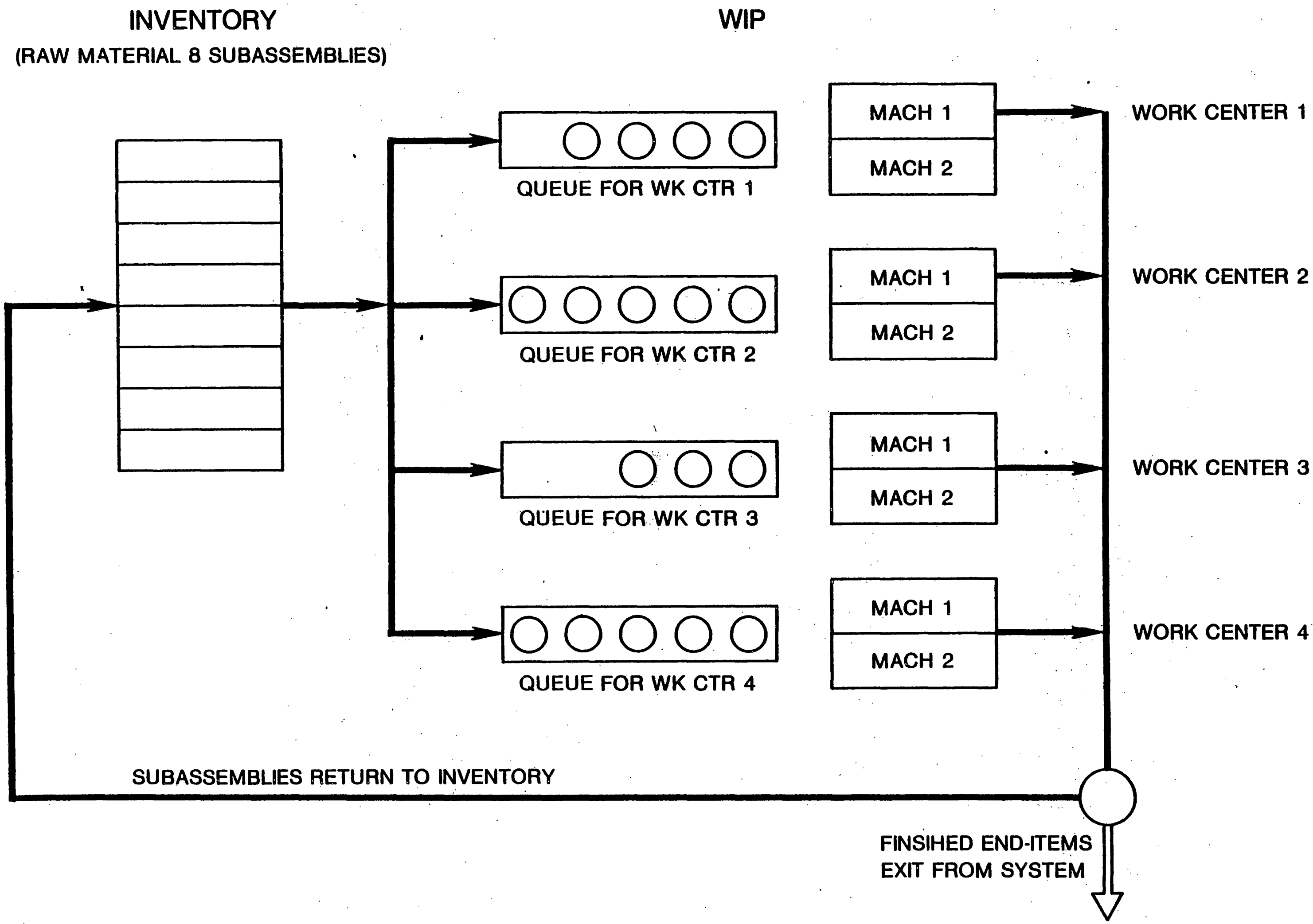

FIGURE 2. EXPERIMENTIAL PRODUCTION SYSTEM

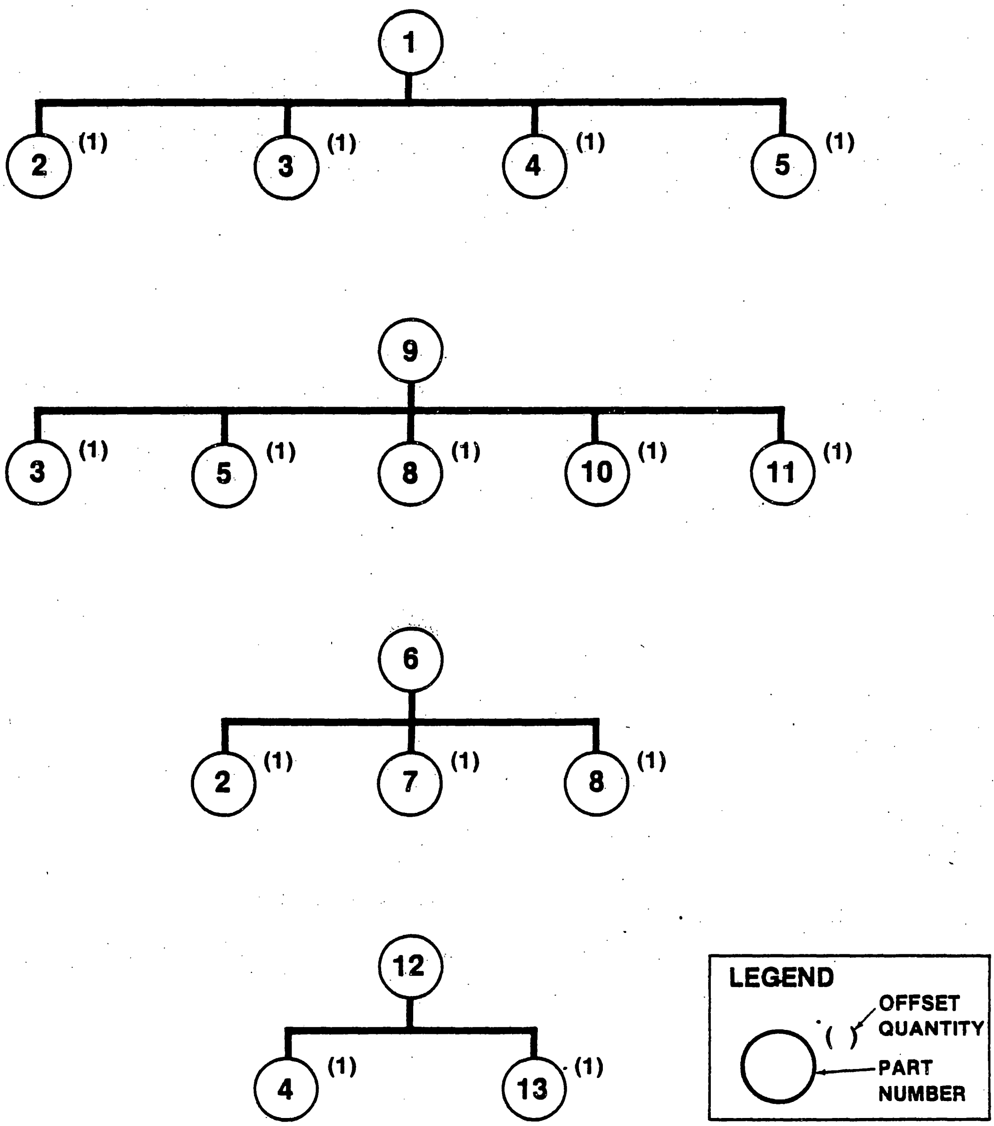

FIGURE 3. FLAT PRODUCT STRUCTURES

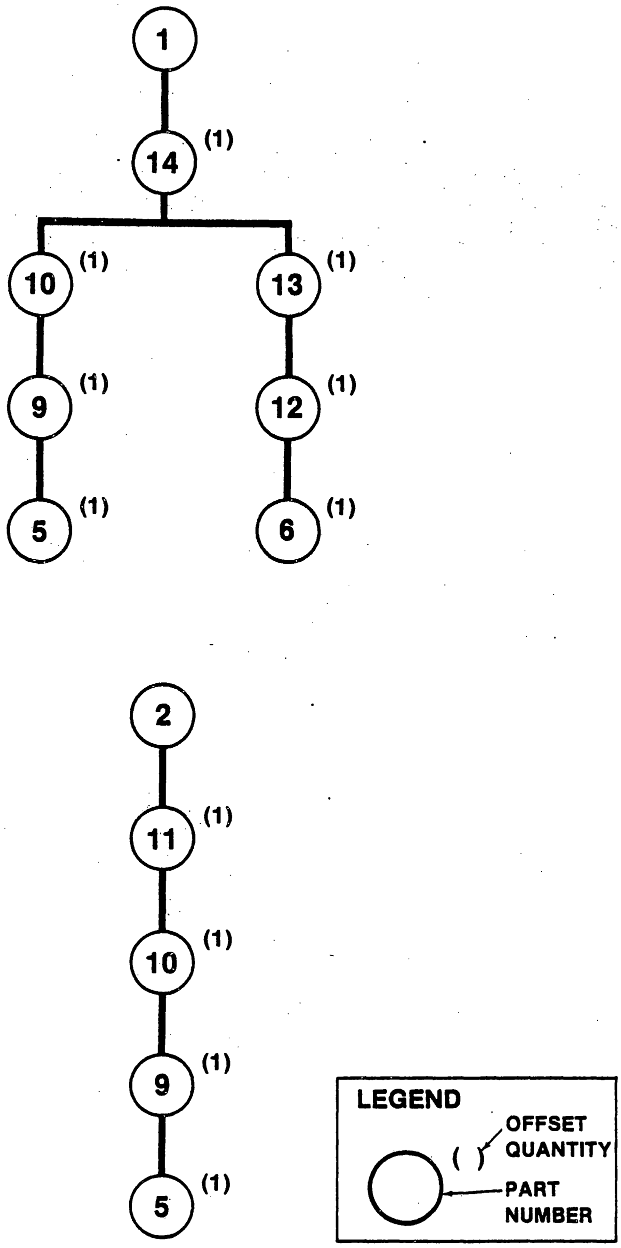

FIGURE 4. TALL PRODUCT STRUCTURES

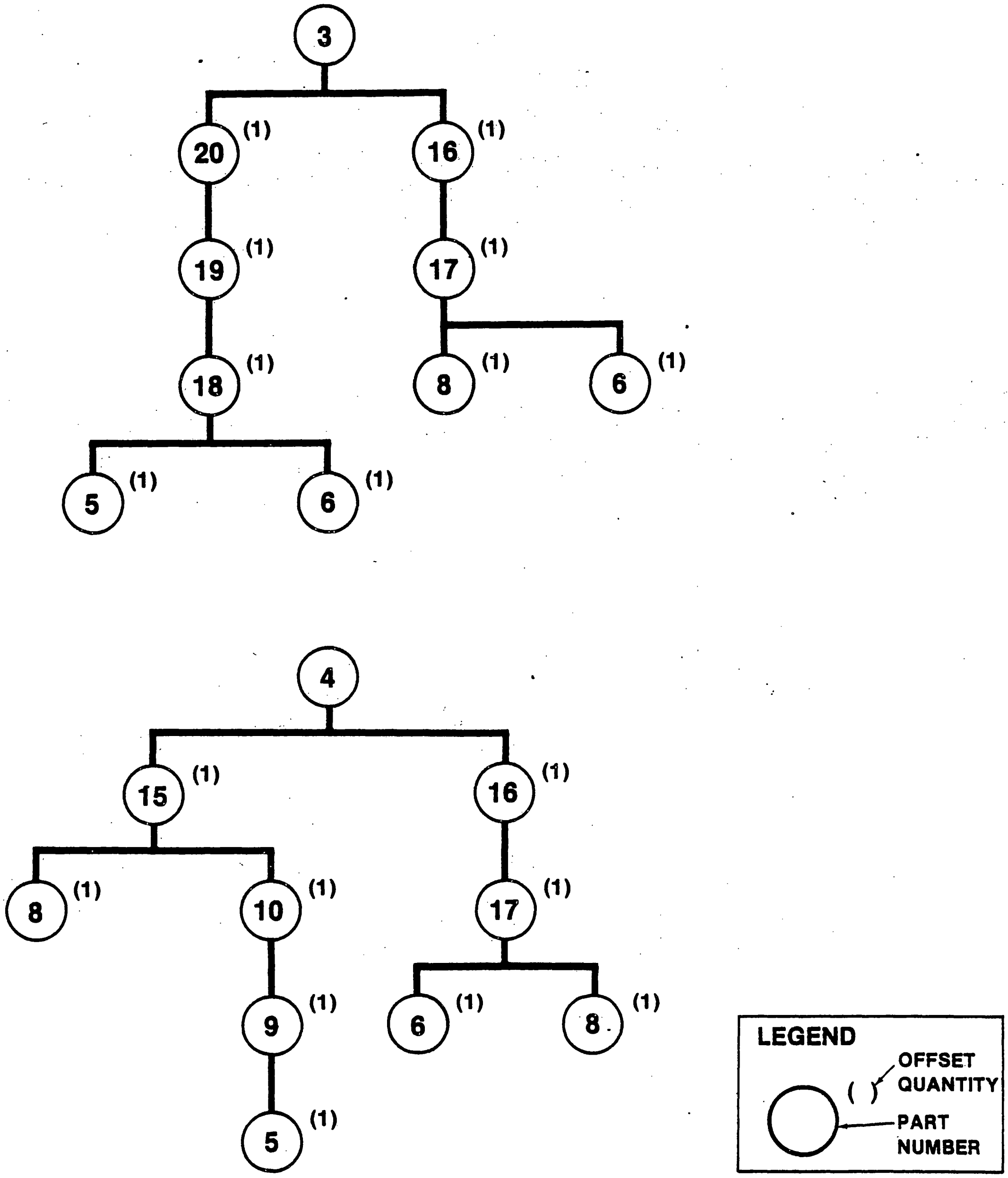

FIGURE 5. TALL PRODUCT STRUCTURES

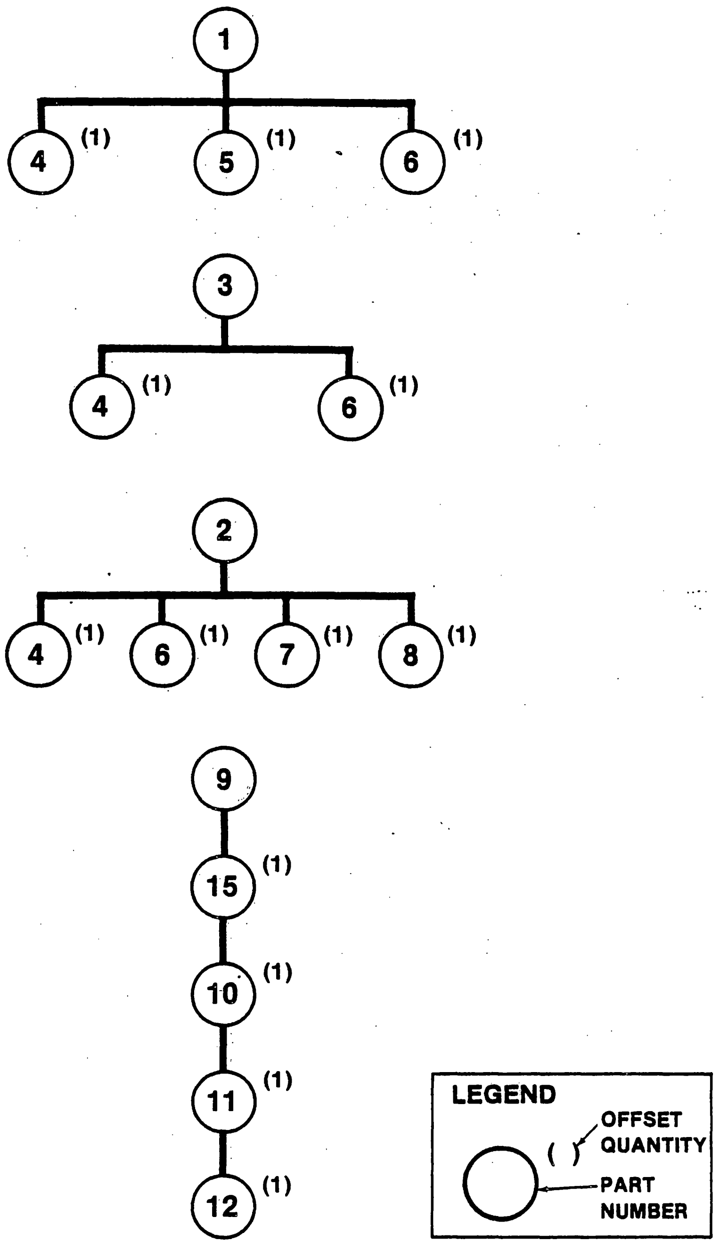

FIGURE 6 . TALL & FLAT PRODUCT STRUCTURES

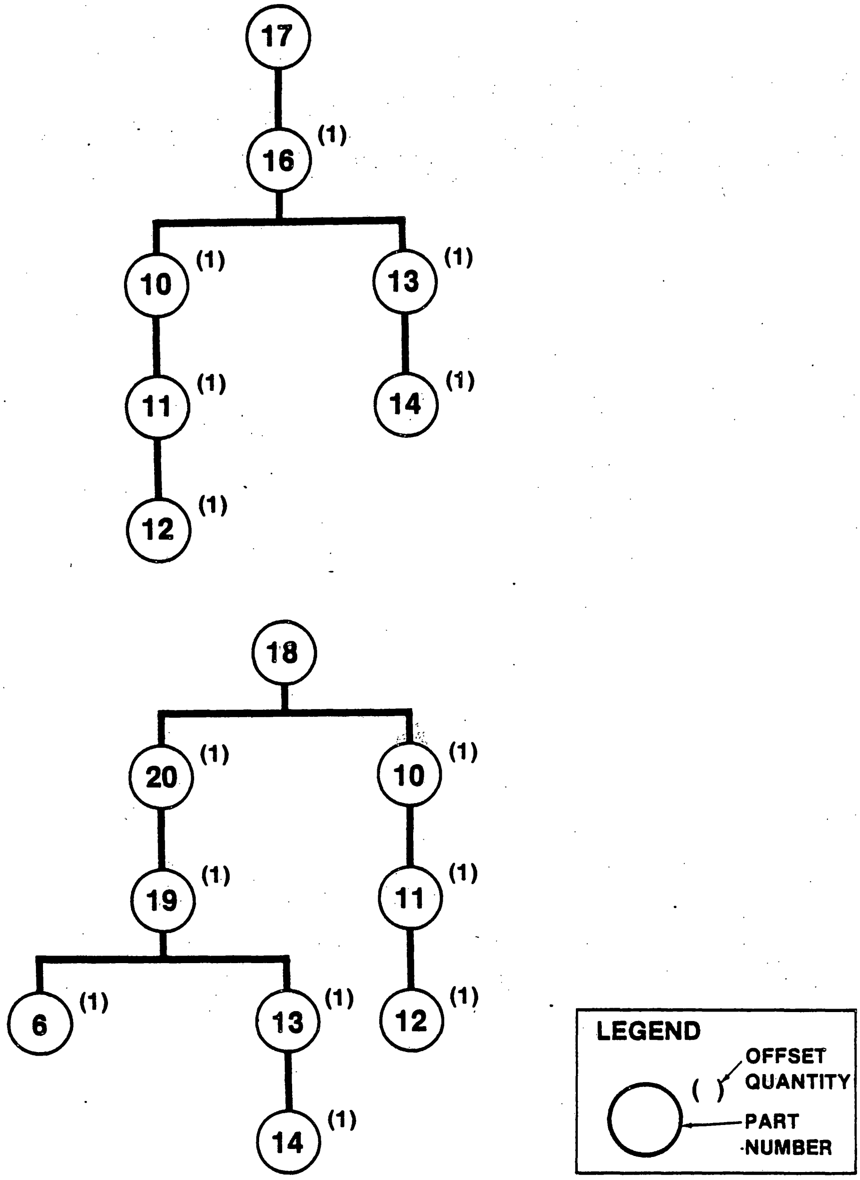

FIGURE 7. TALL & FLAT PRODUCT STRUCTURES

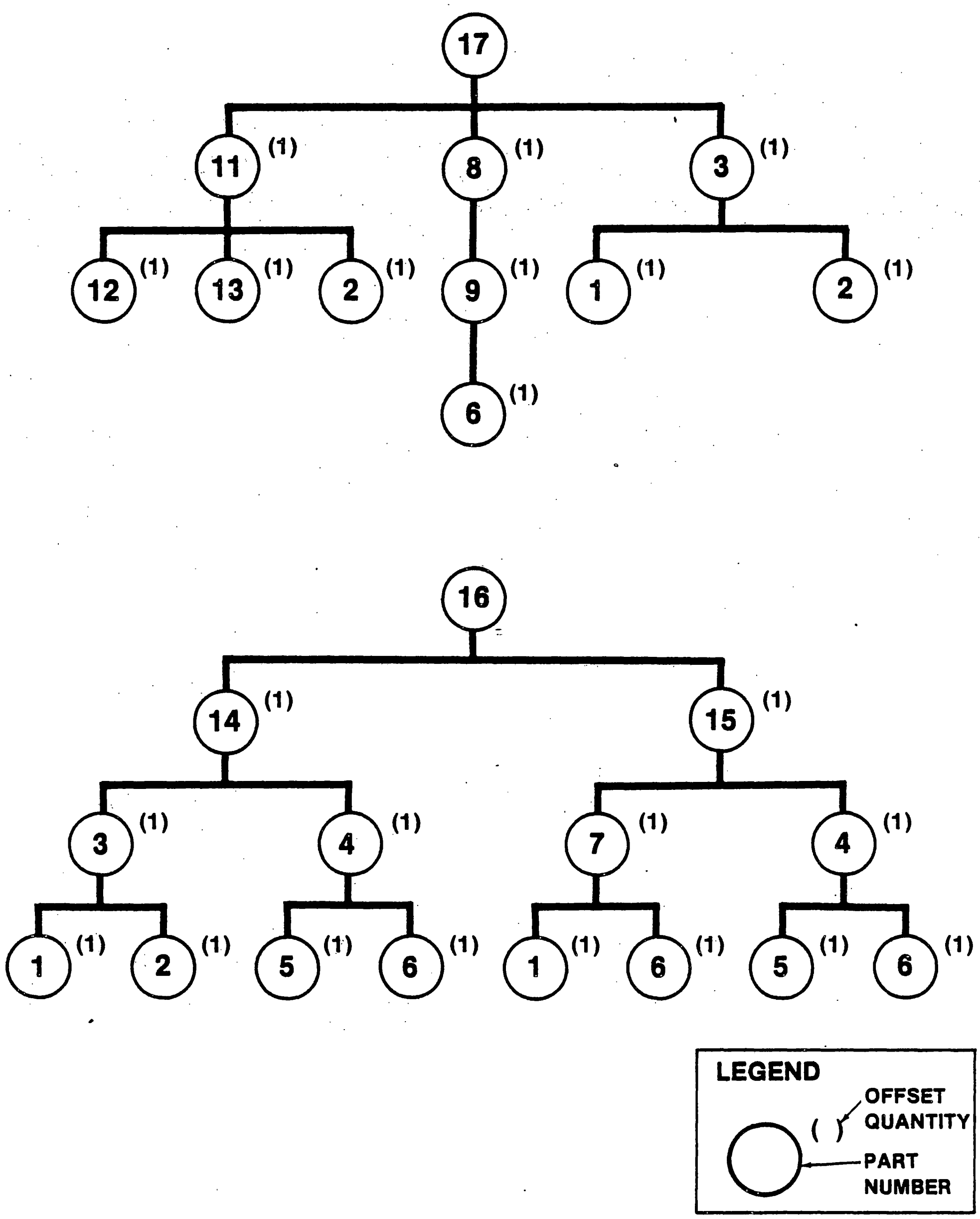

FIGURE 8. MIXED PRODUCT STRUCTURES

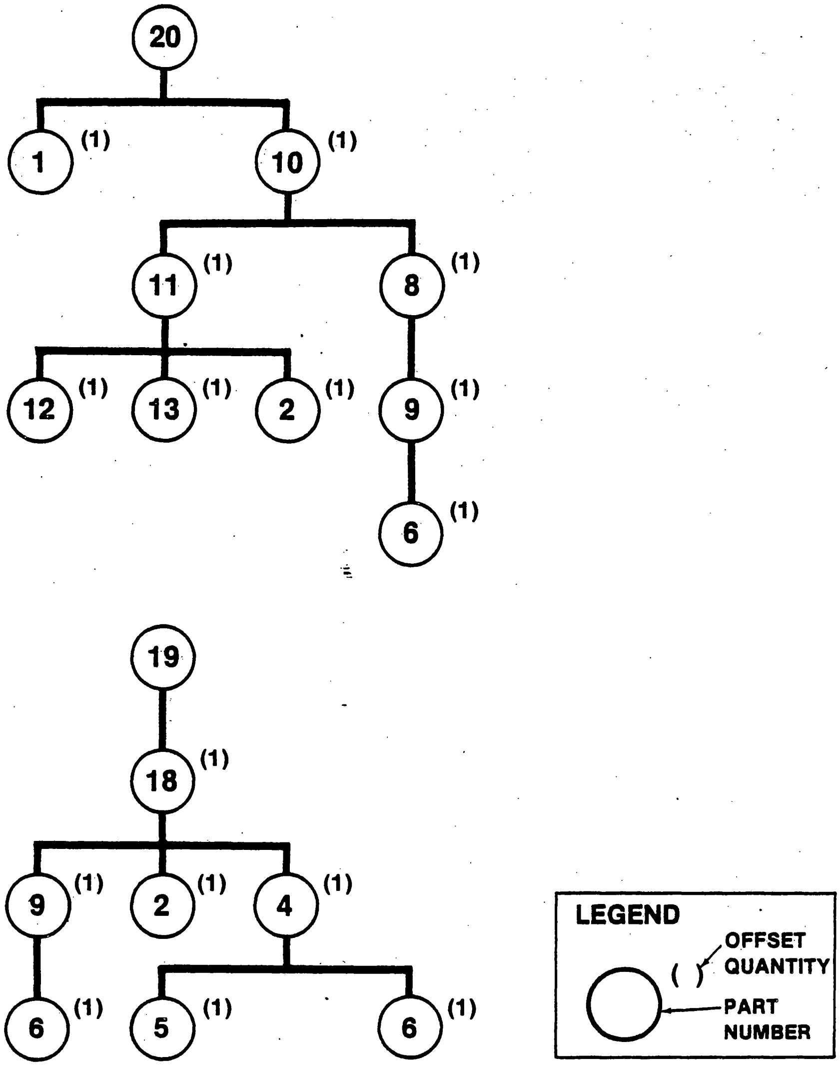

FIGURE 9. MIXED PRODUCT STRUCTURES

TABLE 3

Experimental Design

Run no.	PS	Policy	RF	CL
1A	FLAT	HL	NA	80
1B	FLAT	HL	NA	120
1C	FLAT	BR	0.75	80
1D	FLAT	BR	0.75	120
1E	FLAT	BR	1.25	80
1F	FLAT	BR	1.25	120
2A	TALL	HL	NA	80
2B	TALL	HL	NA	120
2C	TALL	BR	0.75	80
2D	TALL	BR	0.75	120
2E	TALL	BR	1.25	80
2F	TALL	BR	1.25	120
3A	FLAT&TALL	HL	NA	80
3B	FLAT&TALL	HL	NA	120
3C	FLAT&TALL	BR	0.75	80
3D	FLAT&TALL	BR	0.75	120
3E	FLAT&TALL	BR	1.25	80
3F	FLAT&TALL	BR	1.25	120
4A	MIXED	HL	NA	80
4B	MIXED	HL	NA	120
4C	MIXED	BR	0.75	80
4D	MIXED	BR	0.75	120
4E	MIXED	BR	1.25	80
4F	MIXED	BR	1.25	120

NA : Not applicable
HL : High/Low production switching
BR : Backlog Reduction
CL : Control Limit
RF : Reduction Factor
PS : Product Structures

3.5.2 Routings

Routings were generated randomly for each set parts associated with a product structure mix. The number of operations was uniformly distributed between 2 and 6. Operation times were normally distributed with mean 0.10 and standard deviation of 0.05 (negative values rejected) Setup times were fixed at a constant 0.01 . (All time units are hours). Quantity multipliers were set at 1 for all parts, since the quantity multiplier and the operation time are directly related. Details of the routings are in Appendix C with the product structure information. Note that the generation of routings was performed only once for each set of product structures. The routings then served as deterministic input data to the shop simulator.

3.5.3 Master Schedule and Demand Rates

For each set of product structures the same master schedule drove the system. This is a "trace driven" design, and reduces the variance of estimators. Demand rates were set to load the shop at 105 percent of nominal capacity on average. This was based on the loading report generated by the model (see Appendix C). The smoothing factor for all experiments was set at 0.15 . The demand rates for individual items within a product mix were adjusted relative to each other in order to balance the workload at each work center. However, due to the nature of the routings, perfect balance was not possible for the mixed and tall/flat product mixes.

3.5.4 Lead Times

A common industry practice for determining lead times is to allow one week per operation. This was tried in preliminary experiments, but certain parts with longer operation times or more operations continued to cause blockages of their parent assemblies. Lead times for these parts were then increased until the blockage was eliminated or reduced to a very low level. The planning horizon length was set to the maximum cumulative lead of the end items produced. This is a necessary practice in MRP systems to insure capturing all requirements within the planning horizon.

3.5.5 Lot Sizing

Lot for lot ordering was used for all experiments. Orlicky [47] notes that lot for lot ordering results in minimal inventory holding costs. Since inventory holding costs were part of the total cost function discussed in Section 1, using an ordering policy that minimized holding costs for all alternatives provided a common basis for comparing the effect of the output control policies on inventory. One assumption in the analysis of MRP lot sizing procedures is that the planned lead times are equal to the actual manufacturing or delivery lead times. Usually this is not so in actual production plants. If planned lead times are much longer than actual lead times then the average inventory level will be higher than if the actual and planned lead times were equal. Since lead times were maintained at constant values throughout a product structure mix, the difference between actual lead time and planned lead time would be due to the control policy solely.

3.5.6 Priority Rule

Preliminary experiments with eleven priority rules showed that only one rule, SOT, resulted in any difference in system performance. The SOT rule reduced the occurrence of blockages due to component shortage. The rules tested were:

1. Shortest Operation Time First (SOT)
2. Static Slack (SS)
3. Static Slack per Remaining Processing Time (SS/PT)
4. Static Slack per Remaining Operations (SS/RO)
5. First in System First Served (FISFS)
6. Dynamic Slack (DS)
7. Dynamic Slack per Remaining Processing Time (DS/PT)
8. Dynamic Slack per Remaining Operations (DS/RO)

9. C over T (COVERT)
10. Due Date (DD)
11. First Come First Served (FCFS)

Although the SOT rule performs well under high shop utilization it is generally not used in an MRP production shop. Since the MRP system provides due date information, some type of rule that uses that information is more often the choice. The MRP system allows the weekly updating of priorities of open shop orders, and weekly updates are common industry practice. The priorities from the rules above are usually not updated in typical job shop simulations [9]. Since MRP systems do permit the weekly priority updates, the rules listed above were modified for dynamic update forms. This involved altering the priority formulae to account for past due order priorities properly. Buffa refers to this as relative slack priority [9]. The Static Slack rule with weekly update was selected for use in the investigations.

3.5.7 Work Centers

Four work centers with two machines each were used for all experiments. Nominal week length was 40 hours. Maximum week length was 80 hours. Capacity is the week length times the number of machines, so nominal capacity was 80 hours per week, and maximum capacity was 160 hours per week for each work center. Buffa [9] notes that the number of machines in a job shop simulation model has never been shown to be a significant variable.

3.6 SAMPLE SIZE

Reliable estimates of three quantities were desired: average number of hours worked per week, average total inventory level, and average work in process level. Preliminary runs were made for all product mixes, plotting the value of these estimators as a function of the number of weeks of simulated production. Examination of these plots indicated that all estimators varied less than 1% from one observation to the next after 550 simulated weeks. Statistics were cleared after 50 weeks. This gave a sample size of 500 weeks for all runs. All experiments were replicated 11 times to give independent samples of AWL, AI, and AWIP. Independent replications then guaranteed the multi-variate normal sampling distribution required by the Hotelling T^2 test.

3.7 SUMMARY

This chapter presented the experimental objectives and the design of the experiment. A SLAM simulation was developed to model MRP/production systems within the constraints of the experimental design, and two capacity control policies were defined, the production switching (PS) and backlog reduction (BR) policies. A linear cost function (Equation 3.3) based on the ratio of the weekly holding cost per part to the cost per hour for direct labor was defined. A brief overview of the simulation model logic was given, and further detail is in Appendix A, MRPSIM User's Guide.

The experiment using the MRP/production simulation model was based on two control policies and four different mixes of product structure types. For all experiments the master schedule loaded the system at 105 percent of nominal capacity. A single priority rule, Static Slack, was used throughout. Lot for lot ordering was also used throughout.

Chapter IV

RESULTS

4.1 INTRODUCTION

The information presented here is divided into four major sections, as indicated below.

1. Definition of the statistical test used, and the cost sensitivity analysis,
2. Means and standard deviations for weekly labor, total inventory, and work in process.
3. Results of the Hotelling T^2 test.
4. Cost sensitivity analysis.

4.2 STATISTICAL AND COST ANALYSIS PROCEDURES

4.2.1 Hotelling T^2 Test

The Hotelling T^2 test is used to test the hypothesis that two samples were drawn from a multivariate normal population. The null hypothesis then is that the mean vectors of each sample are equal. The alternative hypothesis is that the mean vectors are not equal. The test is stated completely below:

$$H_0 : u_1 = u_2$$

$$H_1 : u_1 \neq u_2$$

The test statistic is:

$$T^2 = [(N_1N_2)/(N_1+N_2)]\bullet(X_1-X_2)'S^{-1}(X_1-X_2)$$

where

N_1 = sample 1 size

N_2 = sample 2 size

X_1 = vector of means for sample 1

X_2 = vector of means for sample 2

S = pooled covariance matrix

p = dimension of mean vectors

The decision rule for a test at the α level is:

Accept $H_0 : u_1 = u_2$ if

$$T^2 \leq [(N_1+N_2-2)p/(N_1+N_2-p-1)]\ F(\alpha;p,N_1+N_2-p-1)$$

and reject otherwise.

As noted earlier, this test is invariant under linear transformations of the data [42]. Therefore, significant differences in weekly labor, inventory level, and work in process level may be detected without applying cost coefficients to the results. Within the major subdivision of product structure, this test is applied pairwise to the six policy alternatives. This gives 15 combinations tested for each product structure.

The test was selected to evaluate the policies because there is reason to believe that weekly labor, inventory level, and work in process levels are dependent. Correlation matrices were produced with SAS. The correlations indicated a dependency between the three measures that is significant at the 0.05 level for most policies.

The assumption of the Hotelling test is that the covariance matrices of each sample population are equal. However, this assumption does not need to be explicitly tested beforehand. Ito and Schull [27] note that the significance of the test is in no way diminished by unequal covariance matrices if the sample sizes are equal. Also, the power function of the test is not affected if the samples are large. Since equal sample sizes are used throughout the application of the test, the possibility of unequal covariance matrices does not affect the robustness of the test.

A program written in the MATRIX sub-language of SAS was used to perform the test. The program appears in Appendix B.

4.2.2 Cost Sensitivity Analysis

The cost function given in Chapter 3 as Equation (3.3) is a parametric cost function based on the ratio of weekly holding cost per part to cost per hour of labor and burden.

Since the estimators of labor are given in hours per week the cost coefficients so defined are compatible in terms of units. The maximum likelihood estimators for weekly labor, inventory level, and work in process level are the means, which are also unbiased estimators. These means may then be used to determine the weekly Equivalent Labor Hours (ELH).

A reasonable range of labor and burden cost is from $10 to $100 per hour. A reasonable range of the holding cost is based on the time value of money (interest rate) and the value of a part. Other cost factors contribute the actual holding cost a firm experiences, such as warehouse costs, insurance, and security. However, a reasonable estimate of the holding cost range is found from the opportunity cost. If the interest is set at 10% annually and part values range from $0.00 to $500,000 the weekly holding costs range from 0.0 to 961.53 $/week/part. This range of values would apply to most manufacturing operations today. Combining the low and high values of labor and holding costs the range of their ratio is then 0.0 to 16.0255. Within this range of values the cost function for each policy is evaluated to determine the range of values where it dominates the others in terms of minimizing weekly cost. A simple computer program used for this purpose appears in Appendix B. The information generated by this analysis is a range of the values of the cost ratio where one policy dominates all others in terms of minimizing weekly equivalent labor hours (ELH).

4.3 SIMULATION RESULTS

Table 4 shows the means and standard deviations for weekly labor, work in process level, and inventory level for each of the 24 experiments.

TABLE 4

Simulation Results

Exp.No.	Labor (hrs/wk)		Inventory[1]		Work in Process	
	mean	SD	mean	SD	mean	SD
1A[2]	344.4	1.81	1453.8	66.4	2791.1	55.8
1B	336.9	1.29	1961.1	136.7	4658.1	138.1
1C	336.7	1.30	1767.9	66.9	4454.9	83.6
1D	335.6	1.34	2781.3	89.8	7140.8	148.1
1E	337.3	1.36	1625.0	63.5	3852.5	83.8
1F	335.9	1.50	2668.1	172.8	6407.4	91.7
2A[3]	352.4	3.07	1053.1	22.0	1967.7	36.9
2B	340.3	3.27	1003.4	27.9	3228.2	92.5
2C	339.6	3.27	992.5	20.8	3067.0	81.8
2D	334.9	3.32	1108.1	42.8	4707.2	120.7
2E	341.8	3.40	984.8	25.3	2621.5	54.0
2F	336.7	3.22	1074.1	50.1	4250.3	126.5
3A[4]	361.6	1.57	1613.3	39.3	2245.9	23.4
3B	353.4	1.32	2180.0	106.7	3761.8	37.3
3C	354.3	1.35	2823.8	131.3	4025.2	61.8
3D	353.4	1.28	3851.8	187.8	5897.5	71.9
3E	355.4	1.43	2062.2	69.5	3487.9	24.8
3F	353.4	1.42	3000.9	142.6	5269.8	116.3
4A[5]	353.0	1.34	2061.8	24.6	2332.4	31.7
4B	345.9	1.10	1742.6	55.4	3674.7	133.7
4C	345.7	1.32	1663.6	29.1	3611.8	47.2
4D	343.8	1.19	2547.8	123.2	5540.2	102.9
4E	346.2	1.45	1676.4	28.4	3192.7	43.4
4F	344.1	1.32	2271.6	107.8	4975.2	84.7

Sample Size=11 replications,550 wks;cleared at week 50
[1]Unit of measure for INVENTORY and WIP is (parts); these two statistics are time-integrated averages.
[2]Flat Product Structures
[3]Tall Product Structures
[4]Tall and Flat Product Structures
[5]Mixed Product Structures

4.4 STATISTICAL TEST RESULTS

The pairwise tests of mean vectors with the Hotelling T^2 test for each product structure are shown in Tables 5,6,7, and 8.

TABLE 5

Flat Product Structure : T^2 Test Results

Exp. Pair	T^2	F	1.-P(F)[1]
1A-1B	2061.9	618.6	0.
1A-1C	3328.5	998.5	0.
1A-1D	13171.6	3951.5	0.
1A-1E	1247.1	374.1	0.
1A-1F	13127.0	3938.0	0.
1B-1C	29.8	8.9	0.0007
1B-1D	2703.3	811.0	0.
1B-1E	332.5	99.8	0.
1B-1F	1914.4	574.3	0.
1C-1D	6194.6	1858.4	0.
1C-1E	370.3	111.1	0.
1C-1F	5287.4	1586.2	0.
1D-1E	6746.5	2023.9	0.
1D-1F	320.1	96.0	0.
1E-1F	5819.1	1745.7	0.

Sample size = 11; Degrees of freedom for F = (3,18)
[1] 1.-P(F) = significance level of test

TABLE 6

Tall Product Structure : T^2 Test Results

Exp. Pair	T^2	F	1.-P(F)[1]
2A-2B	5754.8	1726.4	0.
2A-2C	6901.5	2070.5	0.
2A-2D	10903.5	3271.0	0.
2A-2E	2731.0	819.3	0.
2A-2F	9415.8	2824.7	0.
2B-2C	50.9	15.3	0.
2B-2D	2361.5	708.4	0.
2B-2E	683.1	204.9	0.
2B-2F	1349.9	418.5	0.
2C-2D	3651.2	1095.3	0.
2C-2E	605.4	181.2	0.
2C-2F	2226.3	667.9	0.
2D-2E	4998.9	1499.7	0.
2D-2F	195.6	58.7	0.
2E-2F	3191.5	957.4	0.

Sample size = 11; Degrees of freedom for F = (3,18)
[1] 1.-P(F) = significance level of test

TABLE 7

Tall/Flat Product Structure : T^2 Test Results

Exp. Pair	T^2	F	1.-P(F)[1]
3A-3B	16154.2	4846.3	0.
3A-3C	9536.6	2864.0	0.
3A-3D	29273.9	8782.2	0.
3A-3E	15272.2	4581.7	0.
3A-3F	7822.3	2346.7	0.
3B-3C	353.9	106.2	0.
3B-3D	9886.7	2966.0	0.
3B-3E	596.5	178.9	0.
3B-3F	1978.5	593.5	0.
3C-3D	5420.5	1626.1	0.
3C-3E	1059.0	317.7	0.
3C-3F	984.5	295.4	0.
3D-3E	13213.4	3964.0	0.
3D-3F	367.8	110.4	0.
3E-3F	2852.1	856.6	0.

Sample size = 11; Degrees of freedom for F = (3,18)
[1] 1.-P(F) = significance level of test

TABLE 8

Mixed Product Structure : T^2 Test Results

Exp. Pair	T^2	F	1.-P(F)[1]
4A-4B	3119.8	938.0	0.
4A-4C	8852.7	2655.8	0.
4A-4D	16629.1	4988.7	0.
4A-4E	5193.2	1557.0	0.
4A-4F	11984.1	3595.2	0.
4B-4C	17.6	5.3	0.008
4B-4D	2713.0	814.0	0.
4B-4E	181.7	54.5	0.
4B-4F	1254.7	376.4	0.
4C-4D	5355.4	1606.6	0.
4C-4E	658.8	197.6	0.
4C-4F	2932.9	879.9	0.
4D-4E	6730.1	2019.1	0.
4D-4F	254.9	76.5	0.
4E-4F	4378.3	1313.5	0.

Sample size = 11; Degrees of freedom for F = (3,18)
[1]1.-P(F) = significance level of test

4.5 COST RATIO SENSITIVITY ANALYSIS

Table 9 shows the range of the cost ratio where a particular policy (shown by its experiment number) minimized weekly operation cost as measured in equivalent labor hours (ELH). The cost sensitivity analysis treats each product structure mix separately. The table is ordered by product structure and by order of policy preference with increasing R. Figures 10-13 show graphically the cost functions for each control policy (A-F) for each product structure mix.

TABLE 9

Ranges of the Cost Ratio R where Policies Acheive Minimum Cost

Policy	Lower Bound	ELH[1]	Upper Bound	ELH
1D[2]	0.000000E 00	335.64	0.307098E-03	338.63
1C	0.307098E-03	338.63	0.764803E-03	341.48
1E	0.764803E-03	341.48	0.572791E-02	368.66
1A	0.572791E-02	368.66	0.160255E 02	68262.06
1F	Not optimal over any interval			
1B	" " " " "			
2D[3]	0.000000E 00	334.90	0.267696E-02	350.47
2C	0.267696E-02	350.47	0.485426E-02	359.31
2E	0.485426E-02	359.31	0.181039E-01	407.09
2A	0.181039E-01	407.09	0.160255E 02	48685.20
2F	Not optimal over any interval			
2B	" " " " "			
3F[4]	0.000000E 00	353.40	0.000000E 00	353.40
3B	0.000000E 00	353.40	0.393748E-02	376.80
3A	0.393748E-02	376.80	0.160255E 02	62108.80
3C	Not optimal over any interval			
3D	" " " " "			
3E	" " " " "			
4D[5]	0.000000E 00	343.80	0.356692E-03	346.68
4F	0.356692E-03	346.68	0.883145E-03	350.36
4C	0.883145E-03	350.36	0.123062E-02	352.19
4E	0.123062E-02	352.19	0.143190E-01	415.92
4A	0.143190E-01	415.92	0.160255E 02	70660.19
4B	Not optimal over any interval			

[1]ELH = AWL + R(AI+AWIP), where ELH=Equivalent Labor Hours (Cost), AWL=Average Weekly Labor, R=Ratio of Weekly Inventory Holding Cost to Hourly Labor-Burden rate,AI=Average Inventory,AWIP= Average Work in Process
[2]Flat Product Structures, [3]Tall Product Structures
[4]Tall and Flat Product Structures
[5]Mixed Product Structures

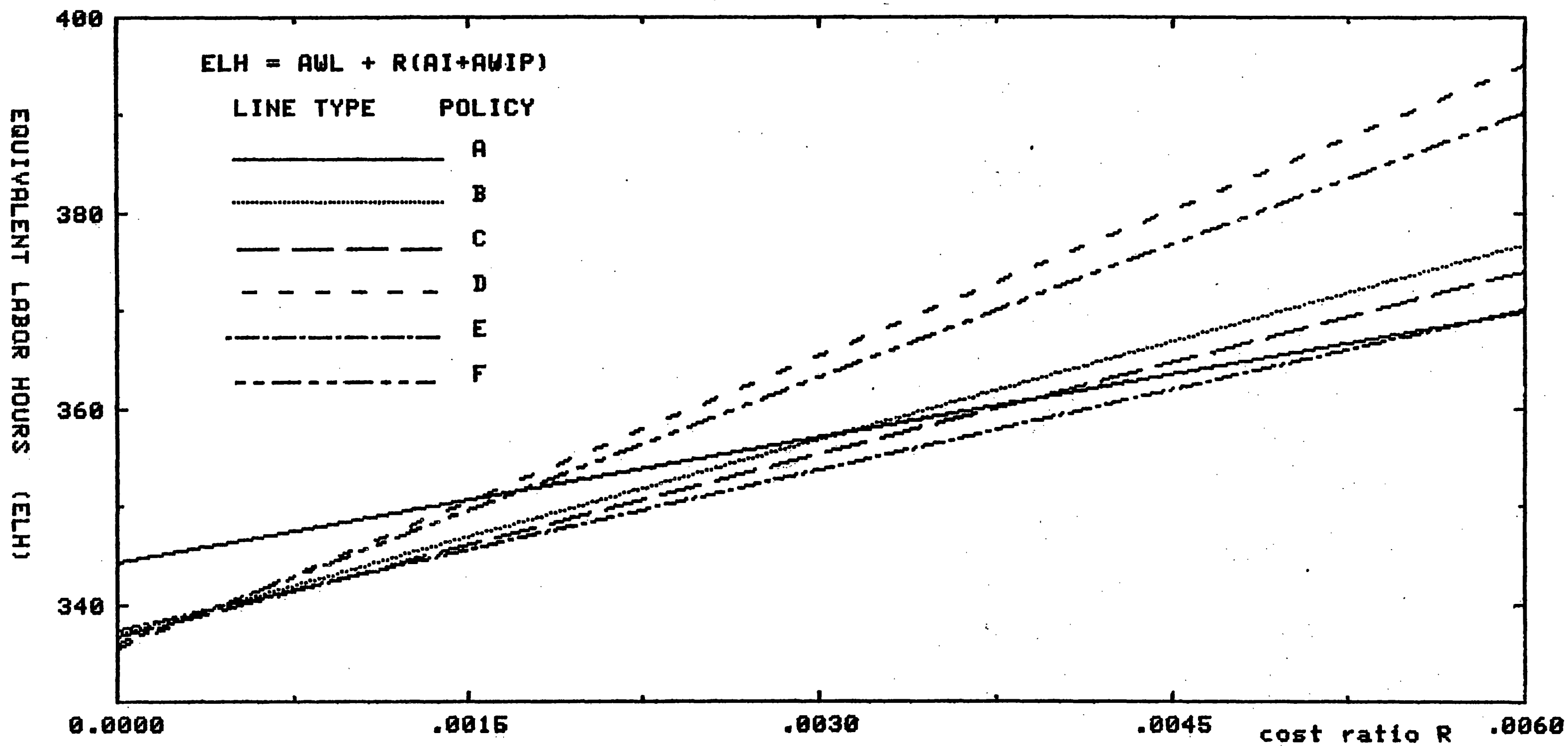

FIGURE 10: PLOT OF COST FUNCTIONS FOR FLAT PRODUCT STRUCTURES

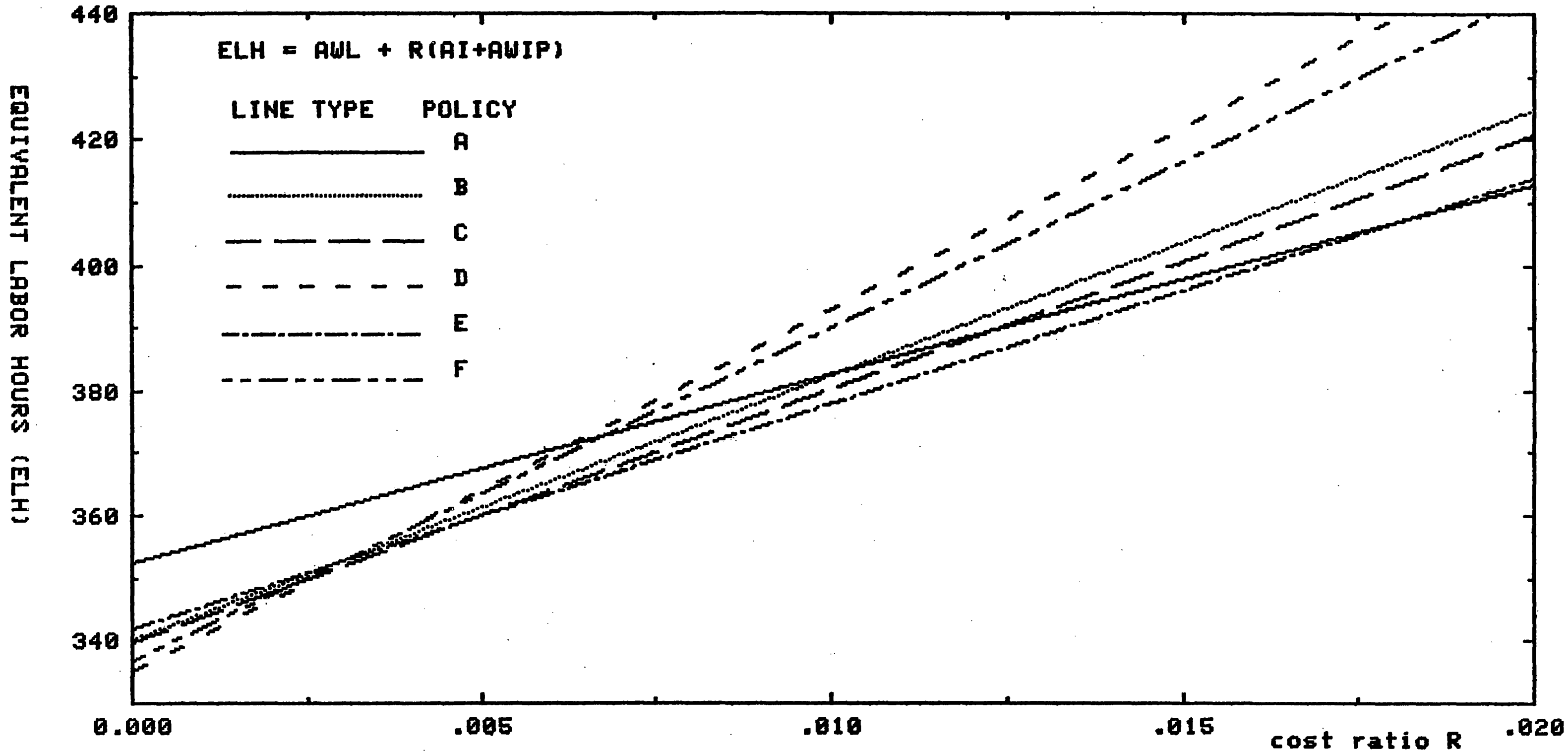

FIGURE 11: PLOT OF COST FUNCTIONS FOR TALL PRODUCT STRUCTURES

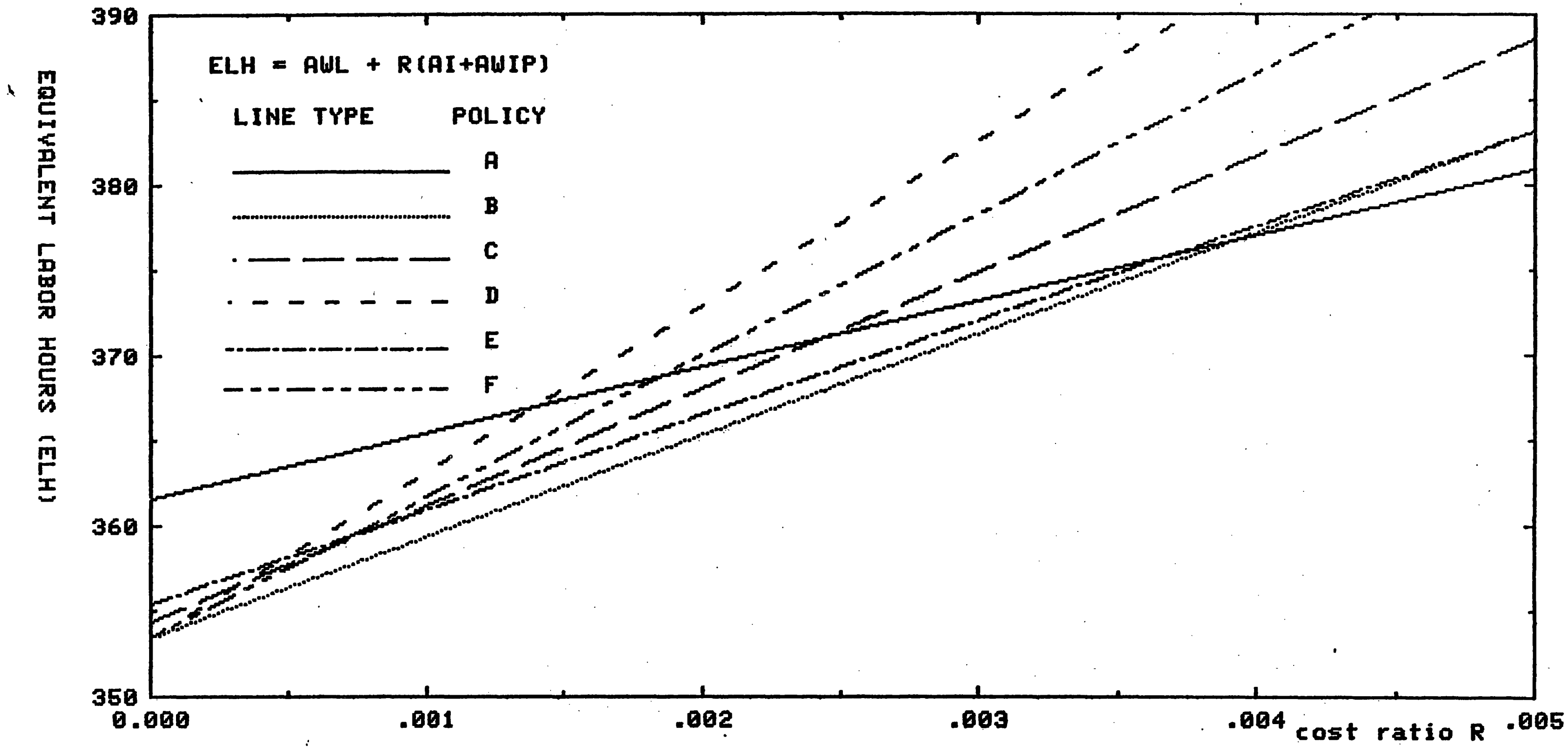

FIGURE 12: PLOT OF COST FUNCTIONS FOR TALL/FLAT PRODUCT STRUCTURES

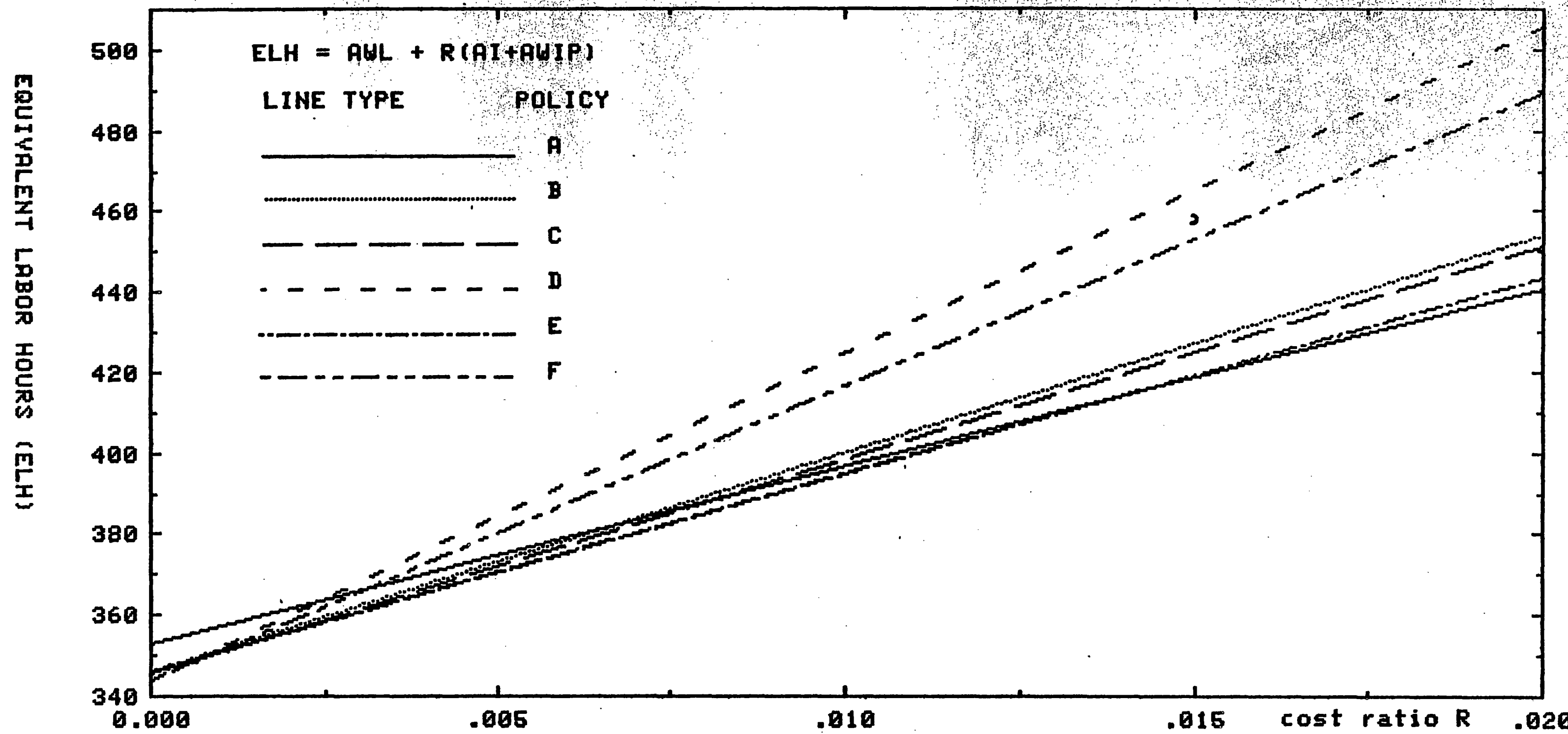

FIGURE 13: PLOT OF COST FUNCTIONS FOR MIXED PRODUCT STRUCTURES

Chapter V

DISCUSSION OF RESULTS

5.1 STATISTICAL TEST

The T^2 test results indicate that each policy gives rise to a unique population of labor hours, inventory and work in process levels. This conclusion is supported at any significance level greater than 0.008 for any policy pair.

5.2 OBSERVATIONS

Several observations about the various control policies are given here. For convenience, the definitions of the policies are restated below:

Policy	Type	Control Limit	Reduction Factor
A	Production Switching	80 std. hrs.	Not used
B	Production Switching	120 std. hrs.	Not used
C	Backlog Reduction	80 std. hrs.	0.75
D	Backlog Reduction	120 std. hrs.	0.75
E	Backlog Reduction	80 std. hrs.	1.25
F	Backlog Reduction	120 std. hrs.	1.25

Five observations about the results follow:

Observation 1 : Policy A was the preferred policy for all four product mixes when the cost ratio R was relatively large.

Observation 2 : Policy D was the preferred policy for all product structure mixes, except the tall/flat, when the cost ratio R was relatively small.

Observation 3 : The production switching (PS) policies were preferred for the tall/flat product structure mix, and the backlog reduction (BR) policies were not preferred on any interval of the cost ratio for this product structure mix. Policy B was preferred for lower values of R and policy A was preferred for relatively larger R.

Observation 4 : The order in which the policies were preferred as the cost ratio R increased was D-C-E-A for the flat and the tall product structure mixes, and was D-F-C-E-A for the mixed product structure mix.

Observation 5 : The weekly labor for each policy (with the exception of policy A which is labor-intensive) for all the product structure mixes did not vary significantly. That is, the weekly labor amounts were within 3 standard deviations of each other.

5.3 CONCLUSIONS

Observations 3 and 4 would indicate that homogeneity of product structure within a product mix leads to more alternative control policies to select from for varying values of the cost ratio R. Conversely, non-homogeneity of product structure within a product mix apparently limits the number of policies that may be considered to minimize operating costs.

Examination of the order in which policies are preferred as R increases indicates that the control limit (CL) has a larger impact on operating costs than other policy parameters. Logically, the CL directly controls the amount of WIP, whereas the effect of the reduction factor (RF) for the BR policies seems to influence labor more than WIP. Recall that only two values of each of these parameters were observed in this investigation, so this may not be supported as a general conclusion.

On a practical level, the results permit the following recommendations to be made:

1. Labor-intensive control policies should be used when the ratio of holding costs to labor costs is high.
2. Labor-conservative control policies should be used when the ratio of holding costs to labor costs is low.

3. When neither labor costs nor holding costs completely dominate the cost function, control policies that balance the two costs to obtain minimum operating costs are indicated.

The logic underlying these recommendations is that labor-intensive policies (low CL) tend to work off any backlogs, thus keeping inventory and WIP levels (and costs) low. Likewise, where labor is the more precious commodity, large backlogs do not impose significant penalties. The quantitative verification of these principles, as shown in Chapter 4, supports observed managerial practices in industry.

The first-line production manager now has a way to control his labor costs that is simple and effective. The simplicity derives from the fact that only knowledge of the backlog at the start of a work week is required in order to make a decision. Detailed knowledge of the planned workload for the coming weeks is not explicitly required as in other methods of capacity control, ie. load/capacity analysis and finite-loading. How much of the backlog will be worked off in the coming week is determined by the control policy parameters. These parameters, in actual practice, will likely be determined by higher management after an analysis based on their particular product structures, product mixes, labor costs, holding costs, and shop configuration. This analysis is possible with the simulation model developed for the current research.

5.4 RESEARCH OPPORTUNITIES

The research presented in this thesis has been constrained to examine a very small subset of the experimental possibilities available for investigation with the simulation model. This was necessary to keep the scope of the research within reasonable bounds. However, many possibilities for further research have been uncovered, and a tool for that research is available now in the simulation model developed by the author.

Although priority rules have been extensively evaluated for job shop environments [6,43,44,45,62,among others], there is only one published study of priority rules for MRP production systems known to this author [23]. Priorities in the multi-level product must generally be of a dependent nature from level to level and across levels in the product structure. This implies that evaluation of priority rules for MRP systems will not be as straightforward a task as for job shops.

The definition of planned lead times for MRP systems is in need of investigation. Current industry practices range from fixed values for all parts to rules of thumb such as allowing a week per operation. During the research for this thesis it has been casually observed that planned lead times for smooth operation of MRP production systems should depend on at least the following items:

1. Number of operations for the part,
2. Processing time(s) for the part,
3. Priority rule, and
4. Shop utilization.

The analysis of the percentage of time spent in queues as shown by Wysk, Davis, et al [70] brought to mind the following rules for defining the planned lead time for manufactured parts:

$$LT = PT/(1.- U) \tag{5.1}$$

And, a refinement for varying utilizations at the different work centers :

$$LT = \sum t_i/(1.- u_i) \tag{5.2}$$

where LT = MRP planned lead time for part

PT = total processing time

t_i = processing time at work center i

U = percent utilization of shop overall

u_i = percent utilization of work center i

Estimates of the expected waiting time are required in dynamic slack type of priority rules, and the above formulae can be used to estimate the waiting time. These formulae have been incorporated into the simulation model's priority function for the DS type of rules.

Product structures remain one of the largest variables in an MRP production system. The impact of product structures and product mixtures on the operating characteristics of the production shop is an area for much further investigation than presented here in this thesis.

Master scheduling practices need to be examined in more depth. Although the master schedule is the driving force behind the whole MRP production system, there has been almost no definitive research done on this topic.

These and many other aspects of MRP production systems are fruitful areas for future research. Many firms are converting their production sytems to MRP-based sytems each year [47,61], so better understanding of how these systems operate will become more important in the future.

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Appendix A

MRPSIM SIMULATION MODEL USER'S GUIDE

A.1 DESCRIPTION OF PROGRAM

The program MRPSIM is an MRP driven production shop simulator written as a discrete event SLAM simulation model. MRPSIM is driven by a master schedule of end items which is generated by exponentially smoothing a Poisson sequence of independent end item demands. MRPSIM performs only lot-for-lot ordering. Parent-component relationships are determined by a bill of material (BOM) processor, which also time phases orders according to their lead times. As orders fall due for release, they are placed in a holding file. If the order requires no component parts ,it is released to the shop immediately. If the part requires components, all components must be available in inventory in sufficient quantity for the order to be released. Once an order has been released to the shop, it is processed according to its routing. All parts have fixed routings with deterministic operation times. The operation time for an order is the standard time for the operation multiplied by the quantity associated with the order, plus the setup time. As an order completes its processing in the shop, it is placed in inventory if it is not an end item; otherwise it leaves the system.

As MRPSIM is designed to evaluate OUTPUT CONTROL policies, two kinds of policies, the high/low production switching policy, and the backlog reduction policy are available. These are described fully in Chapter III of this thesis. Conceptually, the work week length at a work center is determined by the control policy based on the policy parameters and the length in standard hours of work of the queue at the work center. This work week length is implemented within MRPSIM as a performance factor for the standard operation times. This is done to avoid distortion of time integrated statistics. The performance factor is computed as WORK WEEK LENGTH/NOMINAL WEEK LENGTH. For example, if the desired work week length was 60 hours, and the nominal week length was 40, then the performance factor would be 1.5 . Then, the time for an operation at that work center would be computed as OPERATION TIME=STANDARD TIME/PERFORMANCE FACTOR, where the standard time includes the setup time.

Several reports are produced by MRPSIM:

1. Simulation Parameters (Input Echo)
2. Bills of Material and Component Analysis Report
3. Work Center and Capacity Load Analysis
4. Simulation Results

Examples of each of these appear at the end of this User's Guide.

A.2 USING THE PROGRAM

This model is available for public use. A copy of MRPSIM resides at the Virgnia Tech Computing Center on the VM1 system on userid DMM. The source code may be accessed from userid DMM on VM1 by linking for read only access to the minidisk. Copies of MRPSIM may also be obtained from the author directly for the cost of producing a tape copy and postage. Contact the author at:

Kurt M. Gutzmann

7307 Wickford Drive

Alexandria, Virginia, 22310

703-971-3885

You should be familiar with SLAM discrete-event simulation before using the program. See Pritsker's text for help [51]. If you have any difficulties running the program contact Dr. Wysk of the Industrial Engineering and Operations Research Department (X6978).

A.3 LIMITATIONS

The following maximums apply to the program if the user makes no modification to DIMENSION statements:

- 10 work centers
- 10 operations per part
- 20 part numbers (1-20)
- 6 end items (product structures)

40 maximum planning horizon (weeks)

If you need more than the above values, redefine the COMMON and DIMENSION statements throughout the program appropriately.

A.4 PREPARING THE INPUT DATA

The input data deck consists of nine major SECTIONs :

1. SLAM Input Data
2. MRP and Control Policy Parameters
3. Product Structures
4. Master Schedule
5. Lead Times
6. Work Centers
7. Part Routing
8. Priority Rule

Each of these sections is described in detail below.

A.4.1 SLAM Input Data (Sec. 1)

SLAM requires some input cards to control the simulation. The GEN, LIMITS, INIT, PRIORITY, and FIN cards are the mimimum required. These are described fully in Pritsker [51]. The PRIORITY statement should be LVF(4) for all files. From here on let NWCTR be the number of work centers in the model. STATISTIC cards will request statistics collection on lead times by part number (PN), starting backlogs by workcenter, and work week lengths by workcenter. You must supply a STATISTIC card for each statistic on which you want information. The general format of the STATISTIC card is :

STATISTIC,IS, name; (IS is the collection stream number)

The stream number IS are computed within the program as follows:

IS	Statistic
1 to highest part number	lead time for PN IS
20 + work center number	starting backlog for wkctr
30 + work center number	work week length for wkctr
41	time in system (all parts)
42	time in hold pool (all parts)
43	time in shop (all parts)
44	tardiness (all parts)
45	weekly load in shop

See Pritsker [51] for more detail on how to define the STATISTIC card and how to request histograms.

TIM cards are required for the collection of time-integrated statistics. You must supply a TIM card for each statistic on which you want information. The format of the TIM card is:

TIM,XX(IS), name ;

The streams IS are defined within the program as follows:

IS	Statistic
1 through NWCTR	utilization of work center IS
10 + PN	inventory level of part number PN
91	total inventory level (all parts)
96	work in process level
100	number of orders in shop

Use the following card for the INIT card: INIT,0.; The ending point of the simulation is determined by the number of MRP reviews to run, not by the simulation clock time. Specify the number of replications on the proper field of the GEN card.

The SLAM files are defined in the following manner:

```
File Nos. 1 to NWCTR are the queues for each work center
File No. NWCTR+1 is the holding pool for orders
File No. NWCTR+2 is a temporary storage file (required)
```

Therefore the LIMITS card should specify NWCTR+2 number of files. There are 13 attributes for each entity in the system, so MATR should be specified as 13. Specify a maximum number of concurrent entries as 200.

The ATRIB(:) definitions are :

```
ATRIB(1)  Part Number (PN)
ATRIB(2)  Quantity of this order
ATRIB(3)  Due Date of this order
ATRIB(4)  Priority of this order
ATRIB(5)  Time order entered system
ATRIB(6)  Time order release to shop from hold
ATRIB(7)  Total remaining processing time
ATRIB(8)  Work center number of current operation
ATRIB(9)  Number of operations completed
ATRIB(10) Remaining processing time for this operation
ATRIB(11) Order number
ATRIB(12) Start time of current operation
ATRIB(13) End item flag
```

A.4.2 MRP and Control Parameters (Sec. 2)

All of the data on the subsequent portions of the input deck are read in FORTRAN free format (READ(5,*)). This section of the deck consists of three cards.

CARD NO. 1 (Sec. 2)

Field	Description
1	Planning horizon length
2	Number of MRP reviews to simulate
3	Number of product structures
4	Highest part number used

CARD NO. 2 (Sec. 2)

Field	Description
1	Week number at which to clear all statistics
2	Shop control policy selection : 1 = Backlog Reduction Policy (BR) 2 = High/Low Production Switching (HL)
3	Print Bill of Material : 1 = yes, print BOM otherwise, do not print
4	Print Work Center Input and Routings Data : 1 = yes, print work center and routings input data otherwise, do not print
5	Print Master Schedule Input Data 1 = yes, print master schedule input data otherwise, do not print
6	Detail Report Request : 1 = yes, give full SLAM summary for each replication otherwise, give only average labor, inventory, and WIP for each replication
7	Number of Replications (also appears on GEN card)

CARD NO. 3 (Sec. 2)

Field	Description
1	Reduction Factor for BR control policy If HL policy is used, then code a 0 for this field

A.4.3 Product Structure (Sec. 3)

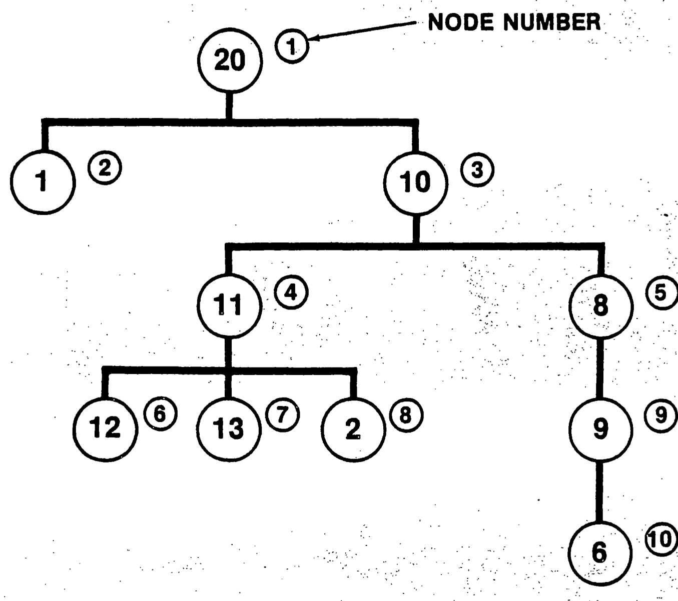
The product structure data is prepared from the product structure tree, usually drawn on a piece of paper. You should have this drawing in front of you when coding this data. Nodes in the structure tree are numbered sequentially from 1 to N starting at the top of the tree and proceeding left to right by level. Figure 14 shows this node identification is done. These node numbers are used to identify the parent-component relationships. For each unique product structure the shop is to produce, you must code each product structure with the following cards:

CARD NO. 1 (Sec 3)

Field	Description
1	Highest part number in this product structure Part numbers should be numbered sequentially from 1. Maximum number of part numbers (PNs) is 20, so all PNs should be between 1 and 20.
2	NREC - number of records following this card that are used to describe this product structure. This should be equal to largest node number you have in the structure tree.
3	NLVL - the number of levels in the product structure tree. The convention here is that the top level part is at level 0. See example for more clarification.

CARD NO. 2 to NREC+1 (Sec. 3)

Field	Description
1	PN - part number at this node in the tree
2	QTY - offset quantity of this part from its parent part
3	PARENT PN - part number of this part's parent
4	PARENT NODE NUMBER - the node number of this part's parent
5	LVL - the level in the tree at which this node appears



FIELD:	(1)	(2)	(3)	(4)	(5)
NODE	20	10	3		
1	20	1	20	0	0
2	1	1	20	1	1
3	10	1	20	1	1
4	11	1	10	3	2
5	8	1	10	3	2
6	12	1	11	4	3
7	13	1	11	4	3
8	2	1	11	4	3
9	9	1	8	5	3
10	6	1	9	9	4

FIGURE 14. PRODUCT STRUCTURE TREE NODE NUMBERING

The above sets of cards will be repeated in a similar manner for each product structure you must describe.

A.4.4 Master Schedule (Sec. 4)

The master schedule is generated by exponentially smoothing a Poisson sequence of weekly demands for each end item. A start-up period is required for the MRP system to operate properly. The length of the start-up period should 1+longest cumulative lead time.

CARD NO. 1 (Sec. 4)

Field	Description
1	NSTART - length of the start-up period

CARD NO. 2 (Sec. 4)

Field

1 for each end item - code the demand rate for the item; this is the mean of the Poisson sequence of demands for that item.

CARD NO. 3 (Sec. 4)

1 for each end item - code the exponentially smoothing constant (.0 to 1.0) to smooth the Poisson demand sequence. By coding a 0.0 for an item's smoothing constant, the demand will be set at a constant rate specified by CARD NO. 2

A.4.5 Lead Times (Sec. 5)

Lead times are usually integral numbers of weeks. Internal to the program they are stored as REAL, but are rounded as INT(Lead Time + .99). One CARD is required for each PN. These must be in Part Number order, 1 to the highest part number, (no missing part numbers allowed).

A.4.6 Work Centers (Sec. 6)

CARD NO. 1 (Sec. 6)

Field	Description
1	NWCTR - the number of work centers in the shop simulator

CARD NO. I=2 to NWCTR+1
(1 CARD for each work center by work center no.)

Field	Description
1	NOMCAP - the nominal week length at work center I
2	MAXCAP - the maximum week length at work center I
3	NMACH - the number of identical machines at work center I
4	CLL - lower control limit for I/O control policy
5	CLU - upper control limit for i/O control policy

A.4.7 Part Routings (Sec. 7)

Four cards are required to define the routing for each part. The routings must be defined in part number sequence, with no missing PNs.

CARD NO. 1 for each PN (Sec. 7)

Field	Description
1	No. of operation for this PN = NOPS(PN)

CARD NO. 2 for each PN (Sec. 7)

Field	Description
1-NOPS	Work center numbers of operations 1 to NOPS(PN)

CARD NO. 3 for each PN (Sec. 7)

Field	Description
1-NOPS	Standard time for each operation 1 to NOPS(PN)

CARD NO. 4 for each PN (Sec. 7)

Field	Description
1-NOPS	Setup time for each operation 1 to NOPS(PN)

A.4.8 Priority Rule (Sec. 8)

The priority rule is sellected by number. If a dynamic slack type rule is selected, a target utilization is required to compute the expected queueing time of a part. If the COVERT rule is selected, a second card is required to define the constant K in the COVERT rule. Codes for priority rule selection are:

```
 1 = SS (Static Slack)
 2 = SS/PT (Static Slack per remaining Processing Time)
 3 = SS/RO (Static Slack per number of Remaining Operations)
 4 = FISFS (First In System First Served)
 5 = DS (Dynamic Slack)
 6 = DS/PT (Dynamic Slack per remaining Processing Time)
 7 = DS/RO (Dynamic Slack per number of Remaining Operations)
 8 = COVERT **
 9 = DD (Due Date)
10 = RS (Relative Slack)
                  (due date - remaining processing time)
       Priority = --------------------------------------
                  ( due date - current date )
```

The SOT (Shortest Operation Time first) rule is selected by coding the SLAM PRIORITY card for LVF(10) for each file that is a work center of holding pool file (nos. 1 through NWCTR+1)

**The COVERT rule requires that the SLAM PRIORITY card be coded HVF(10)for each file that is a work center or holding pool file (nos. 1 through NWCTR+1)

<u>CARD</u> <u>NO</u>. <u>1</u> (<u>Sec</u>. <u>9</u>)

Field	Description
1	Priority Rule Code (1-10)
2	Target Utilization (if DS-type rules not used, code a zero here)
3	NEWPRI - if you want priority update at time a part leaves a work center, code a 1 here; other wise priority update is done only at the weekly MRP review

<u>CARD</u> <u>NO</u>. <u>2</u> (<u>Sec</u>. <u>9</u>) <u>Required</u> <u>only</u> <u>for</u> <u>COVERT</u> <u>rule</u>

Field	Description
1	K parameter of COVERT rule (see Buffa for more [9])

A.5 VARIABLE DEFINITIONS

The definitions of major program variables are given below to assist in debugging:

VARIABLE DEFINITIONS

IBFILE	BLOCKAGE FILE NO.
IHFILE	HOLD FILE NO.
INOW	CURRENT WEEK INDEX
INV(I)	INVENTORY LEVEL OF PN I USED FOR NETTING
IPFLG(I)	COMPONENT LIST GENERATED FLAG FOR ASSY I (1=YES)
IPLAN	PERIOD OF END-ITEM REQUIREMENT
IQTY	QUANTITY OF END-ITEM REQUIREMENT IN PERIOD IPLAN
IR	RECORD NO. BEING PROCESSED
ITEM(I)	PART NO. OF END-ITEM I
KEXFLG	FLAG FOR NO REGENERATION OF COMPONENT LISTS
KPLAN(I,J,K)	PLANNED ORDERS OF PN I IN PD. J FOR END-ITEM K
KSCHD(I,J,K)	SCHEDULED RECEIPTS OF PN I IN PD. J FOR END-ITEM K
MSTR(I,J)	MASTER SCHEDULE: REQUIREMENT OF END-ITEM I IN PD. J
MAXCAP(K)	MAXIMUM CAPACITY OF WORK CENTER K
MROUT(I,J)	WKCTR NO. OF OPER. J FOR PART NO. I
MRP(I,J,K)	GROSS REQS. OF PN I IN PD. J FOR END-ITEM K
NCMP(I)	NO. OF COMPONENT PARTS FOR PN I
NCPN(I,J)	PART NO. OF COMPONENT J IN PART NO. I
NCQT(I,J)	QTY OF COMPONENT J IN PART NO. I
NET(I,J,K)	NET REQUIREMENTS FOR PN I, PD. J, FOR END-ITEM K
NLVLS(I)	NO. OF LEVELS IN PRODUCT STRUCTURE OF ITEM(I)
NMACH(K)	NO. OF IDENTICAL MACHINES AT WORK CENTER K
NOMCAP(K)	NOMINAL CAPACITY IN HOURS OF WORK CENTER K
NOPS(I)	NO. OF OPERATIONS ON ROUTING FOR PART NO. I
NORDS	NO. OF ORDERS PLACED SO FAR
NP	CURRENT PART NO. BEING PROCESSED
NPAR	PARENT PART NO.
NPLAN	PLANNING HORIZON LENGTH
NPRODS	NO. OF END-ITEM PRODUCTS
NQ(I,J)	TOTAL REQS OF PN I FOR END-ITEM J
NREC(I)	NO. OF PRODUCT STRUCTURE RECORDS FOR END-ITEM I
NS(I,J,K)	PRODUCT STRUCTURE INPUTS FOR END-ITEM K I=RECORD NO. FOR J = COLUMNS OF EACH RECORD J=1: PART NO. J=2: QUANTITY PER PARENT J=3: PARENT PART NO. J=4: PARENT RECORD NO. J=5: LEVEL THIS PART IS ON (0=END ITEM LEVEL)
NT(I,J,K)	TOTAL REQS BY LEVEL OF PN I AT LEVEL J OF END-ITEM K
NWCTR	NO. OF WORK CENTERS
NWKS	NO. OF WEEKS TO SIMULATE PRODUCTION
TL(I)	PLANNED LEAD TIME FOR PART NO. I

```
TMTOT(I)       TOTAL STD. RUN TIME FOR PART NO. I (QTY=1)
TSET(I)        TOTAL SET-UP TIME FOR PART NO. I   (QTY=1)
STDTM(I,J)     STD. TIME FOR OPER. J OF PART NO. I
SETUP(I,J)     SET-UP TIME FOR OPER. J OF PART NO. I
```

A.6 SAMPLE RUN

A.6.1 Input Data

The following input deck was used to create this sample:

```
GEN,GUTZMANN,EXAMPLE          ,2/0/1983,1,Y,N,Y,N,Y;
LIM,6,13,600;
STA,1,PN1 LEAD TIME;
STA,2,PN2 LEAD TIME;
STA,3,PN3 LEAD TIME;
STA,4,PN4 LEAD TIME;
STA,5,PN5 LEAD TIME;
STA,6,PN6 LEAD TIME;
STA,7,PN7 LEAD TIME;
STA,8,PN8 LEAD TIME;
STA,9,PN9 LEAD TIME;
STA,10,PN10LEAD TIME;
STA,11,PN11LEAD TIME;
STA,12,PN12LEAD TIME;
STA,13,PN13LEAD TIME;
STA,21,ST BKLOG WC1;
STA,22,ST BKLOG WC2;
STA,23,ST BKLOG WC3;
STA,24,ST BKLOG WC4;
STA,31,WK LENGTH WC1;
STA,32,WK LENGTH WC2;
STA,33,WK LENGTH WC3;
STA,34,WK LENGTH WC4;
STA,41,TIME IN SYS;
STA,42,TIME IN HOLD;
STA,43,TIME IN SHOP;
STA,44,TARDY;
STA,45,TOT SHOP LOAD;
STA,46,WKLY LABOR;
TIM,XX(1),UTIL WKCTR1;
TIM,XX(2),UTIL WKCTR2;
TIM,XX(3),UTIL WKCTR3;
TIM,XX(4),UTIL WKCTR4;
TIM,XX(11),INV PN1;
TIM,XX(12),INV PN2;
TIM,XX(13),INV PN3;
TIM,XX(14),INV PN4;
```

```
TIM,XX(15),INV PN5;
TIM,XX(16),INV PN6;
TIM,XX(17),INV PN7;
TIM,XX(18),INV PN8;
TIM,XX(19),INV PN9;
TIM,XX(20),INV PN10;
TIM,XX(21),INV PN11;
TIM,XX(22),INV PN12;
TIM,XX(23),INV PN13;
TIM,XX(91),INV AVGE TOT;
TIM,XX(96),NO.PARTS IN SHOP;
TIM,XX(100),NO.ORDS. IN SHOP;
PRI/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4);
INI,0.;,
FIN;
12 200   4 13 NO. PLAN PDS,NO. WEEKS TO RUN, NO. PRODS.,HIGHEST PN
20 1 1 1 1 1 1   KC ICNTL  IB IW IM IRPT NREP
1.00
 5 5 1 PRODUCT STRUCTURE NPN,NREC,NLVLS(20)
 1 1 1 0 0 (PART NO.) (QTY) (PARENT PN) (PARENT RECNO) (LEVEL)
 2 1 1 1 1
 3 1 1 1 1
 4 1 1 1 1
 5 1 1 1 1
 8  4 1  SECOND PRODUCT STRUCTURE
 6 1 6 0 0
 2 1 6 1 1
 7 1 6 1 1
 8 1 6 1 1
 11 6 1    ---THIRD PRODUCT STRUCTURE
 9 1 9 0 0
 3 1 9 1 1
 5 1 9 1 1
10 1 9 1 1
11 1 9 1 1
 8 1 9 1 1
 13 3 1   ---- FOURTH PRODUCT STRUCTURE
12 1 12 0 0
13 1 12 1 1
4 1 12 1 1
8            **** MASTER SCHEDULE PARAMETERS ****  NSTART
34.61 79.49 54.13 59.82  DEMAND RATES OF END-ITEM
 .15 .15 .15  .15      SMOOTHING CONSTANTS
 1 1 INVENTORY START AND LEAD TIME IN PN ORDER
 2 2
 2 3
 2 4
 6 5
1 6
2 7
```

```
3 8
 1 9
 4 10
 6 11
 1 12
 2 13
 4     WORK CENTER DATA (NO. OF)
 40 80 2    40 120    NOMCAP MAXCAP NMACHS CLL CLU
 40 80 2    40 120
 40 80 2    40 120
 40 80 2    40 120
 4  ROUTE 1
2 3 1 4
 .064 .181 .068 .076
 .01  .01  .01  .01
 2  ROUTE 2
 1 2
 .092 .053
  .01 .01
  4 ROUTE 3
 3 4 2 1
 .183 .151 .119 .087
 .01  .01  .01  .01
 2  ROUTE 4
 1 4
 .143 .093
 .01 .01
 6  ROUTE 5
 1 4 3 1 4 2
 .056 .174 .181 .047 .004 .067
 .01  .01  .01  .01  .01  .01
  4 ROUTE 6
 1 3 2 1
 .016 .115 .119 .076
  .01 .01  .01  .01
 3  ROUTE 7
 1 2 3
 .069 .125 .119
 .01  .01  .01
 4 ROUTE 8
 2 1 4 2
 .075 .107 .047 .088
 .01  .01  .01  .01
 3 ROUTE 9
 4 2 4
 .107 .102 .181
 .01  .01  .01
 5  ROUTE 10
 3 1 2 3 1
 .033 .074 .076 .109 .106
```

```
.01  .01  .01  .01  .01
 5  ROUTE 11
2 1 4 3 4
.031 .073 .130 .156 .008
.01  .01  .01  .01  .01
2   ROUTE 12
3 4
.179 .152
.01  .01
2 ROUTE 13
4 2
.083 .111
.01 .01
3  .95 0 $$$$$PRIORITY RULE, TARGET UTIL, NUPRI:1=YES,0=NO
.5
0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0  00  0 0
0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0  00  0 0
0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0  00  0 0
0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0  00  0 0
/*
//
```

The product structures coded above are the same as the FLAT product structures used in the body of this thesis. The node numbering for coding the structures appears in Figure 14.

A.6.2 Sample Run Output

The following output was generated:

```
/*Comments added to this listing, denoted by /* comment

/*this listing was edited to fit onto standard page width

M R P   S I M U L A T O R   I N P U T S

NO. REVIEWS TO RUN          200
PLANNING HORIZON LENGTH      12
NO. OF END-ITEMS              4
HIGHEST PART NO.             13

CLEAR PERIOD                 20
POLICY SELECTED               1    /* Backlog Reduction Policy
PRINT B-O-M                   1    /* yes, print
PRINT WCTR & ROUTES           1    /* yes, print
PRINT MSTR SCHED              1    /* yes, print
REPORT MODE                   1    /* give detailed reports
```

```
NO. REPLICATIONS                   1
REDUCTION FACTOR                   1.00   /* factor for control policy

TOTAL GROSS REQD  END ITEMS               /* this is master schedule
                                          /* information
END ITEM PN:  1 REQD:       6959

END ITEM PN:  6 REQD:      16264

END ITEM PN:  9 REQD:      11228

END ITEM PN: 12 REQD:      12114


END ITEM DEMAND PARAMETERS
ITEM NO.      RATE      ALPHA   NSTART:   8
     1        34.6       0.15
     6        79.5       0.15
     9        54.1       0.15
    12        59.8       0.15

/* Bill of Material Reports here

B I L L   O F   M A T E R I A L   N O. 1 OF  4

----- TOP LEVEL PART NO. -----    1



    I N P U T   R E C O R D S    /* data echo

RECNO       PN          QTY    PRNT PN PRNT RECNO      LEVEL
   1         1           1          1         0          0
   2         2           1          1         1          1
   3         3           1          1         1          1
   4         4           1          1         1          1
   5         5           1          1         1          1

   T O T A L   Q T Y   B Y   P A R T   N O.

 /*these are build quantities for one of top level item

            PART NO.   1        TOTAL REQD:  1
            PART NO.   2        TOTAL REQD:  1
            PART NO.   3        TOTAL REQD:  1
            PART NO.   4        TOTAL REQD:  1
            PART NO.   5        TOTAL REQD:  1
```

Q T Y   B Y   L E V E L

/*shows qty required at each level

PN 1	1	0
PN 2	0	1
PN 3	0	1
PN 4	0	1
PN 5	0	1

B I L L   O F   M A T E R I A L   N O. 2 OF 4

----- TOP LEVEL PART NO. ----- 6

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	6	1	6	0	0
2	2	1	6	1	1
3	7	1	6	1	1
4	8	1	6	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	2	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	7	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 2	0	1
PN 6	1	0
PN 7	0	1
PN 8	0	1

B I L L   O F   M A T E R I A L   N O. 3 OF 4

----- TOP LEVEL PART NO. ----- 9

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	9	1	9	0	0
2	3	1	9	1	1
3	5	1	9	1	1
4	10	1	9	1	1
5	11	1	9	1	1
6	8	1	9	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	3	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 3	0	1
PN 5	0	1
PN 8	0	1
PN 9	1	0
PN10	0	1
PN11	0	1

B I L L   O F   M A T E R I A L   N O. 4 OF 4

----- TOP LEVEL PART NO. ----- 12

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	12	1	12	0	0
2	13	1	12	1	1
3	4	1	12	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

```
          PART NO.   4        TOTAL REQD:  1
          PART NO.  12        TOTAL REQD:  1
          PART NO.  13        TOTAL REQD:  1
```

Q T Y   B Y   L E V E L

PN 4	0	1
PN12	1	0
PN13	0	1

C O M P O N E N T S / A S S Y   Q T Y S

/* this shows the component PNs and qtys for each assy part

```
 ASSY. PART NO.  1 NO. OF COMPONENTS: 4  PART NO.  QTY
                                          2         1
                                          3         1
                                          4         1
                                          5         1

 ASSY. PART NO.  6 NO. OF COMPONENTS: 3  PART NO.  QTY
                                          2         1
                                          7         1
                                          8         1

 ASSY. PART NO.  9 NO. OF COMPONENTS: 5  PART NO.  QTY
                                          3         1
                                          5         1
                                         10         1
                                         11         1
                                          8         1

 ASSY. PART NO. 12 NO. OF COMPONENTS: 2  PART NO.  QTY
                                         13         1
                                          4         1
```

W O R K   C E N T E R   D A T A

/* beginning of work center and routing report

4 WORK CENTERS

NO.	NO. MACH.	NOM. CAP.	MAX. CAP.	LO CL	HI CL
1	2	40	80	40.0	120.0
2	2	40	80	40.0	120.0
3	2	40	80	40.0	120.0

4	2	40	80	40.0	120.0

P A R T   R O U T I N G S

PART NO. 1 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.064		0.010
2	3		0.181		0.010
3	1		0.068		0.010
4	4		0.076		0.010
			-----		-----
		TOTAL	0.389	TOTAL	0.040

PART NO. 2 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.092		0.010
2	2		0.053		0.010
			-----		-----
		TOTAL	0.145	TOTAL	0.020

PART NO. 3 NO. OF. OPER.: 4 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.183		0.010
2	4		0.151		0.010
3	2		0.119		0.010
4	1		0.087		0.010
			-----		-----
		TOTAL	0.540	TOTAL	0.040

PART NO. 4 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.143		0.010
2	4		0.093		0.010
			-----		-----
		TOTAL	0.236	TOTAL	0.020

PART NO. 5 NO. OF. OPER.: 6 LEAD TIME: 6.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	1	0.056	0.010
2	4	0.174	0.010
3	3	0.181	0.010
4	1	0.047	0.010
5	4	0.004	0.010
6	2	0.067	0.010

```
                                  -----          -----
                    TOTAL         0.529   TOTAL  0.060

------------------------------------------------------------
PART NO.   6 NO. OF. OPER.:  4 LEAD TIME:   1.
         OPER. NO.  WK. CTR.       STD. TIME      SETUP TIME
           1          1             0.016           0.010
           2          3             0.115           0.010
           3          2             0.119           0.010
           4          1             0.076           0.010
                                    -----           -----
                    TOTAL           0.326   TOTAL   0.040

------------------------------------------------------------
PART NO.   7 NO. OF. OPER.:  3 LEAD TIME:   2.
         OPER. NO.  WK. CTR.       STD. TIME      SETUP TIME
           1          1             0.069           0.010
           2          2             0.125           0.010
           3          3             0.119           0.010
                                    -----           -----
                    TOTAL           0.313   TOTAL   0.030

------------------------------------------------------------
PART NO.   8 NO. OF. OPER.:  4 LEAD TIME:   3.
         OPER. NO.  WK. CTR.       STD. TIME      SETUP TIME
           1          2             0.075           0.010
           2          1             0.107           0.010
           3          4             0.047           0.010
           4          2             0.088           0.010
                                    -----           -----
                    TOTAL           0.317   TOTAL   0.040

------------------------------------------------------------
PART NO.   9 NO. OF. OPER.:  3 LEAD TIME:   1.
         OPER. NO.  WK. CTR.       STD. TIME      SETUP TIME
           1          4             0.107           0.010
           2          2             0.102           0.010
           3          4             0.181           0.010
                                    -----           -----
                    TOTAL           0.390   TOTAL   0.030

------------------------------------------------------------
PART NO.  10 NO. OF. OPER.:  5 LEAD TIME:   4.
         OPER. NO.  WK. CTR.       STD. TIME      SETUP TIME
           1          3             0.033           0.010
           2          1             0.074           0.010
           3          2             0.076           0.010
           4          3             0.109           0.010
           5          1             0.106           0.010
                                    -----           -----
```

```
                                TOTAL   0.398  TOTAL   0.050

------------------------------------------------------------
PART NO. 11 NO. OF. OPER.:  5 LEAD TIME:   6.
         OPER. NO.   WK. CTR.       STD. TIME      SETUP TIME
            1          2               0.031          0.010
            2          1               0.073          0.010
            3          4               0.130          0.010
            4          3               0.156          0.010
            5          4               0.008          0.010
                                       -----          -----
                                TOTAL   0.398  TOTAL   0.050

------------------------------------------------------------
PART NO. 12 NO. OF. OPER.:  2 LEAD TIME:   1.
         OPER. NO.   WK. CTR.       STD. TIME      SETUP TIME
            1          3               0.179          0.010
            2          4               0.152          0.010
                                       -----          -----
                                TOTAL   0.331  TOTAL   0.020

------------------------------------------------------------
PART NO. 13 NO. OF. OPER.:  2 LEAD TIME:   2.
         OPER. NO.   WK. CTR.       STD. TIME      SETUP TIME
            1          4               0.083          0.010
            2          2               0.111          0.010
                                       -----          -----
                                TOTAL   0.194  TOTAL   0.020


U N I T   W O R K   C O N T E N T    /*this shows the single
                                     /*level work content of
WORK CENTER--- 1     2     3     4   /*each part in standard
                                     /*hours
PART NO.: 1   0.068 0.064 0.181 0.076
PART NO.: 2   0.092 0.053 0.0   0.0
PART NO.: 3   0.087 0.119 0.183 0.151
PART NO.: 4   0.143 0.0   0.0   0.093
PART NO.: 5   0.103 0.067 0.181 0.178
PART NO.: 6   0.092 0.119 0.115 0.0
PART NO.: 7   0.069 0.125 0.119 0.0
PART NO.: 8   0.107 0.163 0.0   0.047
PART NO.: 9   0.0   0.102 0.0   0.288
PART NO.:10   0.180 0.076 0.142 0.0
PART NO.:11   0.073 0.031 0.156 0.138
PART NO.:12   0.0   0.0   0.179 0.152
PART NO.:13   0.0   0.111 0.0   0.083


L O A D - C A P A C I T Y   A N A L Y S I S
```

```
/*this shows the average load at each work center based on
/*the demand rate for each end item and the unit work content
WORK CENTER:  1 AVERAGE TOTAL LOAD:      84.00  /*total load &
UNIT MACHINE LOAD                  :      42.00  /*load at each
                                                 /*machine in
WORK CENTER:  2 AVERAGE TOTAL LOAD:      83.90  /*std hrs
UNIT MACHINE LOAD                  :      41.95

WORK CENTER:  3 AVERAGE TOTAL LOAD:      84.00
UNIT MACHINE LOAD                  :      42.00

WORK CENTER:  4 AVERAGE TOTAL LOAD:      84.00
UNIT MACHINE LOAD                  :      42.00


PRODUCT LOADING REPORT
/*this shows the contribution of each end item to total work
/*load at each work center based on its demand rate
ITEM:  1 IN WC ORDER:      17.06      10.49      18.86      17.24
ITEM:  2 IN WC ORDER:      28.62      36.57      18.60       3.74
ITEM:  3 IN WC ORDER:      29.77      30.20      35.83      43.41
ITEM:  4 IN WC ORDER:       8.55       6.64      10.71      19.62


PRODUCT WORK CONTENT REPORT
/*this shows the total work content of each end item by work
/*center, based on a build quantity of 1
ITEM:  1 IN WC ORDER:      0.493      0.303      0.545      0.498
ITEM:  2 IN WC ORDER:      0.360      0.460      0.234      0.047
ITEM:  3 IN WC ORDER:      0.550      0.558      0.662      0.802
ITEM:  4 IN WC ORDER:      0.143      0.111      0.179      0.328


***SUMMARY REPORT FOR RUN    1 OF    1 RUNS***

RUN    LABOR      INVTRY    WIP

 1    334.33    2358.99    6467.69   /*if no detail report requested
                                     /*this summary is all you get
                                     /*for each replication
P R O D U C T I O N   R E P O R T

 PART NO.        ORDERED  PRODUCED       BLKS      BLKD
    1             6577.     6195.          0.     1338.
    2            22186.    22186.          0.        0.
    3            17387.    16981.         12.        0.
    4            18230.    18168.         16.        0.
    5            17744.    16609.       3617.        0.
    6            15378.    14464.          0.      417.
    7            15537.    15376.        411.        0.
```

```
   8          26412.    25399.       48.        0.
   9          10628.     9680.        0.     2664.
  10          10848.    10235.      183.        0.
  11          10956.     9954.      869.        0.
  12          11457.    11278.        0.       25.
  13          11581.    11581.       19.        0.
/*BLKS column shows the number of times this part blocked an
/*assy from release to shop floor
/*BLKD column shows the number of times this assy was blocked
/*from release by shortage of one or more if its components


W O R K   R E P O R T

WK. CTR.     HRS WKD  /*no. of hours total, worked at each
1             8356.   /*work center during this replication
2             8304.
3             8360.
4             8270.

*** SLAM Summary Report Omitted (to fit listing onto page) ***
```

A.7 EVENT CODES

There are three event types in MRPSIM. They are:

1 = Operation completion at a work center (Sbr OPC)

2 = End of the work week at a work center (Sbr ENDWK)

3 = Weekly MRP review (Sbr REVIEW)

A.8 SUBROUTINE DESCRIPTIONS

There are 16 subroutines, 2 function subprograms, and the usual SLAM main program in MRPSIM. A description of the function of each subprogram is given below, in alphabetical order.

A.8.1 B1

B1 is the bill of material processor. It also time phases gross requirements.

A.8.2 BMOUT

BMOUT prints out bill of material information.

A.8.3 COSTLB

COSTLB returns the cost of X hours at work center K.

A.8.4 CRPWRT

CRPWRT prints out the CRP optionally.

A.8.5 ENDWK

ENDWK is the end of work week event processor. The event calendar is searched for active orders on machines. They are then removed from the event list andplaced back in the work center queue with highest priority. The remaining processing time is saved in ATRIB(10).

A.8.6 EVENT

EVENT calls the appropriate event processing routine as defined by the event codes in the prceding section.

A.8.7 INTLC

INTLC reads input data, initializes variables, and calls data echo routines.

A.8.8 IOCNTL

IOCNTL is the interface between the MRP logic and the production shop simulation logic. Orders are loaded into the work center queues from the holding pool. Then, each machine is set to work on an order from the queue. Work week lengths are determined by IOCNTL.

A.8.9 LOTSZE

LOTSZE performs order placement for gross requirements. Since LOT4LOT ordering is only policy, no explicit netting procedure exists in MRPSIM.

A.8.10 MSGEN

MSGEN generates the master schedule for each end-item. This is done by exponentially smoothing a Poisson sequence of demands.

A.8.11 NUPRIO

NUPRIO updates all priorities in the shop. This is done on a weekly basis. Priorities can be updated at every operation completion by coding the appropriate field in the input data for this.

A.8.12 OPC

OPC is the operation completion event processor for the shop simulation logic. There is no arrival event since IOCNTL explicitly load orders into the work centers from the holding pool once per week.

A.8.13 PRIO

PRIO generates job order priorities. Several different priority rules are possible. The rules are modified for dynamic update forms.

A.8.14 REVIEW

REVIEW performs the weekly MRP review. The planning horizon is extended one week into the future, and requirements are generated by re-exploding the bills of material.

A.8.15 STAWRT

STAWRT prints out end of simulation statistics.

A.8.16 SUMRY

SUMRY prints out the customary SLAM SUMMARY Report.

A.8.17 WCOUT

WCOUT prints out work center and part routing information.

A.8.18 WRAP

WRAP is a utility that wraps the storage arrays around themselves periodically in order to save storage space.

A.9 FORTRAN SOURCE CODE

```
      DIMENSION NSET(15000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/DREAD/IRED
      COMMON QSET(15000)
      EQUIVALENCE (NSET(1),QSET(1))
C---
C---
C---     M R P S I M  - AN MRP/PRODUCTION SIMULATOR (SLAM)
C---
C---            BY: KURT M. GUTZMANN
C---
C---       C COPYRIGHT 1983  BY KURT M. GUTZMANN  1983
C---            ALL RIGHTS RESERVED
C---
      STOP
      END
      IRED=0
      NNSET=15000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END
```

```
      SUBROUTINE EVENT(I)
      GOTO(1,2,3),I
1     CALL OPC
C--- OPERATION COMPLETION AT A WORK CENTER
      RETURN
2     CALL ENDWK
C--- END OF WORK WEEK AT A WORK CENTER
      RETURN
3     CALL REVIEW
C--- WEEKLY MRP REVIEW
      RETURN
      END
```

```
      SUBROUTINE REVIEW
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/CAPCRP/CRP(20,10),PERF(20)
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
C--- INCREMENT TIME COUNTERS
      INOW=INOW+1
      KNW=KNW+1
      IF(INOW.EQ.(1+2*NPLAN)) CALL WRAP
      IF(KNW.LE.NWKS)GOTO10
C--- LAST REVIEW HERE
      NREP=NREP+1
      XLBR(NREP)=CCAVG(46)
      XINV(NREP)=TTAVG(IHIPN+NWCTR+1)
      XWIP(NREP)=TTAVG(IHIPN+NWCTR+2)
      MSTOP=-1
         RETURN
10    N2=INOW+NPLAN-1
      NK2=KNW+NPLAN-1
      DO 1 I=1,IHIPN
      DO 1 J=1,120
      DO 1 K=1,NPRODS
1     MRP(I,J,K)=0
      DO 2 I=1,NPRODS
      DO 4 J=KNW,NK2
      IPLAN=J-NWRAP*NPLAN
      IQTY=MSTR(I,J)
C--- RE-EXPLODE REQUIREMENTS
4     CALL B1(I)
2     CALL LOTSZE(I)
      DO 3 K=1,NPRODS
      DO 3 I=1,IHIPN
C--- LOAD PLANNED ORDERS FOR INOW INTO HOLDING FILE (IHFILE)
      IF(KPLAN(I,INOW,K).LE.0)GOTO3
      ATRIB(1)=I
      ATRIB(2)=KPLAN(I,INOW,K)
```

```
      ATRIB(3)=40.*(KNW+INT(TL(I)+.99))
      ATRIB(4)=PRIO(I)
      ATRIB(5)=TNOW
      ATRIB(7)=ATRIB(2)*TMTOT(I)+TSET(I)
      ATRIB(13)=0.
      IF(I.EQ.ITEM(K))ATRIB(13)=1.0
      NORDS=NORDS+1
      ATRIB(11)=NORDS
      CALL FILEM(IHFILE,ATRIB)
      XORD(I)=XORD(I)+ATRIB(2)
3     CONTINUE
      CALL IOCNTL
      RETURN
      END
```

```
      SUBROUTINE IOCNTL
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/CAPCRP/CRP(20,10),PERF(20)
      COMMON/CST1/CSTINV(20),CLABOR(20)
      DIMENSION BLOG(20),CLOAD(20)
       TLD=0.0
       DO 7 I=1,NWCTR
       CLOAD(I)=0.0
C--- MEASURE BACKLOGS AT WORK CENTERS
7      BLOG(I)=SUMQ(10,I)
      IHOLD=NNQ(IHFILE)
      IF(IHOLD.LE.0)GOTO6
      DO 1 I=1,IHOLD
C--- PULL ORDERS FROM HOLD FILE
      CALL RMOVE(1,IHFILE,ATRIB)
      INP=ATRIB(1)
      IF(NCMP(INP).LE.0)GOTO3
C--- CHECK COMPONENT AVAILABILITY
      IHAVE=NCMP(INP)
      IDUM=NCMP(INP)
       DO 2 J=1,IDUM
       NIX=NCPN(INP,J)+10
       IREQ=ATRIB(2)*NCQT(INP,J)
       IF(XX(NIX).GE.(ATRIB(2)*NCQT(INP,J)))GOTO2
       XX(NIX+20)=XX(NIX+20)+1.0
       IHAVE=IHAVE-1
2      CONTINUE
       IF(IHAVE.GE.NCMP(INP))GOTO11
       XX(INP+50)=XX(INP+50)+1.0
C--- BLOCKED DUE TO PART SHORTAGE(S)
       CALL FILEM(IBFILE,ATRIB)
       GOTO1
11     DO 4 J=1,IDUM
       NIX=NCPN(INP,J)+10
```

```
C--- REMOVE ITEMS FROM STOCK
4       XX(NIX)=XX(NIX)-NCQT(INP,J)*ATRIB(2)
3       ATRIB(6)=TNOW
        ATRIB(4)=PRIO(INP)
        ATRIB(8)=MROUT(INP,1)
        ATRIB(9)=0.
        ATRIB(10)=SETUP(INP,1)+ATRIB(2)*STDTM(INP,1)
C--- LOAD INTO WORK CENTER QUEUE
        CALL FILEM(MROUT(INP,1),ATRIB)
        XX(96)=XX(96)+ATRIB(2)
        XX(100)=XX(100)+1.
C       DO 8 K=1,NWCTR
C8       CLOAD(K)=CLOAD(K)+ATRIB(2)*WC(INP,K)
        CLOAD(MROUT(INP,1))=CLOAD(MROUT(INP,1))+ATRIB(10)
1       CONTINUE
        IBLOCK=NNQ(IBFILE)
C--- PUT BLOCKED ORDERS BACK IN HOLD FROM TEMP FILE
        IF(IBLOCK.LE.0)GOTO6
        DO 66 I=1,IBLOCK
        CALL RMOVE(1,IBFILE,ATRIB)
        ATRIB(4)=PRIO(-999)
        CALL FILEM(IHFILE,ATRIB)
66      CONTINUE
6       XX(94)=0.
C--- UPDATE PRIORITIES
        CALL NUPRIO
        DO 5 I=1,NWCTR
        XX(I)=0.
        BT=BLOG(I)+CLOAD(I)
        KK=I+20
        CALL COLCT(BT,KK)
        TLD=TLD+BT
        WKLEN=NOMCAP(I)
C--- SET WORK WEEK LENGTHS BASED ON BACKLOG
        GOTO(901,902),ICNTRL
901     IF(BT.GT.CLU(I))WKLEN=NOMCAP(I)+REDFAC*(BT-CLU(I))
        IF(WKLEN.GT.MAXCAP(I))WKLEN=MAXCAP(I)
        GOTO903
902     IF(BT.GT.CLU(I))WKLEN=MAXCAP(I)
903     PERF(I)=WKLEN/40.0
        IF(PERF(I).LT.1.)PERF(I)=1.
        XX(94)=XX(94)+WKLEN*NMACH(I)
        XX(I+70)=XX(I+70)+WKLEN
        IK=I+30
        CALL COLCT(WKLEN,IK)
        DO55J=2,13
55      ATRIB(J)=0
        ATRIB(1)=I
        CALL SCHDL(2,40.0,ATRIB)
        IDUM=NNQ(I)
```

```
      IF(IDUM.LE.0)GOTO5
      IF(IDUM.GT.NMACH(I))IDUM=NMACH(I)
      XX(I)=IDUM
C--- LOAD MACHINES
      DO 45 J=1,IDUM
      CALL RMOVE(1,I,ATRIB)
      ATRIB(8)=I
      STM=ATRIB(10)/PERF(I)
      ATRIB(12)=TNOW
45    CALL SCHDL(1,STM,ATRIB)
5     CONTINUE
      CALL SCHDL(3,40.001,ATRIB)
C------CALL CRPWRT(CRP,NWCTR,NPLAN,INOW)
      CALL COLCT(TLD,45)
      CALL COLCT(XX(94),46)
      XX(91)=0.
      DO 99 I=1,IHIPN
      IDUM=I+4
      XX(91)=XX(91)+TTAVG(IDUM)
99    XX(97)=XX(97)+XX(I+10)
      IF(KNW.EQ.KCLEAR)CALL CLEAR
      IF(KNW.LE.KCLEAR)RETURN
      XX(92)=XX(92)+XX(94)
      XX(95)=XX(92)/FLOAT(KNW-KCLEAR)
      XX(98)=XX(97)/FLOAT(KNW-KCLEAR)
      XX(93)=XX(95)+XX(91)
C--- USE GPLOT FOR GRAPHS OF VARIABLES OVER TIME
C     CALL GPLOT(1)
      RETURN
      END
```

```
      SUBROUTINE B1(NNN)
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
C--- BILL OF MATERIAL PROCESSOR
         NS(1,2,NNN)=IQTY
         NDUM=NREC(NNN)
         DO 10 II=1,NDUM
         IR=NDUM+1-II
         NP=NS(IR,1,NNN)
         TLEAD=0.0
         NLVL=NS(IR,5,NNN)+1
         MFAC=NS(IR,2,NNN)
         NPNN=NS(IR,4,NNN)
         IF(NPNN.EQ.0)GOTO12
11       MFAC=MFAC*NS(NPNN,2,NNN)
         TLEAD=TLEAD+TL(NPNN)
         NPNN=NS(NPNN,4,NNN)
         IF(NPNN.GT.0) GOTO11
12       NT(NP,NLVL,NNN)=MFAC+NT(NP,NLVL,NNN)
         ITL=TLEAD+.99
         INDX=IPLAN-ITL
         IF(INDX.LE.0) INDX=1
         MRP(NP,INDX,NNN)=MFAC+MRP(NP,INDX,NNN)
10       CONTINUE
         IF(KXFLG.GE.1)RETURN
         KD=NREC(NNN)
         DO 101 K=1,KD
         IF(IPFLG(NS(K,1,NNN)).GE.1)GOTO101
         LVL=NS(K,5,NNN)+1
         IF(LVL.GT.NLVLS(NNN))GOTO109
         IN=K
103      IN=IN+1
         IF(IN.GT.KD)GOTO101
         IF(NS(IN,5,NNN).GT.LVL)GOTO101
102      IF(NS(IN,4,NNN).NE.K)GOTO103
          NCMP(NS(K,1,NNN))=NCMP(NS(K,1,NNN))+1
          NCPN(NS(K,1,NNN),NCMP(NS(K,1,NNN)))=NS(IN,1,NNN)
          NCQT(NS(K,1,NNN),NCMP(NS(K,1,NNN)))=NS(IN,2,NNN)
          IPFLG(NS(K,1,NNN))=1
          GOTO103
101      CONTINUE
109      DO 606 I=1,IHIPN
         DO 606 J=1,10
606      NQ(I,NNN)=NQ(I,NNN)+NT(I,J,NNN)
         RETURN
```

END

```
      SUBROUTINE LOTSZE(NNN)
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
       N2=INOW+NPLAN
       DO 10 I=1,IHIPN
       DO 10 J=INOW,N2
       INDX=J-INT(TL(I)+.99)
       KPLAN(I,INDX,NNN)=MRP(I,J,NNN)
10     CONTINUE
       RETURN
       END
```

```
      SUBROUTINE BMOUT(KKK)
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      IF(KKK.LT.0)GOTO999
      WRITE(6,100)KKK,NPRODS,NS(1,1,KKK)
100   FORMAT('1',////,10X,'B I L L   O F   M A T E R I A L   N
O.',I2,
     &' OF ',I2,//,10X,'----- TOP LEVEL PART NO. ----- ',I3,//)
      WRITE(6,102)
102   FORMAT(//,10X,'I N P U T   R E C O R D S',//,T8,'RECNO',T20,
     &'PN',T30,'QTY',T36,'PRNT PN',T44,'PRNT RECNO',T60,'LEVEL')
      NDUM=NREC(KKK)
      DO 1 I=1,NDUM
1     WRITE(6,103)I,(NS(I,J,KKK),J=1,5)
103   FORMAT(T10,I2,T20,I2,T30,I2,T40,I2,T50,I2,T60,I2)
      WRITE(6,104)
104   FORMAT(//,10X,'T O T A L   Q T Y   B Y   P A R T   N O.',/)
      NDUM=NPN(KKK)
      DO 2 I=1,NDUM
2     IF(NQ(I,KKK).GT.0)WRITE(6,105)I,NQ(I,KKK)
105   FORMAT(T20,'PART NO.',T30,I2,T40,'TOTAL REQD: ',I2)
      WRITE(6,106)
106   FORMAT(//,10X,'Q T Y   B Y   L E V E L',/)
      NL1=NLVLS(KKK)+1
      DO 3 I=1,NDUM
3     IF(NQ(I,KKK).GT.0)WRITE(6,107)I,(NT(I,J,KKK),J=1,NL1)
107   FORMAT(9X,'PN',I2,1X,10(8X,I2))
      RETURN
999   WRITE(6,108)
108   FORMAT('1',//,10X,'C O M P O N E N T S / A S S Y   Q T Y
S',/)
      DO 4 I=1,IHIPN
      IF (NCMP(I).LE.0)GOTO4
      IDUM=NCMP(I)
      WRITE(6,109)I,NCMP(I)
109   FORMAT(/,9X,'ASSY. PART NO. ',I2,' NO. OF
COMPONENTS:',I2,T50,
     &'PART NO.',T60,'QTY')
      DO 5 J=1,IDUM
5     WRITE(6,110)NCPN(I,J),NCQT(I,J)
110   FORMAT(T50,I2,T60,I2)
4     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WCOUT
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)
      DIMENSION WLD(10),WLU(10),WCP(6,10),WUL(6,10)
      WRITE(6,101)NWCTR
      DO 1 I=1,NWCTR
1     WRITE(6,102)I,NMACH(I),NOMCAP(I),MAXCAP(I),CLL(I),CLU(I)
      WRITE(6,1021)REDFAC
1021  FORMAT(//,10X,'CONTROL REDUCTION FACTOR : ',F5.2)
      WRITE(6,103)
      DO 2 I=1,IHIPN
      WRITE(6,104)I,NOPS(I),TL(I)
      IDUM=NOPS(I)
      DO 3 J=1,IDUM
3     WRITE(6,105)J,MROUT(I,J),STDTM(I,J),SETUP(I,J)
2     WRITE(6,106)TMTOT(I),TSET(I)
      WRITE(6,201)(I,I=1,NWCTR)
      DO 202 I=1,IHIPN
202   WRITE(6,203)I,(WC(I,J),J=1,NWCTR)
      DO 300 J=1,NWCTR
      WLD(J)=0.
      DO 300 I=1,6
      WUL(I,J)=0.0
300   WCP(I,J)=0.0
      DO 301 J=1,NWCTR
      DO 301 I=1,IHIPN
      DO 301 KKK=1,NPRODS
      WUL(KKK,J)=WUL(KKK,J)+NQ(I,KKK)*WC(I,J)
      WCP(KKK,J)=WCP(KKK,J)+RAT(KKK)*NQ(I,KKK)*WC(I,J)
301   WLD(J)=WLD(J)+RAT(KKK)*NQ(I,KKK)*WC(I,J)
      WRITE(6,204)
      DO 302 J=1,NWCTR
      WLU(J)=WLD(J)/FLOAT(NMACH(J))
302   WRITE(6,205)J,WLD(J),WLU(J)
      WRITE(6,206)
      DO 303 KKK=1,NPRODS
303   WRITE(6,207)KKK,(WCP(KKK,J),J=1,NWCTR)
      WRITE(6,209)
      DO 304 KKK=1,NPRODS
304   WRITE(6,208)KKK,(WUL(KKK,J),J=1,NWCTR)
```

```
      RETURN
101   FORMAT('1',//,10X,'W O R K   C E N T E R   D A T A',//,
     &10X,I2,' WORK CENTERS',//,10X,'NO.',T19,'NO. MACH.',T29,
     &'NOM. CAP.',T39,'MAX. CAP.',T52,'LO CL',T62,'HI CL',/)
102   FORMAT(10X,4(I3,7X),2(F5.1,5X))
103   FORMAT('1',///,10X,'P A R T   R O U T I N G S',/)
104   FORMAT(/,10X,60('-'),/,10X,'PART NO. ',I2,' NO. OF. OPER.:
',I2,
     &' LEAD TIME: ',F4.0,
     &/,T20,'OPER. NO. ',T30,' WK. CTR. ',T45,' STD. TIME ',
     &T60,' SETUP TIME ')
105   FORMAT(20X,2(I2,8X),,5X,2(F8.3,7X))
106   FORMAT(48X,'-----',10X,'-----',/,40X,2('TOTAL',F8.3,2X))
201   FORMAT('1',///,10X,'U N I T   W O R K   C O N T E N
T',//,10X,
     &'WORK CENTER---',10(I2,4X))
203   FORMAT(/,10X,'PART NO.:',I2,3X,10(F5.3,1X))
204   FORMAT('1',///,10X,'L O A D - C A P A C I T Y   A N A L Y S I
S',/)
205   FORMAT(/,10X,'WORK CENTER: ',I2,' AVERAGE TOTAL LOAD: ',F9.2,
     &' UNIT MACHINE LOAD: ',F9.2)
206   FORMAT(//,10X,'PRODUCT LOADING REPORT',/)
207   FORMAT(/,10X,'ITEM: ',I2,' IN WC ORDER: ',4(F9.2,1X))
208   FORMAT(/,10X,'ITEM: ',I2,' IN WC ORDER: ',4(F9.3,1X))
209   FORMAT(//,10X,'PRODUCT WORK CONTENT REPORT',/)
      END
```

```
      SUBROUTINE INTLC
      COMMON/DREAD/IRED
      COMMON/CST1/CSTINV(20),CLABOR(20)
      COMMON/PRI1/COVK,TUTIL,IPRIO,NUPRI
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
         WRITE(6,9999)
9999  FORMAT('1',//,10X,'M R P S I M  VERSION 1.0 ',
    &'MRP PRODUCTION SIMULATOR',
    &//,10X,'C COPYRIGHT 1983 BY KURT M. GUTZMANN',
    &//,10X,'ALL RIGHTS RESERVED')
         INOW=0
         KNW=0
         NWRAP=0
         KXFLG=0
         NORDS=0
         MSTOP=1
         DO 131 I=1,20
         DO 131 J=1,120
         DO 131 K=1,6
         NET(I,J,K)=0
         MRP(I,J,K)=0
         KPLAN(I,J,K)=0
131      KSCHD(I,J,K)=0
         DO 132 I=1,20
         XORD(I)=0.
132      XPRD(I)=0.
         DO 322 J=1,2000
322      MSTR(I,J)=0
          IF(IRED.LE.0) GOTO 133
          CALL MSGEN(RAT,ALPHA,NRD,NSTART)
          CALL SCHDL(3,0.0,ATRIB)
          RETURN
133        DO 31 I=1,20
         NCMP(I)=0
```

```
          TL(I)=0.
          INV(I)=0
          IPFLG(I)=0
          IGROSS(I)=0
            DO 32 J=1,10
          NQ(I,J)=0
          NCPN(I,J)=0
          WC(I,J)=0.0
32        NCQT(I,J)=0
            DO 31 J=1,120
            DO 31 K=1,6
31          NT(I,J,K)=0
      READ(5,*) NPLAN,NWKS,NPRODS,IHIPN
      READ(5,*)KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,IRPT,NRPLS
      READ(5,*)REDFAC
      WRITE(6,101)NWKS,NPLAN,NPRODS,IHIPN

WRITE(6,1011)KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,IRPT,NRPLS,REDFAC
        DO  7  K=1,NPRODS
        READ(5,*) NPN(K),NREC(K),NLVLS(K)
        KDUM=NREC(K)
          DO 2 I=1,KDUM
2         READ(5,*) (NS(I,J,K),J=1,5)
          ITEM(K)=NS(1,1,K)
          KITEM(ITEM(K))=K
7     CONTINUE
      READ(5,*)NSTART
      READ(5,*)(RAT(I),I=1,NPRODS)
      READ(5,*)(ALPHA(I),I=1,NPRODS)
      NRD=NPLAN+NWKS
      CALL MSGEN(RAT,ALPHA,NRD,NSTART)
        DO 11 I=1,NPRODS
        DO 11 J=1,NRD
11      IGROSS(I)=IGROSS(I)+MSTR(I,J)
        IF(IMPRNT.NE.1)GOTO911
        WRITE(6,111)
        DO 113 K=1,NPRODS
113     WRITE(6,112)ITEM(K),IGROSS(K)
        WRITE(6,211)NSTART
        DO 202 I=1,NPRODS
202     WRITE(6,212)ITEM(I),RAT(I),ALPHA(I)
911      CONTINUE
3         DO 5 I=1,IHIPN
5         READ(5,*)TL(I)
8         READ(5,*) NWCTR
          DO 9 I=1,NWCTR
9         READ(5,*)NOMCAP(I),MAXCAP(I),NMACH(I),CLL(I),CLU(I)
          DO 10 I=1,IHIPN
          READ(5,*)NOPS(I)
          IDUM=NOPS(I)
          READ(5,*)(MROUT(I,J),J=1,IDUM)
```

```
      READ(5,*)(STDTM(I,J),J=1,IDUM)
      READ(5,*)(SETUP(I,J),J=1,IDUM)
      DO 10 J=1,IDUM
      TSET(I)=TSET(I)+SETUP(I,J)
10    TMTOT(I)=TMTOT(I)+STDTM(I,J)
      READ(5,*) IPRIO,TUTIL,NUPRI
      IF(IPRIOR.EQ.8) READ(5,*)COVK
      DO 201 I=1,IHIPN
      IDM=NOPS(I)
      DO 201 J=1,IDM
201   WC(I,MROUT(I,J))=WC(I,MROUT(I,J))+STDTM(I,J)
      IHFILE=NWCTR+1
      IBFILE=IHFILE+1
      IQTY=1
      IPLAN=NPLAN
      DO 12 I=1,NPRODS
      CALL B1(I)
      IF(IBPRNT.EQ.1)CALL BMOUT(I)
12    CONTINUE
      KXFLG=1
      IF(IBPRNT.EQ.1)CALL BMOUT(-1)
      IF(IWPRNT.EQ.1)CALL WCOUT
      IMPRNT=0
      IBPRNT=0
      IWPRNT=0
      NREP=0
      CALL SCHDL(3,0.0,ATRIB)
      IRED=1
      RETURN
101    FORMAT('1',//,10X,'M R P    S I M U L A T O R   I N P U T S',
     &//,10X,'NO. REVIEWS TO RUN ',T40,I4,/,10X,
     &'PLANNING HORIZON LENGTH',T40,I2,/,10X,'NO. OF END-ITEMS'
     &,T40,I2,/,10X,'HIGHEST PART NO.',T40,I2)
1011   FORMAT(/,10X'CLEAR PERIOD',T40,I3,/,10X,'POLICY SELECTED
',T40,
     &I3,/,10X,'PRINT B-O-M',T40,I3,/,10X,'PRINT WCTR &
ROUTES',T40,I3,
     &/,10X,'PRINT MSTR SCHED',T40,I3,/,10X,'REPORT MODE',T40,I3,
     &/,10X,'NO. REPLICATIONS',T40,I3,/,10X,'REDUCTION
FACTOR',T40,F4.2)
111     FORMAT(/,10X,'TOTAL GROSS REQD  END ITEMS')
112     FORMAT(/,10X,,'END ITEM PN: ',I2,' REQD: ',I9)
116     FORMAT('1',//,10X,'M A S T E R   S C H E D U L E ',//
     &,10X,'PERIOD REQD',T30,4('PN:',I3,4X),/,10X,50('-'))
117     FORMAT(12X,I4,T32,10(I5,5X))
211     FORMAT(//,10X,'END ITEM DEMAND PARAMETERS',/,10X,'ITEM
NO.',T23,
     &'RATE',T32,'ALPHA',T40,'NSTART: ',I3)
212     FORMAT(13X,I3,T22,F5.1,T32,F5.2)
      END
```

```
      SUBROUTINE OPC
      COMMON/PRI1/COVK,TUTIL,IPRIO,NUPRI
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/CAPCRP/CRP(20,10),PERF(20)
       LMNO=ATRIB(8)+.5
       XX(LMNO)=XX(LMNO)-1.
       ATRIB(9)=ATRIB(9)+1.
       NOPC=ATRIB(9)
       JT=ATRIB(1)
       IF(NOPC.LT.NOPS(JT))GOTO12
       XPRD(JT)=XPRD(JT)+ATRIB(2)
       XX(100)=XX(100)-1.0
       XX(96)=XX(96)-ATRIB(2)
       DO 99 KK=1,NPRODS
       IF(JT.EQ.ITEM(KK))GOTO21
99     CONTINUE
       XX(JT+10)=XX(JT+10)+ATRIB(2)
21     TSYS=TNOW-ATRIB(5)
       CALL COLCT(TSYS,41)
       THOLD=ATRIB(6)-ATRIB(5)
       CALL COLCT(THOLD,42)
       TSHOP=TNOW-ATRIB(6)
       CALL COLCT(TSHOP,43)
       TARDY=TNOW-ATRIB(3)
       CALL COLCT(TARDY,44)
       CALL COLCT(TSYS,JT)
       GOTO6
12     NXOP=NOPC+1
       ATRIB(7)=ATRIB(7)-ATRIB(10)
       NXMNO=MROUT(JT,NXOP)
       STM=SETUP(JT,NXOP)+ATRIB(2)*STDTM(JT,NXOP)
       ATRIB(10)=STM
       STM=STM/PERF(NXMNO)
       ATRIB(8)=MROUT(JT,NXOP)
```

```
      IF(NUPRI.GE.1) ATRIB(4)=PRIO(JT)
      IF(XX(NXMNO).LT.(FLOAT(NMACH(NXMNO))))GOTO3
1     CALL FILEM(NXMNO,ATRIB)
      GOTO6
3     XX(NXMNO)=XX(NXMNO)+1.
      ATRIB(12)=TNOW
      CALL SCHDL(1,STM,ATRIB)
6     IF(NNQ(LMNO).LE.0)RETURN
      XX(LMNO)=XX(LMNO)+1.0
      CALL RMOVE(1,LMNO,ATRIB)
      ATRIB(12)=TNOW
      ATRIB(8)=LMNO
      STM=ATRIB(10)/PERF(LMNO)
      CALL SCHDL(1,STM,ATRIB)
      RETURN
      END
```

```
      SUBROUTINE ENDWK
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)

COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/BM/NT(20,10,10),NQ(20,10),NCMP(20),NCQT(20,10),
     +NS(25,5,10),IR,NP,NPAR,NPN(20),NREC(20),TL(20),NCPN(20,10),
     +IPFLG(20)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
       MNO=ATRIB(1)
      IF(XX(MNO).LE.0.)GOTO99
      NCAL=NNQ(NCLNR)
      IF(NCAL.LE.0) GOTO99
      DO 12 I=1,NCAL
      NEXT=MMFE(NCLNR)
10    IF(NEXT.EQ.0)GOTO12
      CALL COPY(-NEXT,NCLNR,ATRIB)
      ITST=ATRIB(14)
      IF(ITST.NE.1)GOTO13
      ITST=ATRIB(8)
      IF(MNO.EQ.ITST)GOTO11
13    NEXT=NSUCR(NEXT)
      GOTO10
11    CALL RMOVE(-NEXT,NCLNR,ATRIB)
      ATRIB(10)=ATRIB(12)-TNOW+ATRIB(10)
      ATRIB(4)=PRIO(-999)
      CALL FILEM(MNO,ATRIB)
12    CONTINUE
99    RETURN
      END
```

```
      FUNCTION PRIO(JOB)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/ROUTE/WC(20,10),NOPS(20),MROUT(20,10)
     &,STDTM(20,10),SETUP(20,10)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/PRI1/COVK,TUTIL,IPRIO,NUPRI
       IF(JT.GT.0)GOTO111
       PRIO=-99999+KNW
       IF(IPRIO.EQ.8) PRIO=99999-KNW
       RETURN
111    GOTO(1,2,3,4,5,6,7,8,9,10,9),IPRIO
1      PRIO=ATRIB(3)-TNOW
           RETURN
2      P=ATRIB(3)-TNOW
       D=ATRIB(7)
       IF(P.GE.0.)D=1./D
       PRIO=P*D
           RETURN
3      P=ATRIB(3)-TNOW
       D=FLOAT(NOPS(JOB))-ATRIB(9)
       IF(P.GE.0.)D=1./D
       PRIO=P*D
           RETURN
4      PRIO=ATRIB(5)
           RETURN
5      PRIO=(ATRIB(3)-TNOW)-(ATRIB(7)/(1.-TUTIL))
           RETURN
6      P=(ATRIB(3)-TNOW-(ATRIB(7)/(1.-TUTIL)))
       D=ATRIB(7)
       IF(P.GE.0.)D=1./D
       PRIO=P*D
           RETURN
7      P=((ATRIB(3)-TNOW)-(ATRIB(7)/(1.-TUTIL)))
       D=FLOAT(NOPS(JOB))-ATRIB(9)
       IF(P.GE.0.)D=1./D
       PRIO=P*D
           RETURN
8      D=ATRIB(3)
       XNI=D-(ATRIB(7)/(1.-TUTIL))
       UI=D-ATRIB(7)
       CKI=COVK*(UI-XNI)
       IF(CKI.LE.00)CKI=.000001
       SI=UI-TNOW
       IF(SI.LT.CKI)GOTO 81
       CI=0.0
       GOTO 84
```

```
81      IF(SI.LT.0.)GOTO 82
        CI=(CKI-SI)/CKI
        GOTO84
82      CI=1.0
84      IF(ATRIB(10).LE.00.)ATRIB(10)=.0001
        PRIO=CI/ATRIB(10)
        RETURN
9       ATRIB(4)=ATRIB(3)
        RETURN
10      PRIO=(ATRIB(3)-ATRIB(7))/(ATRIB(3)-TNOW)
        RETURN
        END
```

```
      SUBROUTINE CRPWRT(C,NC,N,INDX)
      DIMENSION C(20,10)
      WRITE(6,100)
100   FORMAT(///,10X,'CAPACITY REQUIREMENTS PLAN',//)
      NN=INDX+N-1
      WRITE(6,101)(I,I=INDX,NN)
101   FORMAT(10X,'PERIOD----',2X,20(I2,4X))
      DO 1 I=1,NC
1     WRITE(6,102)I,(C(I,J),J=1,N)
102   FORMAT(/,10X,'WKCTR-',I2,'--',20(F5.1,1X))
      DO 2 I=1,10
      DO 2 J=1,10
2     C(I,J)=0.0
      RETURN
      END
```

```
      SUBROUTINE STAWRT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
      WRITE(6,1)
      DO 10 I=1,IHIPN
10    WRITE(6,3) I,XORD(I),XPRD(I),XX(I+30),XX(I+50)
      WRITE(6,2)
      DO 20 I=1,NWCTR
20    WRITE(6,4)I,XX(I+70)
2     FORMAT(///,10X,'W O R K   R E P O R T',//,10X,'WK. CTR.',T20,
     &'HRS WKD')
4     FORMAT(10X,I2,8X,F9.0)
1     FORMAT('1',//,10X,'P R O D U C T I O N   R E P O R T',//,
     &8X,'PART
NO.',T22,'ORDERED',T31,'PRODUCED',T45,'BLKS',T55,'BLKD')
3     FORMAT(10X,I2,8X,5F10.0)
      RETURN
      END
```

```
      SUBROUTINE MSGEN(R,A,N,NS)
COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)
      DIMENSION R(20),A(20),S(2000)
103   DO 1 I=1,NPRODS
       B=1.-A(I)
      DO 2 J=1,N
2     S(J)=NPSSN(R(I),I)
      MSTR(I,1)=R(I)+.5
      DO 3 J=2,N
      J1=J-1
3     MSTR(I,J)=.50+(B*MSTR(I,J1)+A(I)*S(J))
      DO 4 J=1,NS
4     MSTR(I,J)=0
1     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WRAP
COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)
COMMON/MS2BM/IPLAN,IQTY,NPLAN,MSTR(20,2000),KXFLG,NPRODS,NLVLS(20)
      COMMON/IN/NET(20,120,6),NWRAP,INV(20),KPLAN(20,120,6)
     &,KSCHD(20,120,6),ITEM(20),INVDUM(20)
      N2=2*NPLAN+1
      DO 1 K=1,NPRODS
      DO 1 I=1,IHIPN
      JNU=NPLAN
      DO 1 J=N2,40
      JNU=JNU+1
      KPLAN(I,JNU,K)=KPLAN(I,J,K)
1     KSCHD(I,JNU,K)=KSCHD(I,J,K)
      INOW=NPLAN+1
      NWRAP=NWRAP+1
      RETURN
      END
```

```
      SUBROUTINE NUPRIO
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC

COMMON/EXC1/NORDS,NWKS,KNW,INOW,IBFILE,IHIPN,IHFILE,MRP(20,120,6)
      COMMON/PRI1/COVK,TUTIL,IPRIO,NUPRI
      IF(IPRIO.EQ.10)RETURN
C----    UPDATES ALL PRIORITIES IN SHOP
31    DO 3 K=1,NWCTR
      IDUM=NNQ(K)
      IF(IDUM.LE.0)GOTO 3
      DO 4 I=1,IDUM
      CALL RMOVE(1,K,ATRIB)
      IF(ATRIB(4).LE.-999.)GOTO4
      JT=ATRIB(1)
      ATRIB(4)=PRIO(JT)
4     CALL FILEM(IBFILE,ATRIB)
      DO 5 I=1,IDUM
      CALL RMOVE(1,IBFILE,ATRIB)
5     CALL FILEM(K,ATRIB)
3     CONTINUE
      RETURN
      END
```

```
      FUNCTION COSTLB(X,K)
      COMMON/CST1/CSTINV(20),CLABOR(20)

COMMON/WK/NWCTR,NOMCAP(20),MAXCAP(20),NMACH(20),TMTOT(20),TSET(20)
     &,CLU(20),CLL(20),REDFAC
      COSTLB=NMACH(K)*X
      RETURN
      END
```

```
      SUBROUTINE SUMRY
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP
     &,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT
     &,TNOW,XX(100)
      COMMON/KNTR/XORD(20),XPRD(20),IGROSS(20),KITEM(20),RAT(20)
     &,ALPHA(20),KCLEAR,ICNTRL,IBPRNT,IWPRNT,IMPRNT,
     &XLBR(20),XINV(20),XWIP(20),IRPT,NRPLS,NREP
      WRITE(6,101)NREP,NRPLS
      IF(NREP.LT.NRPLS)GOTO10
      WRITE(6,103)
      DO 5 I=1,NREP
5     WRITE(6,102)I,XLBR(I),XINV(I),XWIP(I)
101   FORMAT('1',//,10X,'***SUMMARY REPORT FOR RUN ',I3,' OF ',I3,
     &' RUNS***')
103   FORMAT(/,10X,'RUN ',3X,'LABOR',5X,'INVTRY',4X,'WIP',/)
102   FORMAT(10X,I2,3F10.2)
10    IF(IRPT.NE.1)RETURN
      CALL STAWRT
      CALL PRNTC(0)
      CALL PRNTT(0)
      CALL PRNTF(0)
      RETURN
      END
```

Appendix B

STATISTICAL AND SENSITIVITY ANALYSIS PROGRAMS

B.1 HOTELLING T^2 TEST SAS MATRIX SUBLANGUAGE

```
OPTIONS NOCENTER NONOTES NODATE NONUMBER;
DATA X1;
INFILE X1;
INPUT X Y Z;
DATA X2;
INFILE X2;
INPUT X Y Z;
PROC MATRIX;
FETCH X1 DATA=X1;
FETCH X2 DATA=X2;
S1=X1(+,);
N1=NROW(X1);
N2=NROW(X2);
XB1=S1#/N1;
S2=X2(+,);
XB2=S2#/N2;
XP1=X1'*X1-S1'*S1#/N1;
XP2=X2'*X2-S2'*S2#/N2;
S=(XP1+XP2)#/(N1+N2-2);
D=(XB1-XB2);
D2=(N1#N2)#/(N1+N2);
T=D*(INV(S))*D';
T=T*D2;
NF=(N1+N2-4)#/((N1+N2-2)*3);
DF=N1+N2-4;
F=NF*T;
FP=PROBF(F,3,DF);
SG=1-FP;
PRINT T F FP SG;
```

B.2 COST SENSITIVITY ANALYSIS PROGRAM

```
      DIMENSION X(16),A(6),B(6),C(6),E(6)
      DIMENSION R1(6),R2(6),C1(6),C2(6),IPOL(6)
      DATA C1,C2/6*999999.,6*-999999./
      DATA R1,R2/12*100./
      DATA IPOL/'A','B','C','D','E','F'/
      READ(5,*)ISET
      WRITE(6,100)ISET
100   FORMAT('1',//,10X,'TOTAL COST OPTIMIZATION RATIO/POLICY',
     &//,10X,'POLICY SET ',I3,//,10X,'POLICY',T24,'LBR',T34,'INV',
     &T44,'WIP',T54,'COMBINED')
      X(16)=16.0
      DO 1 I=1,6
      READ(5,*)A(I),B(I),C(I)
      E(I)=B(I)+C(I)
1     WRITE(6,101)IPOL(I),A(I),B(I),C(I),E(I)
101   FORMAT(10X,A4,5X,4(F7.1,3X))
      L=0
      DO 2 I=1,5
      J2=I+1
      DO 2 J=J2,6
      L=L+1
      X(L)=(A(I)-A(J))/(E(J)-E(I))
2     IF(X(L).LT.0.0)X(L)=0
      DO 3 I=1,14
      I2=I+1
      DO 3 J=I2,15
      IF(X(I).LT.X(J))GOTO3
      T=X(I)
      X(I)=X(J)
      X(J)=T
3     CONTINUE
      IMIN=0
      XMIN=999.0E10
      DO 5 I=1,6
      IF(A(I).GT.XMIN)GOTO5
      XMIN=A(I)
      IMIN=I
5     CONTINUE
      WRITE(6,201)
201   FORMAT(/,10X,'SUMMARY RESULTS')
      WRITE(6,107)
107   FORMAT(//,T12,'POLICY',T25,'R LOW',T42,'COST',T52,'R HI',
     &T68,'COST')
      IMIN=0
      DO 6 K=1,15
      K2=K+1
      XR=X(K)+.001*(X(K2)-X(K))
```

```
      XMIN=999.E20
      DO 7 I=1,6
      D=A(I)+XR*(B(I)+C(I))
      IF(D.GT.XMIN)GOTO7
      XMIN=D
      IMIN=I
7     CONTINUE
      CC1=A(IMIN)+X(K)*(B(IMIN)+C(IMIN))
      CC2=A(IMIN)+X(K2)*(B(IMIN)+C(IMIN))
      IF(CC1.GT.C1(IMIN))GOTO17
      C1(IMIN)=CC1
      R1(IMIN)=X(K)
17    IF(CC2.LT.C2(IMIN))GOTO18
      C2(IMIN)=CC2
      R2(IMIN)=X(K2)
105   FORMAT(10X,A4,4X,E15.6,1X,F10.2,1X,E15.6,F10.2)
18    CONTINUE
6     CONTINUE
      DO93 I=1,5
      I2=I+1
      DO93 J=I2,6
      IF(R1(I).LT.R1(J))GOTO93
      IT=IPOL(I)
      IPOL(I)=IPOL(J)
      IPOL(J)=IT
      T=R1(I)
      R1(I)=R1(J)
      R1(J)=T
      T=R2(I)
      R2(I)=R2(J)
      R2(J)=T
      T=C1(I)
      C1(I)=C1(J)
      C1(J)=T
      T=C2(I)
      C2(I)=C2(J)
      C2(J)=T
93    CONTINUE
      DO 9 I=1,6
      IF(C2(I).LT.0)GOTO99
      WRITE(6,105)IPOL(I),R1(I),C1(I),R2(I),C2(I)
      GOTO9
99    WRITE(6,199)IPOL(I)
199   FORMAT(10X,A4,' NOT OPTIMAL OVER ANY INTERVAL')
9     CONTINUE
      STOP
      END
```

TOTAL COST OPTIMIZATION RATIO/POLICY

POLICY SET 1

POLICY	LBR	INV	WIP	COMBINED
A	344.4	1453.8	2791.1	4244.9
B	336.9	1971.1	4658.1	6629.1
C	336.7	1767.9	4454.9	6222.8
D	335.6	2781.3	7140.8	9922.1
E	337.3	1625.0	3852.5	5477.4
F	335.9	2668.1	6407.4	9075.4

POLICY	R LOW	COST	R HI	COST
D	0.000000E 00	335.64	0.307098E-03	338.69
C	0.307098E-03	338.63	0.764803E-03	341.48
E	0.764803E-03	341.48	0.572791E-02	368.66
A	0.572791E-02	368.66	0.160000E 02	68262.06
F	NOT OPTIMAL OVER ANY INTERVAL			
B	NOT OPTIMAL OVER ANY INTERVAL			

POLICY SET 2

POLICY	LBR	INV	WIP	COMBINED
A	352.4	1053.1	1967.7	3020.8
B	340.3	1003.4	3228.2	4231.6
C	339.6	992.5	3067.0	4059.5
D	334.9	1108.1	4707.2	5815.3
E	341.8	984.8	2621.5	3606.3
F	336.7	1074.1	4250.3	5324.4

POLICY	R LOW	COST	R HI	COST
0.000000E 00	334.90	0.267696E-02	350.47	
C	0.267696E-02	350.47	0.485426E-02	359.31
E	0.485426E-02	359.31	0.181039E-01	407.09
A	0.181039E-01	407.09	0.160000E 02	48685.20
F	NOT OPTIMAL OVER ANY INTERVAL			
B	NOT OPTIMAL OVER ANY INTERVAL			

POLICY SET 3

POLICY	LBR	INV	WIP	COMBINED
A	361.6	1613.3	2245.9	3859.2
B	353.4	2180.0	3761.8	5941.8
C	354.3	2823.8	4025.2	6849.0
D	353.4	3851.8	5897.5	9749.3
E	355.4	2062.2	3487.9	5550.1
F	353.4	3000.9	5269.8	8270.7

POLICY	R LOW	COST	R HI	COST
F	0.000000E 00	353.40	0.000000E 00	353.40
B	0.000000E 00	353.40	0.393748E-02	376.80
A	0.393748E-02	376.80	0.160000E 02	62108.80
E	NOT OPTIMAL OVER ANY INTERVAL			
D	NOT OPTIMAL OVER ANY INTERVAL			
C	NOT OPTIMAL OVER ANY INTERVAL			

POLICY SET 4

POLICY	LBR	INV	WIP	COMBINED
A	353.0	2061.8	2332.4	4394.2
B	345.9	1742.6	3674.7	5417.3
C	345.7	1663.6	3611.8	5275.4
D	343.8	2547.8	5540.2	8088.0
E	346.2	1676.4	3192.7	4869.1
F	344.1	2271.6	4975.2	7246.8

POLICY	R LOW	COST	R HI	COST
D	0.000000E 00	343.80	0.356692E-03	346.68
F	0.356692E-03	346.68	0.883145E-03	350.50
C	0.883145E-03	350.36	0.123062E-02	352.19
E	0.123062E-02	352.19	0.143190E-01	415.92
A	0.143190E-01	415.92	0.160000E 02	70660.19
B	NOT OPTIMAL OVER ANY INTERVAL			

APPENDIX C

INPUT TO MODEL

Flat Product Structures

SLAM Data Echo - Flat Product Structures

```
GEN,GUTZMANN,FLAT PRODUCTS,2/0/1983,1,Y,N,Y,N,Y;
LIM,6,13,600;
STA,1,PN1 LEAD TIME;
STA,2,PN2 LEAD TIME;
STA,3,PN3 LEAD TIME;
STA,4,PN4 LEAD TIME;
STA,5,PN5 LEAD TIME;
STA,6,PN6 LEAD TIME;
STA,7,PN7 LEAD TIME;
STA,8,PN8 LEAD TIME;
STA,9,PN9 LEAD TIME;
STA,10,PN10LEAD TIME;
STA,11,PN11LEAD TIME;
STA,12,PN12LEAD TIME;
STA,13,PN13LEAD TIME;
STA,21,ST BKLOG WC1;
STA,22,ST BKLOG WC2;
STA,23,ST BKLOG WC3;
STA,24,ST BKLOG WC4;
STA,31,WK LENGTH WC1;
STA,32,WK LENGTH WC2;
STA,33,WK LENGTH WC3;
STA,34,WK LENGTH WC4;
STA,41,TIME IN SYS;
STA,42,TIME IN HOLD;
STA,43,TIME IN SHOP;
STA,44,TARDY;
STA,45,TOT SHOP LOAD;
STA,46,WKLY LABOR;
TIM,XX(1),UTIL WKCTR1;
TIM,XX(2),UTIL WKCTR2;
TIM,XX(3),UTIL WKCTR3;
TIM,XX(4),UTIL WKCTR4;
TIM,XX(11),INV PN1;
TIM,XX(12),INV PN2;
TIM,XX(13),INV PN3;
TIM,XX(14),INV PN4;
TIM,XX(15),INV PN5;
TIM,XX(16),INV PN6;
TIM,XX(17),INV PN7;
TIM,XX(18),INV PN8;
```

```
TIM,XX(19),INV PN9;
TIM,XX(20),INV PN10;
TIM,XX(21),INV PN11;
TIM,XX(22),INV PN12;
TIM,XX(23),INV PN13;
TIM,XX(91),INV AVGE TOT;
TIM,XX(96),NO.PARTS IN SHOP;
TIM,XX(100),NO.ORDS. IN SHOP;
PRI/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4);
INI,0.;,
FIN;
```

MRPSIM Input Echo - Flat Product Structures

```
M R P    S I M U L A T O R   I N P U T S

NO. REVIEWS TO RUN                1
PLANNING HORIZON LENGTH        12
NO. OF END-ITEMS                4
HIGHEST PART NO.               13

CLEAR PERIOD                    20
POLICY SELECTED                  1
PRINT B-O-M                      1
PRINT WCTR & ROUTES              1
PRINT MSTR SCHED                 1
REPORT MODE                      1
NO. REPLICATIONS                 1
REDUCTION FACTOR               1.00

TOTAL GROSS REQD  END ITEMS

END ITEM PN:  1 REQD:         172

END ITEM PN:  6 REQD:         394

END ITEM PN:  9 REQD:         268

END ITEM PN: 12 REQD:         294


END ITEM DEMAND PARAMETERS
ITEM NO.     RATE      ALPHA    NSTART:   8
     1       34.6       0.15
     6       79.5       0.15
     9       54.1       0.15
    12       59.8       0.15
```

B I L L O F M A T E R I A L N O. 1 OF 4

----- TOP LEVEL PART NO. ----- 1

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	1	1	1	0	0
2	2	1	1	1	1
3	3	1	1	1	1
4	4	1	1	1	1
5	5	1	1	1	1

T O T A L Q T Y B Y P A R T N O.

PART NO.	1	TOTAL REQD:	1
PART NO.	2	TOTAL REQD:	1
PART NO.	3	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 1	1	0
PN 2	0	1
PN 3	0	1
PN 4	0	1
PN 5	0	1

B I L L   O F   M A T E R I A L   N O. 2 OF 4

----- TOP LEVEL PART NO. ----- 6

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	6	1	6	0	0
2	2	1	6	1	1
3	7	1	6	1	1
4	8	1	6	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	2	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	7	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 2	0	1
PN 6	1	0
PN 7	0	1
PN 8	0	1

B I L L   O F   M A T E R I A L   N O. 3 OF 4

----- TOP LEVEL PART NO. -----   9

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	9	1	9	0	0
2	3	1	9	1	1
3	5	1	9	1	1
4	10	1	9	1	1
5	11	1	9	1	1
6	8	1	9	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	3	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 3	0	1
PN 5	0	1
PN 8	0	1
PN 9	1	0
PN10	0	1
PN11	0	1

B I L L   O F   M A T E R I A L   N O. 4 OF 4

----- TOP LEVEL PART NO. ----- 12

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	12	1	12	0	0
2	13	1	12	1	1
3	4	1	12	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	4	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 4	0	1
PN12	1	0
PN13	0	1

C O M P O N E N T S / A S S Y   Q T Y S

ASSY. PART NO. 1 NO. OF COMPONENTS: 4	PART NO.	QTY
	2	1
	3	1
	4	1
	5	1
ASSY. PART NO. 6 NO. OF COMPONENTS: 3	PART NO.	QTY
	2	1
	7	1
	8	1
ASSY. PART NO. 9 NO. OF COMPONENTS: 5	PART NO.	QTY
	3	1
	5	1
	10	1
	11	1
	8	1
ASSY. PART NO. 12 NO. OF COMPONENTS: 2	PART NO.	QTY
	13	1
	4	1

W O R K   C E N T E R   D A T A

4 WORK CENTERS

NO.	NO. MACH.	NOM. CAP.	MAX. CAP.	LO CL	HI CL
1	2	40	80	40.0	120.0
2	2	40	80	40.0	120.0
3	2	40	80	40.0	120.0
4	2	40	80	40.0	120.0

P A R T   R O U T I N G S

PART NO. 1 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.064		0.010
2	3		0.181		0.010
3	1		0.068		0.010
4	4		0.076		0.010
			-----		-----
		TOTAL	0.389	TOTAL	0.040

PART NO. 2 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.092		0.010
2	2		0.053		0.010
			-----		-----
		TOTAL	0.145	TOTAL	0.020

PART NO. 3 NO. OF. OPER.: 4 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.183		0.010
2	4		0.151		0.010
3	2		0.119		0.010
4	1		0.087		0.010
			-----		-----
		TOTAL	0.540	TOTAL	0.040

PART NO. 4 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.143		0.010
2	4		0.093		0.010
			-----		-----
		TOTAL	0.236	TOTAL	0.020

PART NO. 5 NO. OF. OPER.: 6 LEAD TIME: 6.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.056		0.010
2	4		0.174		0.010
3	3		0.181		0.010
4	1		0.047		0.010
5	4		0.004		0.010
6	2		0.067		0.010
			-----		-----
		TOTAL	0.529	TOTAL	0.060

PART NO. 6 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.016		0.010
2	3		0.115		0.010
3	2		0.119		0.010
4	1		0.076		0.010
			-----		-----
		TOTAL	0.326	TOTAL	0.040

PART NO. 7 NO. OF. OPER.: 3 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.069		0.010
2	2		0.125		0.010
3	3		0.119		0.010
			-----		-----
		TOTAL	0.313	TOTAL	0.030

PART NO. 8 NO. OF. OPER.: 4 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.075		0.010
2	1		0.107		0.010
3	4		0.047		0.010
4	2		0.088		0.010
			-----		-----
		TOTAL	0.317	TOTAL	0.040

PART NO. 9 NO. OF. OPER.: 3 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.107		0.010
2	2		0.102		0.010
3	4		0.181		0.010
			-----		-----
		TOTAL	0.390	TOTAL	0.030

PART NO. 10 NO. OF. OPER.: 5 LEAD TIME: 4.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.033		0.010
2	1		0.074		0.010
3	2		0.076		0.010
4	3		0.109		0.010
5	1		0.106		0.010
			-----		-----
		TOTAL	0.398	TOTAL	0.050

PART NO. 11 NO. OF. OPER.: 5 LEAD TIME: 6.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.031		0.010
2	1		0.073		0.010
3	4		0.130		0.010
4	3		0.156		0.010
5	4		0.008		0.010
			-----		-----
		TOTAL	0.398	TOTAL	0.050

PART NO. 12 NO. OF. OPER.: 2 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.179		0.010
2	4		0.152		0.010
			-----		-----
		TOTAL	0.331	TOTAL	0.020

PART NO. 13 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.083		0.010
2	2		0.111		0.010
			-----		-----
		TOTAL	0.194	TOTAL	0.020

U N I T   W O R K   C O N T E N T

WORK CENTER---	1	2	3	4
PART NO.: 1	0.068	0.064	0.181	0.076
PART NO.: 2	0.092	0.053	0.0	0.0
PART NO.: 3	0.087	0.119	0.183	0.151
PART NO.: 4	0.143	0.0	0.0	0.093
PART NO.: 5	0.103	0.067	0.181	0.178
PART NO.: 6	0.092	0.119	0.115	0.0
PART NO.: 7	0.069	0.125	0.119	0.0
PART NO.: 8	0.107	0.163	0.0	0.047
PART NO.: 9	0.0	0.102	0.0	0.288
PART NO.:10	0.180	0.076	0.142	0.0
PART NO.:11	0.073	0.031	0.156	0.138
PART NO.:12	0.0	0.0	0.179	0.152
PART NO.:13	0.0	0.111	0.0	0.083

L O A D - C A P A C I T Y   A N A L Y S I S

WORK CENTER: 1 AVERAGE TOTAL LOAD: 84.00
UNIT MACHINE LOAD: 42

WORK CENTER: 2 AVERAGE TOTAL LOAD: 83.90
UNIT MACHINE LOAD: 41

WORK CENTER: 3 AVERAGE TOTAL LOAD: 84.00
UNIT MACHINE LOAD: 42

WORK CENTER: 4 AVERAGE TOTAL LOAD: 84.00
UNIT MACHINE LOAD: 42

PRODUCT LOADING REPORT

ITEM: 1 IN WC ORDER:	17.06	10.49	18.86	17.24
ITEM: 2 IN WC ORDER:	28.62	36.57	18.60	3.74
ITEM: 3 IN WC ORDER:	29.77	30.20	35.83	43.41
ITEM: 4 IN WC ORDER:	8.55	6.64	10.71	19.62

PRODUCT WORK CONTENT REPORT

ITEM: 1 IN WC ORDER:	0.493	0.303	0.545	0.498
ITEM: 2 IN WC ORDER:	0.360	0.460	0.234	0.047
ITEM: 3 IN WC ORDER:	0.550	0.558	0.662	0.802
ITEM: 4 IN WC ORDER:	0.143	0.111	0.179	0.328

Tall Product Structures

SLAM Data Echo - Tall Product Structures

```
GEN,GUTZMANN,TALL PRODUCTS ,2/0/1983,1,Y,N,Y,N,Y;
LIM,6,13,600;
STA,1,PN1 LEAD TIME;
STA,2,PN2 LEAD TIME;
STA,3,PN3 LEAD TIME;
STA,4,PN4 LEAD TIME;
STA,5,PN5 LEAD TIME;
STA,6,PN6 LEAD TIME;
STA,7,PN7 LEAD TIME;
STA,8,PN8 LEAD TIME;
STA,9,PN9 LEAD TIME;
STA,10,PN10LEAD TIME;
STA,11,PN11LEAD TIME;
STA,12,PN12LEAD TIME;
STA,13,PN13LEAD TIME;
STA,14,PN14LEAD TIME;
STA,15,PN15LEAD TIME;
STA,16,PN16LEAD TIME;
STA,17,PN17LEAD TIME;
STA,18,PN18LEAD TIME;
STA,19,PN19LEAD TIME;
STA,20,PN20LEAD TIME;
STA,21,ST BKLOG WC1;
STA,22,ST BKLOG WC2;
STA,23,ST BKLOG WC3;
STA,24,ST BKLOG WC4;
STA,31,WK LENGTH WC1;
STA,32,WK LENGTH WC2;
STA,33,WK LENGTH WC3;
STA,34,WK LENGTH WC4;
STA,41,TIME IN SYS;
STA,42,TIME IN HOLD;
STA,43,TIME IN SHOP;
STA,44,TARDY;
STA,45,TOT SHOP LOAD;
STA,46,WKLY LABOR;
TIM,XX(1),UTIL WKCTR1;
TIM,XX(2),UTIL WKCTR2;
TIM,XX(3),UTIL WKCTR3;
TIM,XX(4),UTIL WKCTR4;
TIM,XX(11),INV PN1;
TIM,XX(12),INV PN2;
TIM,XX(13),INV PN3;
TIM,XX(14),INV PN4;
TIM,XX(15),INV PN5;
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TIM,XX(16),INV PN6;
TIM,XX(17),INV PN7;
TIM,XX(18),INV PN8;
TIM,XX(19),INV PN9;
TIM,XX(20),INV PN10;
TIM,XX(21),INV PN11;
TIM,XX(22),INV PN12;
TIM,XX(23),INV PN13;
TIM,XX(24),INV PN14;
TIM,XX(25),INV PN15;
TIM,XX(26),INV PN16;
TIM,XX(27),INV PN17;
TIM,XX(28),INV PN18;
TIM,XX(29),INV PN19;
TIM,XX(30),INV PN20;
TIM,XX(91),INV AVGE TOT;
TIM,XX(96),NO.PARTS IN SHOP;
TIM,XX(100),NO.ORDS. IN SHOP;
PRI/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4);
INI,0.;,
FIN;
```

MRPSIM Input Echo - Tall Product Structures

M R P   S I M U L A T O R   I N P U T S

NO. REVIEWS TO RUN	1
PLANNING HORIZON LENGTH	40
NO. OF END-ITEMS	4
HIGHEST PART NO.	20
CLEAR PERIOD	50
POLICY SELECTED	1
PRINT B-O-M	1
PRINT WCTR & ROUTES	1
PRINT MSTR SCHED	1
REPORT MODE	1
NO. REPLICATIONS	1
REDUCTION FACTOR	1.25

TOTAL GROSS REQD END ITEMS

END ITEM PN: 1 REQD: 28

END ITEM PN: 2 REQD: 67

END ITEM PN: 3 REQD: 24

END ITEM PN: 4 REQD: 2

END ITEM DEMAND PARAMETERS

ITEM NO.	RATE	ALPHA	NSTART: 40
1	28.7	0.15	
2	69.1	0.15	
3	22.8	0.15	
4	1.3	0.15	

B I L L   O F   M A T E R I A L   N O. 1 OF 4

----- TOP LEVEL PART NO. -----   1

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	1	1	1	0	0
2	14	1	1	1	1
3	10	1	14	2	2
4	13	1	14	2	2
5	9	1	10	3	3
6	12	1	13	4	3
7	5	1	9	5	4
8	6	1	12	6	4

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	1	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1
PART NO.	14	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 1	1	0	0	0	0
PN 5	0	0	0	0	1
PN 6	0	0	0	0	1
PN 9	0	0	0	1	0
PN10	0	0	1	0	0
PN12	0	0	0	1	0
PN13	0	0	1	0	0
PN14	0	1	0	0	0

B I L L   O F   M A T E R I A L   N O. 2 OF 4

----- TOP LEVEL PART NO. ----- 2

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	2	1	1	0	0
2	11	1	2	1	1
3	10	1	11	2	2
4	9	1	10	3	3
5	5	1	9	4	4

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	2	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 2	1	0	0	0	0
PN 5	0	0	0	0	1
PN 9	0	0	0	1	0
PN10	0	0	1	0	0
PN11	0	1	0	0	0

B I L L O F M A T E R I A L N O. 3 OF 4

----- TOP LEVEL PART NO. ----- 3

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	3	1	1	0	0
2	20	1	3	1	1
3	16	1	3	1	1
4	19	1	20	2	2
5	17	1	16	3	2
6	18	1	19	4	3
7	8	1	17	5	3
8	6	1	17	5	3
9	5	1	18	6	4
10	6	1	18	6	4

T O T A L Q T Y B Y P A R T N O.

PART NO.	3	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	2
PART NO.	8	TOTAL REQD:	1
PART NO.	16	TOTAL REQD:	1
PART NO.	17	TOTAL REQD:	1
PART NO.	18	TOTAL REQD:	1
PART NO.	19	TOTAL REQD:	1
PART NO.	20	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 3	1	0	0	0	0
PN 5	0	0	0	0	1
PN 6	0	0	0	1	1
PN 8	0	0	0	1	0
PN16	0	1	0	0	0
PN17	0	0	1	0	0
PN18	0	0	0	1	0
PN19	0	0	1	0	0
PN20	0	1	0	0	0

B I L L   O F   M A T E R I A L   N O. 4 OF 4

----- TOP LEVEL PART NO. ----- 4

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	4	1	1	0	0
2	15	1	4	1	1
3	16	1	4	1	1
4	10	1	15	2	2
5	8	1	15	2	2
6	17	1	16	3	2
7	9	1	10	4	3
8	6	1	17	6	3
9	8	1	17	6	3
10	5	1	9	7	4

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	4	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	2
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	15	TOTAL REQD:	1
PART NO.	16	TOTAL REQD:	1
PART NO.	17	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 4	1	0	0	0	0
PN 5	0	0	0	0	1
PN 6	0	0	0	1	0
PN 8	0	0	1	1	0
PN 9	0	0	0	1	0
PN10	0	0	1	0	0
PN15	0	1	0	0	0
PN16	0	1	0	0	0
PN17	0	0	1	0	0

C O M P O N E N T S / A S S Y   Q T Y S

ASSY. PART NO.	NO. OF COMPONENTS:	PART NO.	QTY
1	1	14	1
2	1	11	1
3	2	20	1
		16	1
4	2	15	1
		16	1
9	1	5	1
10	1	9	1
11	1	10	1
12	1	6	1
13	1	12	1
14	2	10	1
		13	1
15	2	10	1
		8	1
16	1	17	1
17	2	8	1
		6	1
18	2	5	1
		6	1

ASSY. PART NO. 19 NO. OF COMPONENTS: 1

PART NO.	QTY
18	1

ASSY. PART NO. 20 NO. OF COMPONENTS: 1

PART NO.	QTY
19	1

W O R K   C E N T E R   D A T A

4 WORK CENTERS

NO.	NO. MACH.	NOM. CAP.	MAX. CAP.	LO CL	HI CL
1	2	40	80	40.0	120.0
2	2	40	80	40.0	120.0
3	2	40	80	40.0	120.0
4	2	40	80	40.0	120.0

P A R T   R O U T I N G S

PART NO. 1 NO. OF. OPER.: 2 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.107		0.010
2	1		0.181		0.010
			-----		-----
		TOTAL	0.288	TOTAL	0.020

PART NO. 2 NO. OF. OPER.: 3 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.111		0.010
2	4		0.049		0.010
3	2		0.112		0.010
			-----		-----
		TOTAL	0.272	TOTAL	0.030

PART NO. 3 NO. OF. OPER.: 5 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.094		0.010
2	2		0.096		0.010
3	3		0.163		0.010
4	4		0.021		0.010
5	2		0.122		0.010
			-----		-----
		TOTAL	0.496	TOTAL	0.050

PART NO. 4 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.189		0.010
2	3		0.160		0.010
3	4		0.213		0.010
4	3		0.154		0.010
			-----		-----
		TOTAL	0.716	TOTAL	0.040

PART NO. 5 NO. OF. OPER.: 5 LEAD TIME: 8.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.156		0.010
2	3		0.173		0.010
3	2		0.118		0.010
4	1		0.021		0.010
5	3		0.156		0.010
			-----		-----

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                    TOTAL   0.624  TOTAL   0.050

------------------------------------------------------------
PART NO.  6 NO. OF. OPER.:  3 LEAD TIME:   5.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          3               0.038           0.010
     2          4               0.089           0.010
     3          1               0.139           0.010
                                -----           -----
                    TOTAL       0.266  TOTAL    0.030

------------------------------------------------------------
PART NO.  7 NO. OF. OPER.:  3 LEAD TIME:   3.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          2               0.110           0.010
     2          4               0.060           0.010
     3          1               0.116           0.010
                                -----           -----
                    TOTAL       0.286  TOTAL    0.030

------------------------------------------------------------
PART NO.  8 NO. OF. OPER.:  6 LEAD TIME:   7.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          3               0.113           0.010
     2          2               0.190           0.010
     3          1               0.150           0.010
     4          2               0.118           0.010
     5          4               0.124           0.010
     6          1               0.023           0.010
                                -----           -----
                    TOTAL       0.718  TOTAL    0.060

------------------------------------------------------------
PART NO.  9 NO. OF. OPER.:  4 LEAD TIME:   9.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          4               0.122           0.010
     2          2               0.057           0.010
     3          1               0.101           0.010
     4          4               0.081           0.010
                                -----           -----
                    TOTAL       0.361  TOTAL    0.040

------------------------------------------------------------
PART NO. 10 NO. OF. OPER.:  5 LEAD TIME:   9.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          1               0.109           0.010
     2          4               0.129           0.010
     3          2               0.087           0.010
     4          1               0.096           0.010
     5          3               0.105           0.010
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                                 -----           -----
                        TOTAL    0.526  TOTAL    0.050

------------------------------------------------------------
PART NO. 11 NO. OF. OPER.:  3 LEAD TIME:   4.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          3                0.109           0.010
     2          2                0.094           0.010
     3          4                0.137           0.010
                                 -----           -----
                        TOTAL    0.340  TOTAL    0.030

------------------------------------------------------------
PART NO. 12 NO. OF. OPER.:  5 LEAD TIME:   6.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          4                0.063           0.010
     2          1                0.178           0.010
     3          3                0.171           0.010
     4          4                0.132           0.010
     5          2                0.003           0.010
                                 -----           -----
                        TOTAL    0.547  TOTAL    0.050

------------------------------------------------------------
PART NO. 13 NO. OF. OPER.:  2 LEAD TIME:   6.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          1                0.164           0.010
     2          4                0.181           0.010
                                 -----           -----
                        TOTAL    0.345  TOTAL    0.020

------------------------------------------------------------
PART NO. 14 NO. OF. OPER.:  5 LEAD TIME:   6.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          1                0.145           0.010
     2          4                0.004           0.010
     3          3                0.089           0.010
     4          4                0.066           0.010
     5          2                0.115           0.010
                                 -----           -----
                        TOTAL    0.419  TOTAL    0.050

------------------------------------------------------------
PART NO. 15 NO. OF. OPER.:  6 LEAD TIME:   8.
   OPER. NO.  WK. CTR.        STD. TIME       SETUP TIME
     1          4                0.142           0.010
     2          1                0.082           0.010
     3          4                0.112           0.010
     4          3                0.065           0.010
     5          4                0.151           0.010
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     6          3                  0.043           0.010
                                   -----           -----
                          TOTAL    0.595   TOTAL   0.060

------------------------------------------------------------
PART NO. 16 NO. OF. OPER.:  2 LEAD TIME:   2.
   OPER. NO.   WK. CTR.        STD. TIME       SETUP TIME
     1          4                  0.042           0.010
     2          1                  0.112           0.010
                                   -----           -----
                          TOTAL    0.154   TOTAL   0.020

------------------------------------------------------------
PART NO. 17 NO. OF. OPER.:  3 LEAD TIME:   3.
   OPER. NO.   WK. CTR.        STD. TIME       SETUP TIME
     1          4                  0.111           0.010
     2          2                  0.144           0.010
     3          3                  0.072           0.010
                                   -----           -----
                          TOTAL    0.327   TOTAL   0.030

------------------------------------------------------------
PART NO. 18 NO. OF. OPER.:  3 LEAD TIME:   6.
   OPER. NO.   WK. CTR.        STD. TIME       SETUP TIME
     1          2                  0.031           0.010
     2          4                  0.192           0.010
     3          1                  0.038           0.010
                                   -----           -----
                          TOTAL    0.261   TOTAL   0.030

------------------------------------------------------------
PART NO. 19 NO. OF. OPER.:  5 LEAD TIME:   5.
   OPER. NO.   WK. CTR.        STD. TIME       SETUP TIME
     1          4                  0.127           0.010
     2          2                  0.075           0.010
     3          3                  0.099           0.010
     4          1                  0.053           0.010
     5          3                  0.112           0.010
                                   -----           -----
                          TOTAL    0.466   TOTAL   0.050

------------------------------------------------------------
PART NO. 20 NO. OF. OPER.:  2 LEAD TIME:   2.
   OPER. NO.   WK. CTR.        STD. TIME       SETUP TIME
     1          3                  0.084           0.010
     2          1                  0.102           0.010
                                   -----           -----
                          TOTAL    0.186   TOTAL   0.020
```

U N I T   W O R K   C O N T E N T

WORK CENTER---	1	2	3	4
PART NO.: 1	0.181	0.0	0.0	0.107
PART NO.: 2	0.111	0.112	0.0	0.049
PART NO.: 3	0.094	0.218	0.163	0.021
PART NO.: 4	0.0	0.0	0.314	0.402
PART NO.: 5	0.021	0.274	0.329	0.0
PART NO.: 6	0.139	0.0	0.038	0.089
PART NO.: 7	0.116	0.110	0.0	0.060
PART NO.: 8	0.173	0.308	0.113	0.124
PART NO.: 9	0.101	0.057	0.0	0.203
PART NO.:10	0.205	0.087	0.105	0.129
PART NO.:11	0.0	0.094	0.109	0.137
PART NO.:12	0.178	0.003	0.171	0.195
PART NO.:13	0.164	0.0	0.0	0.181
PART NO.:14	0.145	0.115	0.089	0.070
PART NO.:15	0.082	0.0	0.108	0.405
PART NO.:16	0.112	0.0	0.0	0.042
PART NO.:17	0.0	0.144	0.072	0.111
PART NO.:18	0.038	0.031	0.0	0.192
PART NO.:19	0.053	0.075	0.211	0.127
PART NO.:20	0.102	0.0	0.084	0.0

L O A D - C A P A C I T Y   A N A L Y S I S

WORK CENTER: 1 AVERAGE TOTAL LOAD: 84.00
UNIT MACHINE LOAD: 42

```
WORK CENTER:  2 AVERAGE TOTAL LOAD:      84.00
UNIT MACHINE LOAD:      42

WORK CENTER:  3 AVERAGE TOTAL LOAD:      84.00
UNIT MACHINE LOAD:      42

WORK CENTER:  4 AVERAGE TOTAL LOAD:      84.00
UNIT MACHINE LOAD:      42
```

PRODUCT LOADING REPORT

ITEM: 1 IN WC ORDER:	32.55	15.38	21.01	27.95
ITEM: 2 IN WC ORDER:	30.27	43.12	37.53	35.80
ITEM: 3 IN WC ORDER:	19.89	23.98	23.94	18.16
ITEM: 4 IN WC ORDER:	1.29	1.51	1.53	2.09

PRODUCT WORK CONTENT REPORT

ITEM: 1 IN WC ORDER:	1.134	0.536	0.732	0.974
ITEM: 2 IN WC ORDER:	0.438	0.624	0.543	0.518
ITEM: 3 IN WC ORDER:	0.871	1.050	1.048	0.795
ITEM: 4 IN WC ORDER:	1.006	1.178	1.192	1.629

Tall & Flat Product Structures

SLAM Data Echo - Tall and Flat Product Structures

```
GEN,GUTZMANN,TALL FLAT ,2/0/1983,1,Y,N,Y,N,Y;
LIM,6,13,600;
STA,1,PN1 LEAD TIME;
STA,2,PN2 LEAD TIME;
STA,3,PN3 LEAD TIME;
STA,4,PN4 LEAD TIME;
STA,5,PN5 LEAD TIME;
STA,6,PN6 LEAD TIME;
STA,7,PN7 LEAD TIME;
STA,8,PN8 LEAD TIME;
STA,9,PN9 LEAD TIME;
STA,10,PN10LEAD TIME;
STA,11,PN11LEAD TIME;
STA,12,PN12LEAD TIME;
STA,13,PN13LEAD TIME;
STA,14,PN14LEAD TIME;
STA,15,PN15LEAD TIME;
STA,16,PN16LEAD TIME;
STA,17,PN17LEAD TIME;
STA,18,PN18LEAD TIME;
STA,19,PN19LEAD TIME;
STA,20,PN20LEAD TIME;
STA,21,ST BKLOG WC1;
STA,22,ST BKLOG WC2;
STA,23,ST BKLOG WC3;
STA,24,ST BKLOG WC4;
STA,31,WK LENGTH WC1;
STA,32,WK LENGTH WC2;
STA,33,WK LENGTH WC3;
STA,34,WK LENGTH WC4;
STA,41,TIME IN SYS;
STA,42,TIME IN HOLD;
STA,43,TIME IN SHOP;
STA,44,TARDY;
STA,45,TOT SHOP LOAD;
STA,46,WKLY LABOR;
TIM,XX(1),UTIL WKCTR1;
TIM,XX(2),UTIL WKCTR2;
TIM,XX(3),UTIL WKCTR3;
TIM,XX(4),UTIL WKCTR4;
TIM,XX(11),INV PN1;
TIM,XX(12),INV PN2;
TIM,XX(13),INV PN3;
TIM,XX(14),INV PN4;
TIM,XX(15),INV PN5;
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TIM,XX(16),INV PN6;
TIM,XX(17),INV PN7;
TIM,XX(18),INV PN8;
TIM,XX(19),INV PN9;
TIM,XX(20),INV PN10;
TIM,XX(21),INV PN11;
TIM,XX(22),INV PN12;
TIM,XX(23),INV PN13;
TIM,XX(24),INV PN14;
TIM,XX(25),INV PN15;
TIM,XX(26),INV PN16;
TIM,XX(27),INV PN17;
TIM,XX(28),INV PN18;
TIM,XX(29),INV PN19;
TIM,XX(30),INV PN20;
TIM,XX(91),INV AVGE TOT;
TIM,XX(96),NO.PARTS IN SHOP;
TIM,XX(100),NO.ORDS. IN SHOP;
PRI/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4);
INI,0.;,
FIN;
```

MRPSIM Input Echo - Tall and Flat Product Structures

```
M R P   S I M U L A T O R   I N P U T S

NO. REVIEWS TO RUN              1
PLANNING HORIZON LENGTH        40
NO. OF END-ITEMS                6
HIGHEST PART NO.               20

CLEAR PERIOD                   50
POLICY SELECTED                 1
PRINT B-O-M                     1
PRINT WCTR & ROUTES             1
PRINT MSTR SCHED                1
REPORT MODE                     1
NO. REPLICATIONS               11
REDUCTION FACTOR               1.25

TOTAL GROSS REQD  END ITEMS

END ITEM PN: 17 REQD:          14

END ITEM PN: 18 REQD:           5

END ITEM PN:  1 REQD:          26

END ITEM PN:  2 REQD:         123

END ITEM PN:  3 REQD:          11

END ITEM PN:  9 REQD:          29


END ITEM DEMAND PARAMETERS
ITEM NO.      RATE       ALPHA    NSTART:  40
    17        15.0        0.15
    18         5.0        0.15
     1        25.0        0.15
     2       120.0        0.15
     3        10.0        0.15
     9        30.0        0.15
```

B I L L   O F   M A T E R I A L   N O. 1 OF 6

----- TOP LEVEL PART NO. ----- 17

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	17	1	17	0	0
2	16	1	17	1	1
3	10	1	16	2	2
4	13	1	16	2	2
5	11	1	10	3	3
6	14	1	13	4	3
7	12	1	11	5	4

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1
PART NO.	14	TOTAL REQD:	1
PART NO.	16	TOTAL REQD:	1
PART NO.	17	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN10	0	0	1	0	0
PN11	0	0	0	1	0
PN12	0	0	0	0	1
PN13	0	0	1	0	0
PN14	0	0	0	1	0
PN16	0	1	0	0	0
PN17	1	0	0	0	0

B I L L O F M A T E R I A L N O. 2 OF 6

----- TOP LEVEL PART NO. ----- 18

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	18	1	18	0	0
2	20	1	18	1	1
3	10	1	18	1	1
4	19	1	20	2	2
5	11	1	10	3	2
6	13	1	19	4	3
7	6	1	19	4	3
8	12	1	11	5	3
9	14	1	13	6	4

T O T A L Q T Y B Y P A R T N O.

PART NO.	6	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1
PART NO.	14	TOTAL REQD:	1
PART NO.	18	TOTAL REQD:	1
PART NO.	19	TOTAL REQD:	1
PART NO.	20	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 6	0	0	0	1	0
PN10	0	1	0	0	0
PN11	0	0	1	0	0
PN12	0	0	0	1	0
PN13	0	0	0	1	0
PN14	0	0	0	0	1
PN18	1	0	0	0	0
PN19	0	0	1	0	0
PN20	0	1	0	0	0

B I L L   O F   M A T E R I A L   N O. 3 OF 6

----- TOP LEVEL PART NO. ----- 1

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	1	1	1	0	0
2	4	1	1	1	1
3	5	1	1	1	1
4	6	1	1	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	1	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 1	1	0
PN 4	0	1
PN 5	0	1
PN 6	0	1

B I L L O F M A T E R I A L N O. 4 OF 6

----- TOP LEVEL PART NO. ----- 2

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	2	1	2	0	0
2	4	1	2	1	1
3	6	1	2	1	1
4	7	1	2	1	1
5	8	1	2	1	1

T O T A L Q T Y B Y P A R T N O.

PART NO.	2	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	7	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 2	1	0
PN 4	0	1
PN 6	0	1
PN 7	0	1
PN 8	0	1

B I L L   O F   M A T E R I A L   N O. 5 OF 6

----- TOP LEVEL PART NO. ----- 3

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	3	1	3	0	0
2	4	1	3	1	1
3	6	1	3	1	1

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	3	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 3	1	0
PN 4	0	1
PN 6	0	1

B I L L   O F   M A T E R I A L   N O. 6 OF 6

----- TOP LEVEL PART NO. -----   9

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	9	1	9	0	0
2	15	1	9	1	1
3	10	1	15	2	2
4	11	1	10	3	3
5	12	1	11	4	4

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	15	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 9	1	0	0	0	0
PN10	0	0	1	0	0
PN11	0	0	0	1	0
PN12	0	0	0	0	1
PN15	0	1	0	0	0

COMPONENTS/ASSY QTYS

ASSY. PART NO. 1 NO. OF COMPONENTS: 3	PART NO.	QTY
	4	1
	5	1
	6	1
ASSY. PART NO. 2 NO. OF COMPONENTS: 4	PART NO.	QTY
	4	1
	6	1
	7	1
	8	1
ASSY. PART NO. 3 NO. OF COMPONENTS: 2	PART NO.	QTY
	4	1
	6	1
ASSY. PART NO. 9 NO. OF COMPONENTS: 1	PART NO.	QTY
	15	1
ASSY. PART NO. 10 NO. OF COMPONENTS: 1	PART NO.	QTY
	11	1
ASSY. PART NO. 11 NO. OF COMPONENTS: 1	PART NO.	QTY
	12	1
ASSY. PART NO. 13 NO. OF COMPONENTS: 1	PART NO.	QTY
	14	1
ASSY. PART NO. 15 NO. OF COMPONENTS: 1	PART NO.	QTY
	10	1
ASSY. PART NO. 16 NO. OF COMPONENTS: 2	PART NO.	QTY
	10	1
	13	1
ASSY. PART NO. 17 NO. OF COMPONENTS: 1	PART NO.	QTY
	16	1
ASSY. PART NO. 18 NO. OF COMPONENTS: 2	PART NO.	QTY
	20	1
	10	1
ASSY. PART NO. 19 NO. OF COMPONENTS: 2	PART NO.	QTY
	13	1
	6	1
ASSY. PART NO. 20 NO. OF COMPONENTS: 1	PART NO.	QTY
	19	1

W O R K   C E N T E R   D A T A

4 WORK CENTERS

NO.	NO. MACH.	NOM. CAP.	MAX. CAP.	LO CL	HI CL
1	2	40	80	40.0	120.0
2	2	40	80	40.0	120.0
3	2	40	80	40.0	120.0
4	2	40	80	40.0	120.0

P A R T   R O U T I N G S

PART NO. 1 NO. OF. OPER.: 3 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.102		0.010
2	1		0.164		0.010
3	2		0.178		0.0
			-----		-----
		TOTAL	0.444	TOTAL	0.020

PART NO. 2 NO. OF. OPER.: 2 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.060		0.010
2	4		0.076		0.010
			-----		-----
		TOTAL	0.136	TOTAL	0.020

PART NO. 3 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.078		0.010
2	1		0.138		0.010
3	3		0.178		0.010
4	1		0.087		0.010
			-----		-----
		TOTAL	0.481	TOTAL	0.040

PART NO. 4 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.087		0.010
2	1		0.170		0.010
			-----		-----
		TOTAL	0.257	TOTAL	0.020

PART NO. 5 NO. OF. OPER.: 4 LEAD TIME: 4.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.128		0.010
2	3		0.149		0.010
3	4		0.097		0.010
4	3		0.206		0.010
			-----		-----
		TOTAL	0.580	TOTAL	0.040

PART NO. 6 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.044		0.010
2	4		0.067		0.010
3	3		0.127		0.010
4	2		0.145		0.010
5	4		0.105		0.010
			-----		-----
		TOTAL	0.488	TOTAL	0.050

PART NO. 7 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.078		0.010
2	1		0.063		0.010
3	3		0.086		0.010
			-----		-----
		TOTAL	0.227	TOTAL	0.030

PART NO. 8 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.090		0.010
2	4		0.081		0.010
3	1		0.066		0.010
			-----		-----
		TOTAL	0.237	TOTAL	0.030

PART NO. 9 NO. OF. OPER.: 5 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.187		0.010
2	3		0.102		0.010
3	1		0.257		0.010
4	2		0.011		0.010
5	4		0.089		0.010
			-----		-----
		TOTAL	0.646	TOTAL	0.050

PART NO. 10 NO. OF. OPER.: 2 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.085		0.010
2	4		0.196		0.010
			-----		-----
		TOTAL	0.281	TOTAL	0.020

PART NO. 11 NO. OF. OPER.: 3 LEAD TIME: 4.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	2	0.124	0.010

2	3		0.072		0.010
3	4		0.074		0.010
			-----		-----
		TOTAL	0.270	TOTAL	0.030

PART NO. 12 NO. OF. OPER.: 4 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.115		0.010
2	3		0.149		0.010
3	1		0.142		0.010
4	4		0.055		0.010
			-----		-----
		TOTAL	0.461	TOTAL	0.040

PART NO. 13 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.115		0.010
2	2		0.151		0.010
			-----		-----
		TOTAL	0.266	TOTAL	0.020

PART NO. 14 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.090		0.010
2	3		0.107		0.010
3	1		0.262		0.010
4	3		0.130		0.010
5	2		0.074		0.010
			-----		-----
		TOTAL	0.663	TOTAL	0.050

PART NO. 15 NO. OF. OPER.: 4 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.067		0.010
2	2		0.146		0.010
3	1		0.005		0.010
4	2		0.126		0.010
			-----		-----
		TOTAL	0.344	TOTAL	0.040

PART NO. 16 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.081		0.010
2	3		0.093		0.010
3	1		0.082		0.010

			-----	-----
		TOTAL	0.256	TOTAL 0.030

PART NO. 17 NO. OF. OPER.: 6 LEAD TIME: 1.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	3	0.030	0.010
2	2	0.099	0.010
3	3	0.072	0.010
4	2	0.114	0.010
5	4	0.030	0.010
6	1	0.112	0.010
		-----	-----
	TOTAL	0.457	TOTAL 0.060

PART NO. 18 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	3	0.189	0.010
2	4	0.156	0.010
3	3	0.043	0.010
4	2	0.124	0.010
		-----	-----
	TOTAL	0.512	TOTAL 0.040

PART NO. 19 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	4	0.151	0.010
2	2	0.058	0.010
3	1	0.153	0.010
		-----	-----
	TOTAL	0.362	TOTAL 0.030

PART NO. 20 NO. OF. OPER.: 4 LEAD TIME: 4.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	4	0.080	0.010
2	3	0.154	0.010
3	1	0.104	0.010
4	2	0.025	0.010
		-----	-----
	TOTAL	0.363	TOTAL 0.040

U N I T   W O R K   C O N T E N T

WORK CENTER---	1	2	3	4
PART NO.: 1	0.164	0.178	0.0	0.102
PART NO.: 2	0.0	0.0	0.060	0.076
PART NO.: 3	0.225	0.078	0.178	0.0
PART NO.: 4	0.170	0.0	0.087	0.0
PART NO.: 5	0.0	0.128	0.355	0.097
PART NO.: 6	0.0	0.145	0.171	0.172
PART NO.: 7	0.063	0.0	0.086	0.078
PART NO.: 8	0.066	0.090	0.0	0.081
PART NO.: 9	0.444	0.011	0.102	0.089
PART NO.:10	0.0	0.0	0.085	0.196
PART NO.:11	0.0	0.124	0.072	0.074
PART NO.:12	0.257	0.0	0.149	0.055
PART NO.:13	0.115	0.151	0.0	0.0
PART NO.:14	0.262	0.074	0.237	0.090
PART NO.:15	0.005	0.272	0.067	0.0
PART NO.:16	0.082	0.0	0.093	0.081
PART NO.:17	0.112	0.213	0.102	0.030
PART NO.:18	0.0	0.124	0.232	0.156
PART NO.:19	0.153	0.058	0.0	0.151
PART NO.:20	0.104	0.025	0.154	0.080

L O A D - C A P A C I T Y   A N A L Y S I S

WORK CENTER: 1 AVERAGE TOTAL LOAD: 86.23
UNIT MACHINE LOAD: 43

WORK CENTER: 2 AVERAGE TOTAL LOAD: 65.85
UNIT MACHINE LOAD: 32

WORK CENTER: 3 AVERAGE TOTAL LOAD: 98.98
UNIT MACHINE LOAD: 49

WORK CENTER: 4 AVERAGE TOTAL LOAD: 85.01
UNIT MACHINE LOAD: 42

PRODUCT LOADING REPORT

ITEM: 1 IN WC ORDER:	12.42	8.43	11.07	7.89
ITEM: 2 IN WC ORDER:	4.45	3.50	5.50	4.87
ITEM: 3 IN WC ORDER:	8.35	11.27	15.32	9.27
ITEM: 4 IN WC ORDER:	35.88	28.20	48.48	48.84
ITEM: 5 IN WC ORDER:	3.95	2.23	4.36	1.72
ITEM: 6 IN WC ORDER:	21.18	12.21	14.25	12.42

PRODUCT WORK CONTENT REPORT

ITEM: 1 IN WC ORDER:	0.828	0.562	0.738	0.526
ITEM: 2 IN WC ORDER:	0.891	0.701	1.100	0.974
ITEM: 3 IN WC ORDER:	0.334	0.451	0.613	0.371
ITEM: 4 IN WC ORDER:	0.299	0.235	0.404	0.407
ITEM: 5 IN WC ORDER:	0.395	0.223	0.436	0.172
ITEM: 6 IN WC ORDER:	0.706	0.407	0.475	0.414

Mixed Product Structures

SLAM Input Echo - Mixed Product Structures

```
GEN,GUTZMANN,MIXED PRODUCTS,2/0/1983,1,Y,N,Y,N,Y;
LIM,6,13,600;
STA,1,PN1 LEAD TIME;
STA,2,PN2 LEAD TIME;
STA,3,PN3 LEAD TIME;
STA,4,PN4 LEAD TIME;
STA,5,PN5 LEAD TIME;
STA,6,PN6 LEAD TIME;
STA,7,PN7 LEAD TIME;
STA,8,PN8 LEAD TIME;
STA,9,PN9 LEAD TIME;
STA,10,PN10LEAD TIME;
STA,11,PN11LEAD TIME;
STA,12,PN12LEAD TIME;
STA,13,PN13LEAD TIME;
STA,14,PN14LEAD TIME;
STA,15,PN15LEAD TIME;
STA,16,PN16LEAD TIME;
STA,17,PN17LEAD TIME;
STA,18,PN18LEAD TIME;
STA,19,PN19LEAD TIME;
STA,20,PN20LEAD TIME;
STA,21,ST BKLOG WC1;
STA,22,ST BKLOG WC2;
STA,23,ST BKLOG WC3;
STA,24,ST BKLOG WC4;
STA,31,WK LENGTH WC1;
STA,32,WK LENGTH WC2;
STA,33,WK LENGTH WC3;
STA,34,WK LENGTH WC4;
STA,41,TIME IN SYS;
STA,42,TIME IN HOLD;
STA,43,TIME IN SHOP;
STA,44,TARDY;
STA,45,TOT SHOP LOAD;
STA,46,WKLY LABOR;
TIM,XX(1),UTIL WKCTR1;
TIM,XX(2),UTIL WKCTR2;
TIM,XX(3),UTIL WKCTR3;
TIM,XX(4),UTIL WKCTR4;
TIM,XX(11),INV PN1;
TIM,XX(12),INV PN2;
TIM,XX(13),INV PN3;
TIM,XX(14),INV PN4;
TIM,XX(15),INV PN5;
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TIM,XX(16),INV PN6;
TIM,XX(17),INV PN7;
TIM,XX(18),INV PN8;
TIM,XX(19),INV PN9;
TIM,XX(20),INV PN10;
TIM,XX(21),INV PN11;
TIM,XX(22),INV PN12;
TIM,XX(23),INV PN13;
TIM,XX(24),INV PN14;
TIM,XX(25),INV PN15;
TIM,XX(26),INV PN16;
TIM,XX(27),INV PN17;
TIM,XX(28),INV PN18;
TIM,XX(29),INV PN19;
TIM,XX(30),INV PN20;
TIM,XX(91),INV AVGE TOT;
TIM,XX(96),NO.PARTS IN SHOP;
TIM,XX(100),NO.ORDS. IN SHOP;
PRI/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4);
INI,0.;,
FIN;
```

MRPSIM Input Echo - Mixed Product Structures

M R P   S I M U L A T O R   I N P U T S

NO. REVIEWS TO RUN	1
PLANNING HORIZON LENGTH	40
NO. OF END-ITEMS	4
HIGHEST PART NO.	20
CLEAR PERIOD	50
POLICY SELECTED	1
PRINT B-O-M	1
PRINT WCTR & ROUTES	1
PRINT MSTR SCHED	1
REPORT MODE	1
NO. REPLICATIONS	11
REDUCTION FACTOR	1.25

TOTAL GROSS REQD END ITEMS

END ITEM PN: 20 REQD:	64
END ITEM PN: 19 REQD:	22
END ITEM PN: 17 REQD:	6
END ITEM PN: 16 REQD:	11

END ITEM DEMAND PARAMETERS

ITEM NO.	RATE	ALPHA	NSTART: 40
20	66.0	0.15	
19	23.0	0.15	
17	6.0	0.15	
16	9.0	0.15	

B I L L O F M A T E R I A L N O. 1 OF 4

----- TOP LEVEL PART NO. ----- 20

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	20	1	20	0	0
2	1	1	20	1	1
3	10	1	20	1	1
4	11	1	10	3	2
5	8	1	10	3	2
6	12	1	11	4	3
7	13	1	11	4	3
8	2	1	11	4	3
9	9	1	8	5	3
10	6	1	9	9	4

T O T A L Q T Y B Y P A R T N O.

PART NO.	1	TOTAL REQD:	1
PART NO.	2	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	10	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1
PART NO.	20	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 1	0	1	0	0
PN 2	0	0	0	1
PN 6	0	0	0	0
PN 8	0	0	1	0
PN 9	0	0	0	1
PN10	0	1	0	0
PN11	0	0	1	0
PN12	0	0	0	1
PN13	0	0	0	1
PN20	1	0	0	0

B I L L   O F   M A T E R I A L   N O. 2 OF 4

----- TOP LEVEL PART NO. ----- 19

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	19	1	19	0	0
2	18	1	19	1	1
3	9	1	18	2	2
4	2	1	18	2	2
5	4	1	18	2	2
6	6	1	9	3	3
7	5	1	4	5	3
8	6	1	4	5	3

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	2	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	1
PART NO.	5	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	2
PART NO.	9	TOTAL REQD:	1
PART NO.	18	TOTAL REQD:	1
PART NO.	19	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 2	0	0	1	0
PN 4	0	0	1	0
PN 5	0	0	0	1
PN 6	0	0	0	2
PN 9	0	0	1	0
PN18	0	1	0	0
PN19	1	0	0	0

B I L L O F M A T E R I A L N O. 3 OF 4

----- TOP LEVEL PART NO. ----- 17

I N P U T R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	17	1	17	0	0
2	11	1	17	1	1
3	8	1	17	1	1
4	3	1	17	1	1
5	12	1	11	2	2
6	13	1	11	2	2
7	2	1	11	2	2
8	9	1	8	3	2
9	1	1	3	4	2
10	2	1	3	4	2
11	6	1	9	8	3

T O T A L Q T Y B Y P A R T N O.

PART NO.	1	TOTAL REQD:	1
PART NO.	2	TOTAL REQD:	2
PART NO.	3	TOTAL REQD:	1
PART NO.	6	TOTAL REQD:	1
PART NO.	8	TOTAL REQD:	1
PART NO.	9	TOTAL REQD:	1
PART NO.	11	TOTAL REQD:	1
PART NO.	12	TOTAL REQD:	1
PART NO.	13	TOTAL REQD:	1
PART NO.	17	TOTAL REQD:	1

Q T Y B Y L E V E L

PN 1	0	0	1	0
PN 2	0	0	2	0
PN 3	0	1	0	0
PN 6	0	0	0	1
PN 8	0	1	0	0
PN 9	0	0	1	0
PN11	0	1	0	0
PN12	0	0	1	0
PN13	0	0	1	0
PN17	1	0	0	0

B I L L   O F   M A T E R I A L   N O. 4 OF 4

----- TOP LEVEL PART NO. ----- 16

I N P U T   R E C O R D S

RECNO	PN	QTY	PRNT PN	PRNT RECNO	LEVEL
1	16	1	16	0	0
2	14	1	16	1	1
3	15	1	16	1	1
4	3	1	14	2	2
5	4	1	14	2	2
6	7	1	15	3	2
7	4	1	15	3	2
8	1	1	3	4	3
9	2	1	3	4	3
10	5	1	4	5	3
11	6	1	4	5	3
12	1	1	7	6	3
13	6	1	7	6	3
14	5	1	4	7	3
15	6	1	4	7	3

T O T A L   Q T Y   B Y   P A R T   N O.

PART NO.	1	TOTAL REQD:	2
PART NO.	2	TOTAL REQD:	1
PART NO.	3	TOTAL REQD:	1
PART NO.	4	TOTAL REQD:	2
PART NO.	5	TOTAL REQD:	2
PART NO.	6	TOTAL REQD:	3
PART NO.	7	TOTAL REQD:	1
PART NO.	14	TOTAL REQD:	1
PART NO.	15	TOTAL REQD:	1
PART NO.	16	TOTAL REQD:	1

Q T Y   B Y   L E V E L

PN 1	0	0	0	2
PN 2	0	0	0	1
PN 3	0	0	1	0
PN 4	0	0	2	0
PN 5	0	0	0	2
PN 6	0	0	0	3
PN 7	0	0	1	0

PN14	0	1	0	0
PN15	0	1	0	0
PN16	1	0	0	0

C O M P O N E N T S / A S S Y   Q T Y S

ASSY. PART NO. 3 NO. OF COMPONENTS: 2

PART NO.	QTY
1	1
2	1

ASSY. PART NO. 4 NO. OF COMPONENTS: 2

PART NO.	QTY
5	1
6	1

ASSY. PART NO. 7 NO. OF COMPONENTS: 2

PART NO.	QTY
1	1
6	1

ASSY. PART NO. 8 NO. OF COMPONENTS: 1

PART NO.	QTY
9	1

ASSY. PART NO. 9 NO. OF COMPONENTS: 1

PART NO.	QTY
6	1

ASSY. PART NO. 10 NO. OF COMPONENTS: 2

PART NO.	QTY
11	1
8	1

ASSY. PART NO. 11 NO. OF COMPONENTS: 3

PART NO.	QTY
12	1
13	1
2	1

ASSY. PART NO. 14 NO. OF COMPONENTS: 2

PART NO.	QTY
3	1
4	1

ASSY. PART NO. 15 NO. OF COMPONENTS: 2

PART NO.	QTY
7	1
4	1

ASSY. PART NO. 16 NO. OF COMPONENTS: 2

PART NO.	QTY
14	1
15	1

ASSY. PART NO. 17 NO. OF COMPONENTS: 3

PART NO.	QTY
11	1
8	1
3	1

ASSY. PART NO. 18 NO. OF COMPONENTS: 3

PART NO.	QTY
9	1
2	1

		4	1
ASSY. PART NO. 19	NO. OF COMPONENTS: 1	PART NO.	QTY
		18	1
ASSY. PART NO. 20	NO. OF COMPONENTS: 2	PART NO.	QTY
		1	1
		10	1

W O R K   C E N T E R   D A T A

4 WORK CENTERS

NO.	NO. MACH.	NOM. CAP.	MAX. CAP.	LO CL	HI CL
1	2	40	80	40.0	120.0
2	2	40	80	40.0	120.0
3	2	40	80	40.0	120.0
4	2	40	80	40.0	120.0

P A R T   R O U T I N G S

PART NO. 1 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.066		0.010
2	4		0.081		0.010
3	1		0.090		0.010
			-----		-----
		TOTAL	0.237	TOTAL	0.030

PART NO. 2 NO. OF. OPER.: 2 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.086		0.010
2	2		0.063		0.010
			-----		-----
		TOTAL	0.149	TOTAL	0.020

PART NO. 3 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.078		0.010
2	1		0.105		0.010
3	3		0.145		0.010
4	2		0.127		0.010
5	3		0.067		0.010
			-----		-----
		TOTAL	0.522	TOTAL	0.050

PART NO. 4 NO. OF. OPER.: 4 LEAD TIME: 4.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.170		0.010
2	2		0.128		0.010
3	1		0.149		0.010
4	3		0.097		0.010
			-----		-----
		TOTAL	0.544	TOTAL	0.040

PART NO. 5 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.206		0.010
2	3		0.044		0.010
3	4		0.067		0.010
			-----		-----
		TOTAL	0.317	TOTAL	0.030

PART NO. 6 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.164		0.010
2	1		0.181		0.010
3	2		0.145		0.010
4	1		0.004		0.010
5	2		0.051		0.010
			-----		-----
		TOTAL	0.545	TOTAL	0.050

PART NO. 7 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.138		0.010
2	2		0.042		0.010
			-----		-----
		TOTAL	0.180	TOTAL	0.020

PART NO. 8 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.112		0.010
2	3		0.053		0.010
3	2		0.099		0.010
			-----		-----
		TOTAL	0.264	TOTAL	0.030

PART NO. 9 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.075		0.010
2	4		0.127		0.010
3	1		0.038		0.010
			-----		-----
		TOTAL	0.240	TOTAL	0.030

PART NO. 10 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.192		0.010
2	1		0.008		0.010
			-----		-----
		TOTAL	0.200	TOTAL	0.020

PART NO. 11 NO. OF. OPER.: 4 LEAD TIME: 4.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.076		0.010
2	3		0.060		0.010

3	2		0.178		0.010
4	4		0.064		0.010
			-----		-----
		TOTAL	0.378	TOTAL	0.040

PART NO. 12 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.102		0.010
2	1		0.084		0.010
3	2		0.112		0.010
4	3		0.053		0.010
5	4		0.099		0.010
			-----		-----
		TOTAL	0.450	TOTAL	0.050

PART NO. 13 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	4		0.075		0.010
2	3		0.127		0.010
			-----		-----
		TOTAL	0.202	TOTAL	0.020

PART NO. 14 NO. OF. OPER.: 5 LEAD TIME: 5.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.119		0.010
2	1		0.094		0.010
3	4		0.117		0.010
4	2		0.194		0.010
5	4		0.095		0.010
			-----		-----
		TOTAL	0.619	TOTAL	0.050

PART NO. 15 NO. OF. OPER.: 2 LEAD TIME: 2.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.087		0.010
2	2		0.129		0.010
			-----		-----
		TOTAL	0.216	TOTAL	0.020

PART NO. 16 NO. OF. OPER.: 4 LEAD TIME: 4.

OPER. NO.	WK. CTR.	STD. TIME	SETUP TIME
1	3	0.109	0.010
2	2	0.081	0.010
3	1	0.101	0.010
4	4	0.107	0.010

			-----		-----
		TOTAL	0.398	TOTAL	0.040

PART NO. 17 NO. OF. OPER.: 6 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.122		0.010
2	2		0.023		0.010
3	1		0.024		0.010
4	4		0.044		0.010
5	1		0.083		0.010
6	4		0.081		0.010
			-----		-----
		TOTAL	0.377	TOTAL	0.060

PART NO. 18 NO. OF. OPER.: 3 LEAD TIME: 3.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	1		0.158		0.010
2	3		0.116		0.010
3	1		0.162		0.010
			-----		-----
		TOTAL	0.436	TOTAL	0.030

PART NO. 19 NO. OF. OPER.: 4 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	2		0.110		0.010
2	3		0.139		0.010
3	4		0.136		0.010
4	2		0.038		0.010
			-----		-----
		TOTAL	0.423	TOTAL	0.040

PART NO. 20 NO. OF. OPER.: 3 LEAD TIME: 1.

OPER. NO.	WK. CTR.		STD. TIME		SETUP TIME
1	3		0.039		0.010
2	4		0.068		0.010
3	1		0.074		0.010
			-----		-----
		TOTAL	0.181	TOTAL	0.030

U N I T   W O R K   C O N T E N T

WORK CENTER---	1	2	3	4
PART NO.: 1	0.090	0.066	0.0	0.081
PART NO.: 2	0.0	0.063	0.0	0.086
PART NO.: 3	0.105	0.205	0.212	0.0
PART NO.: 4	0.149	0.128	0.267	0.0
PART NO.: 5	0.206	0.0	0.044	0.067
PART NO.: 6	0.185	0.196	0.164	0.0
PART NO.: 7	0.138	0.042	0.0	0.0
PART NO.: 8	0.0	0.099	0.053	0.112
PART NO.: 9	0.113	0.0	0.0	0.127
PART NO.:10	0.008	0.0	0.0	0.192
PART NO.:11	0.0	0.254	0.060	0.064
PART NO.:12	0.084	0.112	0.053	0.201
PART NO.:13	0.0	0.0	0.127	0.075
PART NO.:14	0.094	0.194	0.119	0.212
PART NO.:15	0.087	0.129	0.0	0.0
PART NO.:16	0.101	0.081	0.109	0.107
PART NO.:17	0.107	0.023	0.122	0.125
PART NO.:18	0.320	0.0	0.116	0.0
PART NO.:19	0.0	0.148	0.139	0.136
PART NO.:20	0.074	0.0	0.039	0.068

L O A D - C A P A C I T Y   A N A L Y S I S

WORK CENTER: 1 AVERAGE TOTAL LOAD: 85.03
UNIT MACHINE LOAD: 42

WORK CENTER: 2 AVERAGE TOTAL LOAD: 90.65
UNIT MACHINE LOAD: 45

WORK CENTER: 3 AVERAGE TOTAL LOAD: 72.03
UNIT MACHINE LOAD: 36

WORK CENTER: 4 AVERAGE TOTAL LOAD: 88.01
UNIT MACHINE LOAD: 44

PRODUCT LOADING REPORT

ITEM: 1 IN WC ORDER:	36.56	52.14	32.74	66.40
ITEM: 2 IN WC ORDER:	26.63	16.81	20.56	9.57
ITEM: 3 IN WC ORDER:	4.10	6.49	4.75	5.74
ITEM: 4 IN WC ORDER:	17.73	15.21	13.99	6.31

PRODUCT WORK CONTENT REPORT

ITEM: 1 IN WC ORDER:	0.554	0.790	0.496	1.006
ITEM: 2 IN WC ORDER:	1.158	0.731	0.894	0.416
ITEM: 3 IN WC ORDER:	0.684	1.081	0.791	0.957
ITEM: 4 IN WC ORDER:	1.970	1.690	1.554	0.701

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