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A DATABASE SUPPORTED DISCRETE PARTS MANUFACTURING SIMULATION

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ABSTRACT

This paper discusses a prototype decision support system for discrete parts manufacturing. Basic decision support system concepts are presented. The context of this analysis effort within the entire technical operations of the firm is shown. The use of typical, real production data stored in a database for both traditional reporting purposes and as data input to a simulation model is discussed. Thus, the model can process both currently known future orders and generate currently unknown future orders in analyzing future production requirements. Furthermore, model outputs which measure the ability of the production system to meet future requirements are stored in the database. Thus, they may be analyzed and reported independently of the running of the model.

1. INTRODUCTION

The following paper discusses a nucleus of decision support for a discrete parts manufacturing. This nucleus consists of a simulation model supported by a relational database.

Part 2 reviews essential features of the components of a decision support system. Part 3 establishes the decision support context for the simulation model, details the logical data model and discusses the inner workings of the simulation model itself. Part 4 discusses two distinct uses of the simulation model. On the one hand a purely deterministic mode can be established. On the other, a mixed probabilistic/deterministic mode can be established which involves some features unique to database supported simulation.

2. THE COMPONENTS OF DECISION SUPPORT

2.1 Database Management Systems

Dozens of database systems are available today. Gio Wiederhold surveys nearly one hundred. Every major hardware vendor and numerous software specialists have such products to market [Datapro Research Corporation]. They range from simple file management utilities to complete database management systems which include data dictionaries, data definition languages, data manipulation languages, query facilities and report generators.

One relational database system which is designed especially for use in simulation modeling is the Simulation Data Language (SDL™) (Standridge). In addition, SDL can be used as a tool for decision support. It was used in the course of this research not only as the repository of manufacturing data for conventional applications and as the destination for outputs from simulation runs, but also as a vehicle for generating random variates to be inputs to the simulation runs.

SDL is a FORTRAN-based data management system. It consists of three basic components. A data definition component allows for the creation of relations appropriate for holding the required data. (A relation can be thought of as a matrix of rows and columns). It also allows for operations to be performed on the relations as the users require. A physical data management component allows the database implementor to account for his unique hardware requirements. The third component is a unique high-level batch programming language to create and manage the database called OIL.

One SDL command that is particularly useful in the context of this research samples from histograms created from either historical data or simulation results. This means the simulation

SDL is a trademark of Pritsker & Associates, Inc.

model can be free from specifications of distribution types for random sampling to assign values needed within the model. Instead, the distribution types are dynamically changing as users update the database. This was preferable to us since enough data existed to give confidence to the sampling.

2.2 Management Science Models
Approaches to the problem of modeling production planning have included mixed integer programming, dynamic progamming and simulation (Baker and Johnson and Montgomery). The first two methods can provide correct solutions to the problem of optimizing some criteria of production but only in the smallest of cases. Problems encountered in the industrial world are of a scale which makes finding exact solutions formidable, if not altogether impossible, by MIP or DP methods. The method of digital simulation offers distinct advantages over other methods for aiding in production planning. It allows for the modeling of real world problems, while accommodating the dynamically changing data on which the production decisions rely. Disadvantages of the method are primarily cost related, as the model run requires significant computer time. However, with the cost of computer hardware continually decreasing, this disadvantage is likely to disappear altogether. The method offers great promise for incorporation into the production planning function for a wide range of manufacturing firms.

As the techniques of simulation are accepted into the firm's planning function, it will be natural to provide data from the firm's database to augment, if not replace, the data such as setup time or unit production time which conventionally is generated within the model by random sampling from assumed distributions. It will be seen that such data used by the firm for day-to-day report processing is in many cases the same data by which the simulation model should be driven.

In this research, a prototype decision support system for a discrete parts manufacturing operation was to be built. This prototype consisted of a GASP IV(Pritsker) simulation model of the operation and an SDL database containing typical information about the operation. This information included machine set-up times, unit production times, and sequences of operations to be performed on particular products. The model was designed to make use of these data. Thus, when revisions in engineering and production plans are updated, then these data outputs of the model could automatically reflect the revisions. Finally, the outputs of the model were stored in the database.

2.3 Decision Support Systems
Neither the DBMS nor the MS model alone provide modern management with the type of tool it needs to operate. But together these components can constitute the nucleus of a decision support system.

Decision support systems constitute a fairly small but growing group of information management tools with unique characteristics. Keen, Alter, Sprague, and others have helped specify just what these systems are and how they can assist in complex decision making. DSS are distinct from the management information systems (MIS) of the seventies. They emphasize the role of computers in assisting managers and technicians rather than replacing them. Their emphasis is more on flexibility than consistency and on support of semi-structured tasks rather than clearly structured tasks. Whereas the MIS necessarily dealt with reporting information about the past, the DSS is oriented toward providing information for making decisions affecting the present and the future.

Structurally one might envision a general decision support system to resemble Figure 1. Most generally, it consists of a data management component storing information regarding the real world system together with one or more application tools (statistical, financial or operations research for example) used to extrapolate from and report to the database. Obviously, a mature DDS would provide several such programs and their respective interfaces with the database. In this research a single simulation model was linked to the database demonstrating the usefulness of such techniques for discrete parts manufacturing.

Current DSS are generally proprietary systems built to support unique tasks. The Empire system from Applied Data Research is marketed as a DSS for general use, however. Several examples described by their developers as DSS are shown in Table 1. Details of their use can be found in Keen and Scott-Morton and in Alter. While they differ considerably in their designs, they share what are coming to be seen as the essential features of a DSS:
-they are management oriented rather than clerical
-they support--not replace--decision making
-they function in semi-structured environments.
The system described in this research shares these features.

3.0 LAYOUT OF THE MODEL AND OF THE DATABASE

3.1 Context of the Model
It is useful to characterize the environment in which the model to be described was developed. The production faciltity is that of a medium sized manufacturer of centrifugal pumps. It consists of about sixty conventional and numerically controlled machine tools processing discrete batches of parts. These batches move from machine to machine in predefined sequences which depend on the specific part, quantity and material called for. Estimates of times at each machine have been made prior to releasing the batch for processing. Orders to make batches of distinct parts are prepared by production planners on the basis of a master schedule in advance of the date fabrication is to begin. These orders are then filed by week of expected release. Each week the appropriate orders are released for production. With the database in place, the orders are to be stored online instead of in a manual file, but the release method will remain the same.

Each week's group of orders consists of a different number. The number to be released in the immediate future generally is greater than that to be released in the distant future. On the appropriate date, that week's accumulated orders are released for production and join other orders in process. In addition, the attributes of typical orders were stored in the database. Samples from histograms of these attributes were used to build currently unknown, future orders. Thus the model uses actual production data when available and samples from histograms of that data when required to generate future, unknown order releases with attributes similar to those observed historically. Such a situation would be encountered when the actual number of orders to be released in a given week was less than the historical average.

The role of this model in the production planning function is to utilize the production data to predict shop status in some future period using deterministic data when available and probabilistic data as required. A unique feature of this approach is that the modeler need not hypothesize distributions from which the probabilistic data comes. In a business where history is accepted as an adequate predictor of future activities (this is true in the stable pump industry), this approach is to be preferred. The model is indifferent to the type of distribution implied by the actual data, yet samples generated will accurately reflect the distribution type. In this sense the model and database work together to modify the model itself.

With support of manufacturing decisions as the overall objective, one can create a structure chart (Figure 2) which places the model in the context of decision support. The node entitled "Simulate Operations" is to become the simulation model of the operations. The structure of the model is dictated by its intended use in conjunction with these other aspects of the DSS.

3.2 The Logical Database

The global data model for the pump company is shown in Figure 3. Each node is a relation or group of related data items. Of particular concern to this research was data regarding product manufacture. This is the conventional routing data found in virtually all manufacturing systems. It is only part of the global data model, but it is of critical importance operationally and was therefore chosen to be used for this research. It can be seen that the use of any other corporate data would be similar to the use of production data. Only the size of the database and the global data model would change.

In the course of normalizing the relations indicated in Figure 3, one arrives at the flat files of Table 2 which hold production data. In this case 472 such entries were used; this is adequate to assure validity of subsequent histogram sampling.

Along with this relation (Table 2) holding input data, a relation to hold model output data is required. These two relations form the core of the database. From them, subsets of rows and columns are created to form the basis for statistical analysis and histogram creation. It can be seen that data in these relations are available for a variety of purposes in addition to driving the simulation model. The production planner may access the relation holding data for a particular week and answer questions regarding that week's data. Last minute changes due to new orders or cancelled orders can be made without altering the model. This would not be the case in a conventional model. One would be forced to re-examine the data on which the chosen distributions were based and perhaps find better fits in alternative distributions. The database oriented model is thus more suited for use in the semi-structured decision support environment where the decision maker himself effectively changes the structure of the model by introducing new inputs.

3.3 The Simulation Model

With the basic assumptions outlined above, a model of shop operation was developed. The language chosen was GASP IV (Pritsker). Compatability with the FORTRAN based SDL was an important factor in the choice. Other languages which support invocation of FORTRAN subprograms would undoubtedly work as well.

The model itself consists of a main segment and several subroutines. Their interrelations are shown in Figure 4. It should be noted that the main module of Figure 4 is functionally the same as the module "Simulate Operations" of Figure 2. The main body of the model (GSPMAIN) reads parameters describing the length of the planning horizon, the average time between order releases, the number of actual orders to be released, the historical average order size and a vector of machine identification numbers which itself may change from run to run. The next segment (ARVSHOP) then opens the database of production data and reads the attributes of orders to be released on the given week. Those attributes include the part identification number, its description, material of construction, product code, a vector of machine identification numbers indicating its path through the shop, a vector of expected times to set up the job on each respective machine, and a vector of expected times to produce a unit of specified product on each respective machine.

If the number of actual orders released at this time is equal to or less than the historical average, the initial arrival of a group of orders is complete. They are then assigned to the machine of first operation and processing begins. However, if the number of actual orders released is less than the historical average, the model generates artifical orders to be processed along with the actual orders. They act as place holders for orders expected but not yet prepared on the date of the model run. The attributes of these artifical orders are generated by sampling from histograms of data in the production database. These orders also are assigned to machines of first operation and processing begins.

The arrival to the machines specified by the production data is handled in a separate subroutine (ARVMACH). This subroutine checks the status of the machine required. If it is idle, the order is immediately set up and production begins. Since the expected time of completion is specified, an event is scheduled to represent completion of the order at the designated machine. If the machine is already busy, the released order is put into a queue until the machine is free.

Departure from a machine is a separate subroutine as well (DEPMACH). If no jobs are queued, the machine is set idle. If jobs are queued, one is dispatched and run. The rule for removal from the queue is shortest processing time first. This dispatching rule can be changed at the discretion of the modeler, of course, but is probably the most commonly used and is appropriate here. If the departure is from the machine of last operation, the job has finished its processing and is removed from the system. If not, it moves to the next scheduled machine.

The subroutine which generates artificial orders (JOBGENR) is a unique feature of this database-oriented model. Here an SDL function is invoked to sample from histograms of pertinent production data (sequence of operations, machine set up and machine operation times). Values are returned which are characteristic of the actual orders planners expect to release and reflect the distributions from which the data come.

If the time horizon of the simulation is less than the average time between order releases, (in this case one week or 168 hours), the model generates only one release of orders, processes the parts and terminates, writing appropriate output measures to the database. Otherwise the next batch of orders is released and the existing job mix is expanded. Processing then continues until the time horizon of the simulation is reached.

4.0 TWO SIMULATION MODES

To develop a useable database for inquiry is in itself a project of more technical than academic interest. But to lay out the database in such a way that the same empirical data used for inquiry is available for prediction and decision making via the simulation model is a project of academic as well as technical interest. By choosing the appropriate parameters for the model run one is able to simulate the operation of the shop in either of two modes. These simulation uses of the empirical data are what distinguishes the database-supported model from the conventional model.

4.1 Purely Deterministic Mode

If the user so desires he may set the parameters of the model to run in a purely deterministic mode. This would be done specifically by setting the number of actual orders to be released equal to the average order size. In the example discussed here both values were set to 10. The echo check of the run parameters is shown in Table 3. The first 10 jobs in the appropriate relation were read at model initialization time and assigned to the designated machines. A summary of input data is shown in Table 4. The output summary appears in Table 5. Except for the time spent in queue at each machine this data would be available from conventional analysis of production data. The output from the simulation includes time in queues as well as time in the system, machine utilization and number of open orders. There are occasions when this information is all the planner requires.

4.2 Mixed Deterministic Probabilistic Mode

On other occasions a planner may require information which can only come from running the model in mixed mode. He may have to know the implication of introducing a new product line which resembles existing products to some degree and is to be introduced at a future date. He would then set the model parameters to generate representative orders similar but not identical to orders for existing products. A simulation is in order since the increased load may or may not be possible in the required time frame. Run parameters for this type of model are given in Table 6. In this case the same number of actual orders (10) are to be released but the average order size is greater (20) so the model generates representative attributes for typical orders and releases them together with the actual orders on the required order release date. These combined orders are summarized in Table 7. The summary report from running the model in this mixed mode appears in Table 8.

During each model run, system performance information (specifically machine queue times) is collected and written to the database. Typically queue times are sought in manufacturing system modeling as a measure of the ability of the system to meet its production requirements. They were used as representative model outputs for this research as well. Selected queue time histograms for both modes of model operation are shown in Figures 5 and 6.

5.0 Summary

The research described here was done to show the value of linking DBMS with an MS model for use in manufacturing decision support. The characteristics of the broader system of which they are a part.

The database management system was seen to be of critical importance. Features of SDL make it a valuable DBMS for the purposes outlined here. It not only provides use in the conventional manner of data definition, inquiry and reporting but also provides important functions for histogram creation and for subsequent sampling from those histograms.

The simulation model was also seen to be of critical importance. In addition to providing a vehicle for semi-structured problem solving, it also demonstrates a unique mode of self-modification. By working in conjunction with the database, it circumvents the conventional specification of distribution types and allows distribution types to be handled dynamically.

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Table 1

Examples of DSS

Empire: Generalized DSS
Portfolio Management System (PMS)
Projector: Financial Planning System
Capacity Information System (CIS)
Brandaid: Marketing Planning
Geodata Analysis and Display System (GADS)
Generalized Management Information System (GMIS)
Connoisseur Foods: The Introduction of Modeling and Data Retrieval Capabilities
Great Eastern Bank: A Portfolio Management System
Gotaas-Larsen Shipping Corporation: A Corporate Planning System
Equitable Life: A Computer-Assisted Underwriting System
Interactive Market Systems: A Media Decision Support System
The Great Northern Bank: A System for Budgeting, Planning and Control
The Cost of Living Council: Decision Support in a Regulatory Setting
AAIMS: An Analytic Information Management System

Table 2
Normalized Production Data

ROWS OF DATA ARE FROM RELATION 101 OF TYPE REGULAR
TABLE 1

ACCORDING TO FORMAT (1X,F 4 .0 , 5X,A 10 , 5X,F 4 .0 , 5X,A 10 , 5X,F 3 .0 , 5X,F
4 .0 , 5X,F 6 .3 , 5X,F 6 .3 , 5X,F 6 .3 , 5X,F 6 .3 , 5X,F 6 .3 , 5X,F
6 .3)

ID	PARTNO	PART		MAT	NOPS	QTY	OP01	OP02	OP03	OP04	OP05	OP06
1.	001-11L-F-	2.	CI		6.	10.	20.000	35.000	35.000	33.000	33.000	20.000
2.	001-14H-B-	2.	CI		5.	10.	16.000	80.000	80.000	60.000	20.000	-1.000
3.	001-14H-B-	2.	SS		5.	10.	16.000	80.000	80.000	60.000	20.000	-1.000
4.	003-11L-B-	2.	CI		3.	10.	1.000	1.000	60.000	-1.000	-1.000	-1.000
5.	003-11L-B-	2.	SS		3.	10.	1.000	1.000	60.000	-1.000	-1.000	-1.000
6.	1 1/2HA193	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
7.	1 1/2HA193	1.	SS		3.	10.	37.000	20.000	20.000	-1.000	-1.000	-1.000
8.	1 1/2H193B	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
9.	1 1/2H4B	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
10.	1 1/2H4B	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
11.	1 1/2H4E-1	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
12.	1 1/2H4E-1	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
13.	1 1/2LA193	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
14.	1 1/2LA193	1.	SS		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
15.	1 1/2L193-	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
16.	1 1/2L4	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
17.	1 1/2L4	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
18.	1 1/2L4B-1	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
19.	1 1/2L4B-1	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
20.	1 1/4HA193	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
21.	1 1/4HA193	1.	SS		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
22.	1 1/4H193	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
23.	1 1/4H193	1.	SS		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
24.	1 1/4H4	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
25.	1 1/4H4	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
26.	1 1/4H4B-1	2.	CI		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
27.	1 1/4H4B-1	2.	SS		5.	10.	20.000	35.000	35.000	33.000	20.000	-1.000
28.	1 1/4LA193	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000
29.	1 1/4LA193	1.	SS		3.	10.	37.000	20.000	20.000	-1.000	-1.000	-1.000
30.	1 1/4L193-	1.	CI		3.	10.	37.000	26.000	20.000	-1.000	-1.000	-1.000

Table3
Run Parameters, Deterministic Mode

RUN PARAMETERS:

NUMBER OF ACTUAL ORDERS TO BE RELEASED:	10
AVERAGE SIZE OF AN ORDER RELEASE:	10
AVERAGE TIME BETWEEN ORDER RELEASES:	168.0
LENGTH OF PLANNING HORIZON:	168.0

IDENTIFICATION NUMBERS OF MACHINES IN THIS MODEL:

1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21
22	23	24	25	26	27	29	30	31	32	33	34	35	36	37	38	39	40	41	42
43	45	46	50	51	55	60	70	80	84	86	87	88	90	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4

Input Data Summary, Deterministic Mode

ACTUAL ORDERS RELEASED

INPUT DATA SUMMARY:

JOB	PART NUMBER	MATERIAL	QTY RUN	SET-UP TIME HRS	UNIT STD HRS	QTY RUN TIME
1	001-11L-F-	CI	10	5.750	1.154	17.290
2	001-14H-4-	CI	10	5.150	1.515	20.300
3	001-14H-B-	SS	10	5.150	1.916	24.310
4	009-11L-B-	CI	10	2.850	.552	8.370
5	009-11L-B-	SS	10	2.850	1.115	14.000
6	1 1/2HA193	CI	10	2.648	.155	4.198
7	1 1/2HA193	SS	10	1.750	.440	6.150
8	1 1/2H193B	CI	10	2.648	.155	4.198
9	1 1/2H48	CI	10	5.000	.652	11.520
10	1 1/2H49	SS	10	5.000	.900	14.000
	ALL PARTS		100	38.796	8.554	124.336

TOTAL PROJECTED TIME BY MACHINE:

MACHINE NUMBER	TOTAL SETUP HOURS	TOTAL RUN HOURS	COMBINED TOTAL HOURS	PERCENT GRAND TOTAL	PERCENT SIMULATED TIME
1	2.700	8.090	10.790	8	6
16	3.500	10.070	13.570	10	8
20	7.146	16.850	23.996	19	14
26	2.400	.280	2.680	2	1
33	3.000	3.210	6.210	4	3
35	7.500	13.770	21.270	17	12
37	3.000	4.750	7.750	6	4
60	6.000	22.290	28.290	22	16
80	3.550	6.230	9.780	7	5
ALL MACHINES	38.796	85.540	124.336	95	69

Table 5

Output Data Summary, Deterministic Mode

SUMMARY STATISTICS

MACHINE NUMBER	PCT TIME RUNNING	NO OF JOBS TO WAIT	NO OF JOBS TO RUN	AVG TIME JOB WAITS	AVG TIME JOB RUNS
1	6	3	4	2.203	2.697
16	8	1	2	6.260	6.785
20	14	6	12	2.663	2.000
26	1	0	2	I	1.340
33	3	1	3	.950	2.070
35	12	4	6	3.859	3.545
37	4	2	3	3.090	2.583
60	16	3	4	4.777	7.072
80	5	2	5	1.660	1.956

AVG TIME AN ORDER SPENDS IN THE SHOP 19.340

AVG NUMBER OF OPEN ORDERS IN THE SHOP 1.2

Table 6

Run Parameters, Mixed Mode

RUN PARAMETERS:
NUMBER OF ACTUAL ORDERS TO BE RELEASED: 10
AVERAGE SIZE OF AN ORDER RELEASE: 20
AVERAGE TIME BETWEEN ORDER RELEASES: 168.0
LENGTH OF PLANNING HORIZON: 168.0

IDENTIFICATION NUMBERS OF MACHINES IN THIS MODEL:

1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21
22	23	24	25	26	27	29	30	31	32	33	34	35	36	37	38	39	40	41	42
43	45	46	50	51	55	60	70	80	84	86	87	88	90	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7
Input Data Summary, Mixed Mode

COMBINED ACTUAL AND GENERATED ORDERS RELEASED

INPUT DATA SUMMARY:

JOB	PART NUMBER	MATERIAL	QTY RUN	SET-UP TIME HRS	UNIT STD HRS	QTY RUN TIME
11	NAME	MATERIAL	10	2.284	.321	5.494
12	NAME	MATERIAL	10	4.025	.438	8.402
13	NAME	MATERIAL	10	4.500	.899	13.494
14	NAME	MATERIAL	10	1.885	.368	5.562
15	NAME	MATERIAL	10	4.469	.564	10.110
16	NAME	MATERIAL	10	4.288	.781	12.096
17	NAME	MATERIAL	10	3.793	.639	10.172
18	NAME	MATERIAL	10	2.631	.521	7.843
19	NAME	MATERIAL	10	4.247	.616	10.407
20	NAME	MATERIAL	10	3.866	.427	8.134
	ALL PARTS		200	74.784	14.127	216.049

TOTAL PROJECTED TIME BY MACHINE:

MACHINE NUMBER	TOTAL SETUP HOURS	TOTAL RUN HOURS	COMBINED TOTAL HOURS	PERCENT GRAND TOTAL	PERCENT SIMULATED TIME
1	4.625	12.272	16.898	7	10
16	3.500	10.070	13.570	6	8
20	13.097	26.809	39.906	18	23
25	.500	1.027	1.527	0	0
26	11.437	12.574	24.011	11	14
33	3.000	3.210	6.210	2	3
34	1.166	1.000	2.166	1	1
35	7.500	13.770	21.270	9	12
36	9.160	14.108	23.268	10	13
37	5.264	8.008	13.272	6	7
38	4.544	8.648	13.192	6	7
43	1.441	1.248	2.689	1	1
60	6.000	22.290	28.290	13	16
80	3.550	6.230	9.780	4	5
ALL MACHINES	113.580	226.805	340.385	189	189

Table 8
Output Data Summary, Mixed Mode

SUMMARY STATISTICS

MACHINE NUMBER	PCT TIME RUNNING	NO OF JOBS TO WAIT	NO OF JOBS TO RUN	AVG TIME JOB WAITS	AVG TIME JOB RUNS
1	10	5	6	3.368	2.816
16	8	1	2	6.260	6.785
20	23	19	20	4.965	1.995
25	0	0	1	I	1.527
26	14	8	11	3.029	2.183
33	3	0	3	I	2.070
34	1	0	1	I	2.166
35	12	4	6	2.195	3.545
36	13	6	8	6.050	2.909
37	7	4	5	5.665	2.654
38	7	5	6	6.627	2.199
43	1	0	1	I	2.689
60	16	3	4	3.347	7.072
80	5	0	5	I	1.956

AVG TIME AN ORDER SPENDS IN THE SHOP 23.432

AVG NUMBER OF OPEN ORDERS IN THE SHOP 2.8

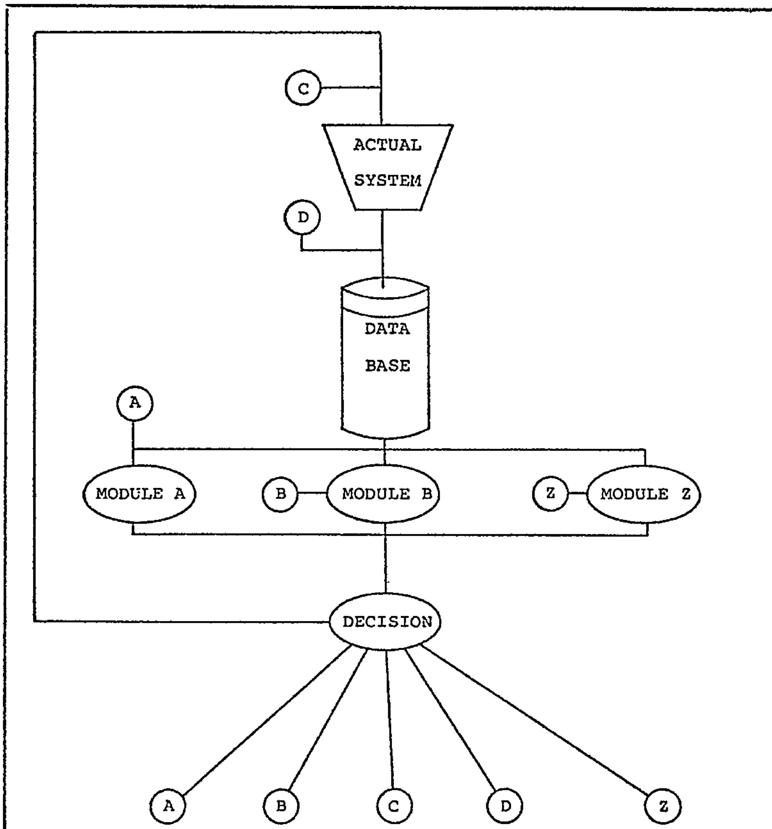

Figure 1. A Generalized DSS.

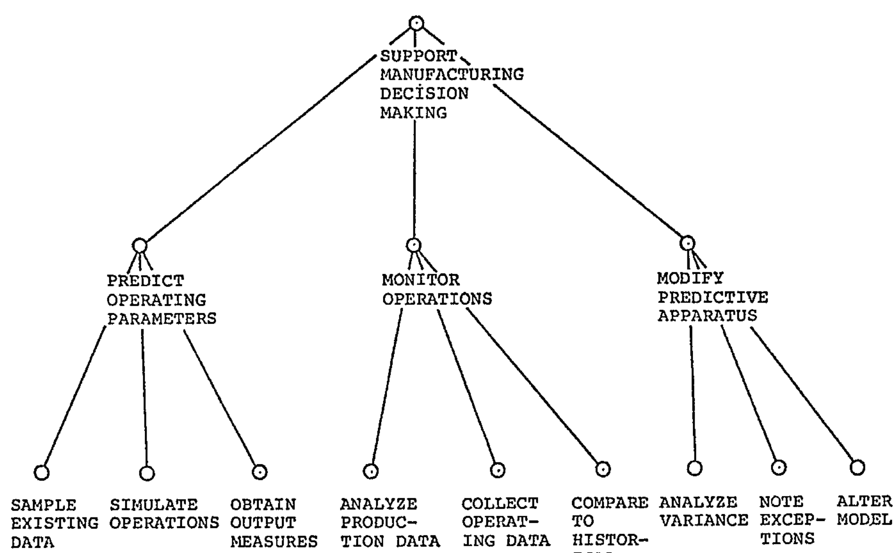

Figure 2 The Simulation Model in DSS Context.

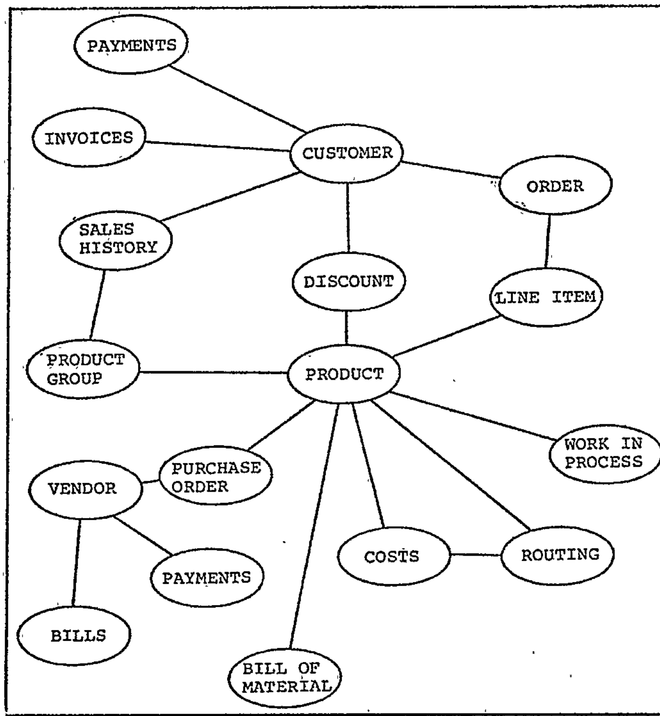

Figure 3 Global Data Model for Pump Manufacture.

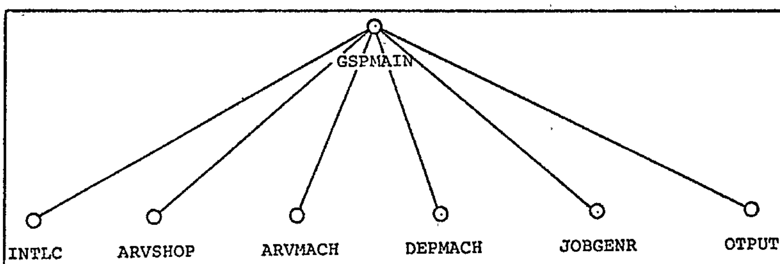

Figure 4. The Simulation Model.

DATA FROM STATISTICS RELATION 815, TIME IN QUEUE,BY MAC
DATA CONCERNING VARIABLE NUMBER 1, TOL
HISTOGRAM NAME IS

LOWER BOUND	UPPER BOUND	DEN COUNT	CUM COUNT	DEN FUNC	CUM FUNC
-.1000E+21	.1000E+01	0.	0.	0.000	0.000
.1000E+01	.2000E+01	2.	2.	.400	.400
.2000E+01	.3000E+01	2.	4.	.400	.800
.3000E+01	.4000E+01	0.	4.	0.000	.800
.4000E+01	.5000E+01	0.	4.	0.000	.800
.5000E+01	.6000E+01	0.	4.	0.000	.800
.6000E+01	.7000E+01	0.	4.	0.000	.800
.7000E+01	.8000E+01	0.	4.	0.000	.800
.8000E+01	.9000E+01	1.	5.	.200	1.000
.9000E+01	.1000E+21	0.	5.	0.000	1.000

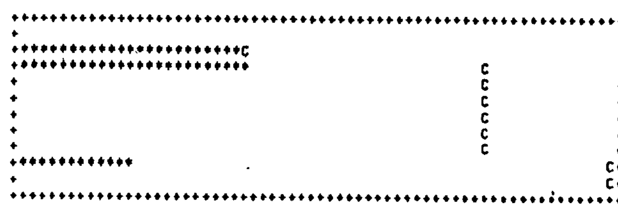

Figure 5 . Histograms of Queue Times, Mixed Mode.

DATA FROM STATISTICS RELATION 813, TIME IN QUEUE, BY MA
DATA CONCERNING VARIABLE NUMBER 1, TOI
HISTOGRAM NAME IS

LOWER BOUND	UPPER BOUND	DEN COUNT	CUM COUNT	DEN FUNC	CUM FUNC
-.1000E+21	.1000E+01	0.	0.	0.000	0.000
.1000E+01	.2000E+01	1.	1.	.333	.333
.2000E+01	.3000E+01	2.	3.	.667	1.000
.3000E+01	.4000E+01	0.	3.	0.000	1.000
.4000E+01	.5000E+01	0.	3.	0.000	1.000
.5000E+01	.6000E+01	0.	3.	0.000	1.000
.6000E+01	.7000E+01	0.	3.	0.000	1.000
.7000E+01	.8000E+01	0.	3.	0.000	1.000
.8000E+01	.9000E+01	0.	3.	0.000	1.000
.9000E+01	.1000E+21	0.	3.	0.000	1.000

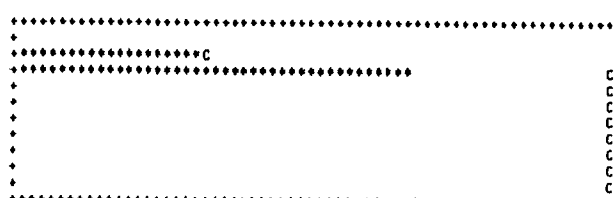

Figure 6 . Histograms of Queue Times, Deterministic Mode.