

A SIMULATION-BASED WORK ORDER RELEASE MECHANISM FOR A FLEXIBLE MANUFACTURING SYSTEM

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ABSTRACT

Most simulation models of flexible manufacturing systems (FMS) are used to evaluate designs or scheduling policies. We demonstrate the use of an FMS simulation model to control the release of work orders into the system. A model of an actual flexible manufacturing system was developed along with an interface to the real-time control database. The model is used to evaluate work order release sequences based on measures of performance. Simulation data obtained from experience with the system is presented and compared with actual data.

1. INTRODUCTION

Traditionally, simulation is used in the initial phases of the life cycle process in the manufacturing environment. This has typically consisted of system design evaluation for proof of concept and/or system improvement [Law and Kelton 1982; Erickson 1989; Muller 1989]. Relatively few simulation models have been employed in the operational phase of the life cycle to control the release of work orders in an FMS. These models have usually been limited to the evaluation of scheduling policies [Stecke and Solberg 1981; Glassey and Petrakian 1989] but were not integrated into the FMS control system.

Our goal was to develop an integrated simulation model of the FMS and use it as a prescriptive tool to support the real-time decision-making process for work order release, fixture build-up, and raw material requirements. The system is simulated from the current time into a future time window to determine the effect of different work order release policies. This approach differs from the traditional use of simulation as a descriptive tool used in the design phase of a manufacturing system in that we are interested in the transient behavior and not the usual steady state performance measures for the system. By this we mean measures such as the actual completion date of a work order. As shown in Figure 1, the basic elements of such a system are:

- work orders having due dates generated from the materials requirement planning (MRP) system,
- an accurate but time efficient simulation model,
- an interface to the control system (for initialization of the simulation model), and
- system measures to evaluate work order release sequences.

An FMS provides some of the advantages of automated transfer line production such as high productivity and machine utilization while still maintaining the flexibility of job shop environments. A typical FMS consists of an automated storage and retrieval system (ASRS), a set of automated multi-capability machining centers, automated material handling system, and a communications and control system. The ASRS supports the

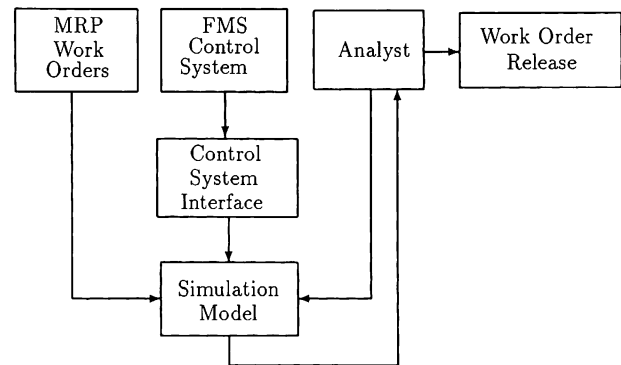


Figure 1. Elements of the Work Order Release Mechanism

warehousing function for raw material, work in process, and finished goods. Machining centers provide the necessary capabilities to process all parts in the FMS. The material handling system is used to transfer parts, fixtures, and pallets between stations (i.e., ASRS, machining centers, buffers, etc.)

At the Sauer/Sundstrand facility in Ames, Iowa, an FMS is being used to manufacture approximately 135 different part types for hydraulic transmission components. In any given month approximately 50 to 60 different part types are processed. As shown in Figure 2, the FMS consists of a one lane ASRS, manual load/unload stations, buffer station, two turning centers, manual finishing cell, shipping station, six machining centers, three automatic guided vehicles (AGV), wash station, and manual cordax station.

2. FMS DESCRIPTION

Raw material for each work order enters the system on the left side of the ASRS. The raw material is placed on a pallet and stored in the ASRS until it is ready to be released. Work orders are released manually by analysts in the computer control who notify the system using computer terminals when to release a work order. The fixture required by the work order part type (stored in the ASRS) is found or manually built using components stored in the ASRS. Once a fixture is available at the load/unload station, the pallet containing the raw material is retrieved and sent to the station. An operator places the raw material on the fixture and notifies the system that the fixture is ready to be processed.

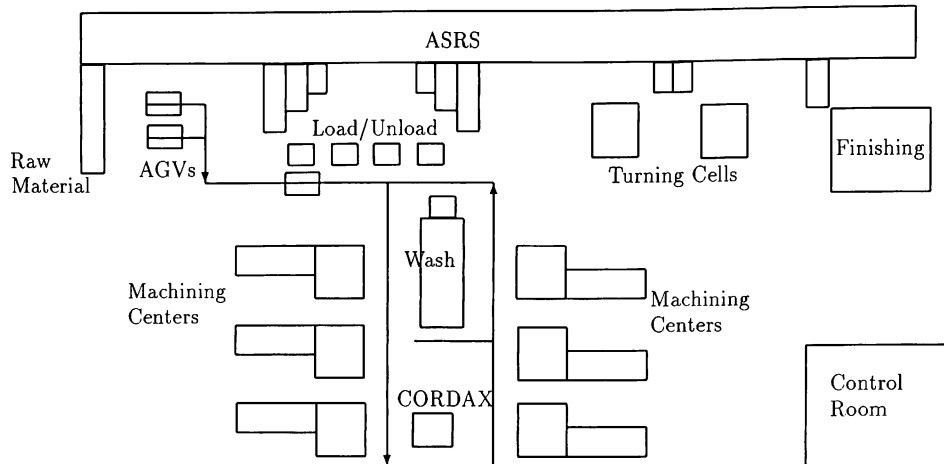


Figure 2. Sauer/Sundstrand Flexible Manufacturing System

The control system determines which machining center should process the part type based on tool library, priority, and current status. An AGV picks up the fixture and delivers it to the selected center. After processing, the AGV picks up the fixture and takes it to machine wash. After washing it is taken by the AGV to the Cordax station or the load/unload station. Upon arrival at the load/unload station the parts are removed from the fixture either moved to another fixture location, transferred to another fixture, or stored in the ASRS where it will wait for the finishing cell. Parts requiring turning operations are loaded manually.

3. CONTROL SYSTEM INTERFACE

The control system is centralized, using an HP 1000 computer connected via a data highway to programmable logic controllers, AGV controller, computer terminals, and machining centers. The system status is maintained in an IMAGE 1000 database. The database contains both static and dynamic data. By static we mean data that is relatively constant such as operation sequences for parts. The dynamic data is updated and accessed by a variety of control programs.

In order to begin the simulation at the current time, we require a snapshot of the system using the IMAGE 1000 database. The snapshot data is used to initialize the model to its starting conditions. The database also contains the work orders (from the MRP system) yet to be released. The interface module consists of two FORTRAN programs which extract information from the database and creates eight data files as shown in Table 1 for initializing the simulation model. These files provide all the information necessary to describe the system at an instant in time. Files are generated on the HP 1000 and then downloaded to a microcomputer where the simulation takes place.

File	Information
ADPS	Status of adapter plates used in fixtures
ASRS	Status of ASRS bins
FCFG	Fixture Configurations
FIXS	Status of built-up fixtures
FIXBS	Status of fixture bases
SCHED	Work orders (from MRP) yet to be released
SEQ	Operation Sequences for Part Types
WIP	Current location of released work orders

Table 1. Snapshot Files from the IMAGE 1000 Database

4. SIMULATION MODEL

A simulation model of the FMS was constructed using SIMAN [Pegden 1986] and a set of FORTRAN modules. These modules contain a set of data structures for the FMS and the associated logic for extracting and retrieving data. The model was designed to run within the 640K memory on an MSDOS microcomputer.

4.1 Initialization

Files generated by the IMAGE 1000 database interface are used to initialize the model. To reduce the memory requirements, only the process sequences for those part types involved in the current snapshot are loaded into the data structures. Each part's process sequence contains the following information:

- Fixture requirements for AGV transportation
- Part quantity per fixture face
- Tool library requirements for machining
- Machining time per part
- ASRS storage requirements

The ASRS locations are initialized based on the status of the fixtures, fixture bases, adapter plates, finished goods and raw stock stored in the ASRS at the time of the system snapshot. Two schedules are used to drive the simulation model. The first schedule comes from the MRP system and defines all the work orders yet to be released into the system. The second schedule contains the sequence in which work orders are to be processed through the Vertical Turning Lathes (VTLs). The schedules are stored in the data structures at the start of the simulation model. The model also uses the following static data files for initialization:

- AGV.DAT : AGV travel times
- PARTS.DAT : Part processing program downloading times
- VTLSET.DAT : Turning lathe setup times based on parts
- VTL.DAT : Turning lathe processing times

Along with these data files, a system configuration file is provided so that the analyst can customize the simulation model, incorporating system parameters not specified within the system snapshot of the IMAGE 1000 database. Specifically, the user can specify the following items at the start of the simulation:

- Shift duration
- Machining center daily status (up/down)
- Tool library assignments
- Operator task priority and shift schedule
- Random system failures (on/off)
- Cordax routing control (fixtures/machine)
- Raw material lead time
- Maximum active fixture quantity on floor
- Output reports format specification
- Process variability control
- Simulation run length

At the start of each simulation, the model is initialized by reading these files along with the files generated by the control system interface. Entities representing the work in process orders are inserted into the appropriate queues and resources (such as the machining centers, AGVs, ASRS, etc.) are set to their initial status (idle, busy, nonoperational).

4.2 Execution of the Model

During the execution of the simulation model, the number of concurrent active work orders is dynamically controlled. The quantity of active work orders is proportional to the number of machining centers in operation. When a work order is completed, a new work order will be released onto the shop floor if the fixture is available or if it can be built from materials stored in the ASRS and the number of fixtures on the floor is below the maximum quantity permitted.

4.3 Simulation Results

The simulation model tracks the performance and completion of each order from release to shipping. Information on each work order is reported in customized output reports. Numerous reports are generated which include the actual simulation time and date, work order numbers and part types associated with the report being generated. The following reports can be generated during any simulation run based the simulated time of occurrence:

- Work order release schedule
- Fixture build/teardown schedule
- Raw material due date requirements
- Vertical turning cell schedule
- Work order completion schedule
- System status report
- System/equipment performance measures

The analyst can select which reports are generated along with one of two formats by using the system configuration file. Table 2 displays a sample of the work order completion schedule.

Upon the completion of the simulation runs, the analyst evaluates the performance of the MRP and VTL schedules along with the work order completion dates. The analyst will rerun the simulation model using the same snapshot information but with different schedules in order to improve upon the system performance and output.

5. COMPARISON WITH ACTUAL DATA

Comparison of simulation results with actual data was accomplished by following the progress of work orders through the system using the IMAGE 1000 database. The simulation model was replicated ten times using the same set of data files to determine a 95% confidence interval for the time that the work order was completed. These results are illustrated in Figure 3 along with the actual data. As one might expect, the width of the confidence interval increases as the time window moves farther into the future. This is most likely due to the accumulation of variability. Note that for 17 of the 39 work orders (43.6%) the actual time occurs within the confidence interval and appears to be evenly spread throughout the time period. We attribute the occurrences of work orders outside the confidence interval mainly to the uncertainty at the finishing cell (the last operation). This operation is completely manual and is scheduled by the operator on the floor, resulting in high variability.

6. CONCLUDING REMARKS

A simulation model and real-time interface module for an operational FMS facility were developed to evaluate work order release sequences on a real-time basis. Unlike most simulation studies, the evaluation is based on the transient behavior of the system and not steady state performance. We look at the time window in which a work order is predicted to be completed in order to determine if a particular work order sequence meets due date requirements set forth by the MRP system. In addition, results of the simulation can be used to schedule the building of fixtures and the loading of raw material.

DATE	TIME	WORK ORDER	PART TYPE	DUE DATE
3/25/1990	12:44	05007082	8200162	3/30/90
3/25/1990	17:27	05007074	8000215	4/ 4/90
3/26/1990	4:44	05007068	4460117	4/ 3/90
3/26/1990	11:11	05007141	8100333	3/26/90
3/26/1990	15:51	05007000	8200162	3/20/90
3/27/1990	1:57	05007031	3103367	3/14/90
3/27/1990	4:20	05007227	9900111	3/30/90
3/27/1990	8:36	05007077	8200117	3/20/90

Table 2. Sample Work Order Completion Schedule

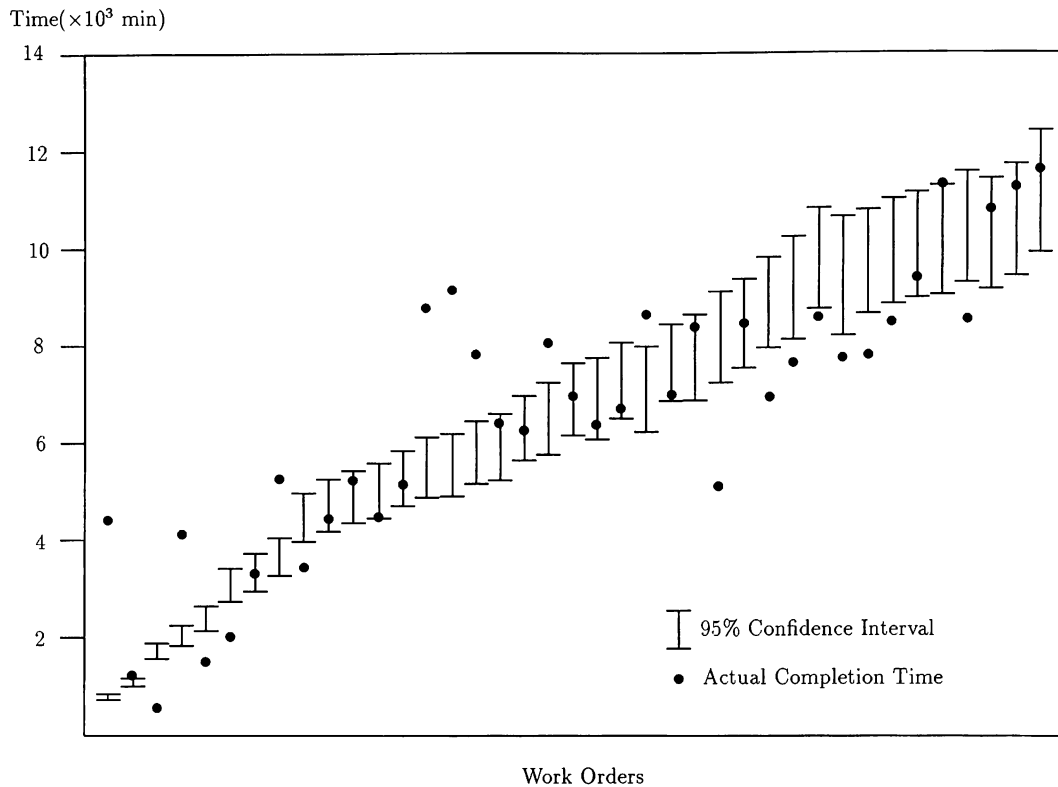


Figure 3. Work Order Completion Time

The model was successfully interfaced with the real-time control database so that initial conditions could be determined. This information is essential when looking at transient behavior as opposed to steady state performance. Simulation results provide analysts with information to make improvements in the short term schedule, resulting in better work order release decisions.

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