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SIMULATION AND ADVANCED MANUFACTURING SYSTEM DESIGN

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ABSTRACT

A case study is presented which demonstrates the design and implementation of an integrated manufacturing system using AutoMod, an integrated simulation tool developed by AutoSimulations, Inc.

1. INTRODUCTION

Computer simulation has been used for many years in manufacturing. One of the most common uses of simulation is to evaluate new manufacturing systems. This paper presents a simulation methodology for manufacturing systems by means of a case history. The case history is a simulation study used to evaluate the computer integrated manufacturing modernization plans of large manufacturer.

1.1. Problems with Simulation

While simulation has been available for many years and has proven highly valuable in the design of automated manufacturing systems, it is used only some of the time. There are three major reasons why simulation is not used more often.

1.1.1. Timeliness of Simulation Results. Traditionally, where simulation is used as part of the design process, the time to develop and verify the models has been so long that design teams were delayed waiting for simulation results. Simulation model development has been a programming problem. First the design team had to explain to the modeler how the system worked and what the purpose of the simulation was. Then the modeler disappeared for weeks or months to write the model. Ideally the modeler should be part of the design team and model development should take only a few days or weeks.

1.1.2. Cost of Model Development. There are two major costs associated with modeling: people and computers. Long development times increase the personnel costs for modeling. Use of general purpose programming languages for modeling or inefficient simulation languages can make the computer costs of modeling prohibitive.

1.1.3. Accuracy of Simulation Results. Frequently, inexperienced modelers working with poor tools produce invalid models. Model errors are generally associated with the translation process from the system description used by the design engineers to the computer based model. Errors can be reduced by making the constructs of the modeling language analogous to the components in the system to be modeled.

2. DESCRIPTION OF THE SYSTEM

The system to be studied was designed by a major manufacturer. The system automatically stores in an AS/RS baskets of components that are later delivered by conveyor and AGVS to robot cells where the pieces are trimmed.

2.1. Process Flow

The system flow is described by defining each material handling device. The characteristics of the individual material handling devices are also described in this section. The operations of the component final storage and delivery system which have been included in the model produced by ASI include:

(1) Automated Storage/Retrieval System (AS/RS)
(2) Conveyor System
(3) Rolltop Automated Guided Vehicle System (AGVS)
(4) Robot Work Cells
(5) Manual Work Cells
(6) Fork Automated Guided Vehicle System (AGVS)
(7) AGVS Battery Charging
(8) Empty Basket Tracking

2.2. Automated Storage/Retrieval System

The AS/RS is physically described as follows:

Number of aisles 3
Number of bays 20
  Bay to bay distance 3.00 ft
  Bay depth 4.00 ft
Number of tiers 11
  Tier height 2.00 ft
Number of SR machines 3 (one per aisle)
  horizontal velocity 500.0 fpm
  horizontal acceleration 1.5 fpss
  vertical velocity 120.0 fpm
  vertical acceleration 1.5 fpss
  shuttle time 15 sec

The SR machines in the system have a capacity of one load per trip. In the event a load is ordered out of the AS/RS and the pickup delivery stand is occupied the load will not be picked up until the traffic count is decreased. This allows the SR machines to continue to put away arriving loads. The input/output conveyors of the AS/RS each have a capacity of four. Although the conveyor can hold four baskets, the base model restricts the number on the input/output spurs to three.

2.3. Conveyor System The conveyor system is an accumulation conveyor with a velocity of 1 ft/sec. The conveyor is used to transport baskets from the wash lines to the AS/RS, from the AS/RS to the AGV system, from the AS/RS to the wash lines, and returns baskets from the AGVS to the wash lines and AS/RS. The baskets being transferred from the wash lines to the AS/RS are new components entering the system. The baskets being transferred from the AS/RS to the AGVS are full and partial baskets. The baskets being transferred from the AS/RS to the wash lines are empty baskets. The baskets being transferred from the AGVS to the wash lines are empty baskets. The baskets being transferred from the AGVS to the AS/RS are partial baskets.

2.4. Rolltop Automated Guided Vehicles System

The rolltop AGV system supplies the robot and manual work cells with baskets of components. The AGVS also returns empty and partial baskets to the conveyor system. This layout requires that the rolltop vehicles and the forked vehicles share guidepath in some locations. Vehicle operation parameters:

Velocity = 220.00 fpm
Acceleration = 0.50 fpss
Deceleration = 0.50 fpss
Pickup time = 10.00 sec
Setdown time = 10.00 sec

2.5. Robot Work Cells

There are 24 robot work cells. The 24 cells are divided into two work groups of twelve cells each. The division of the cells is required because not all of the components can be worked by some of the robots. When a new set of components arrives at a cell the first basket is dumped into a holding bin and the basket is held to take away any components left from the previous part. When the previous part is finished the cell takes an average of 2 minutes to make a part change over. The new components are then worked if there is a pallet available. When the quantity required for shipment has been reached the part is shipped by box if the shipping quantity is less than 100 or it is shipped by pallet if the shipping quantity is greater than 99. Shipments of boxes are not modeled: once the shipping order is created the shipment leaves the system. Shipments by pallet are picked up by the forked AGVs and in this manner also leave control of the robot cells.

Robot operation parameters:

Component dump time
- full cycle = 60 sec
  (leave vehicle, dump, and back to vehicle)
- half cycle = 30 sec
  (leave vehicle, and dump components)

Component trim time = given in data
part change time = 2 min average

2.6. Manual Work Cells

There are 10 manual work cells. The manual cells follow the same schedule as the robot cells with the exception that all components once trimmed leave the system. The forked vehicles do not access the manual cells.

Manual operation parameters:

Component dump time
- full cycle = 60 sec
  (leave vehicle, dump, and back to vehicle)
- half cycle = 30 sec
  (leave vehicle, and dump components)

Component trim time = given in data
part change time = 2 min average

2.7. Forked Automated Guided Vehicles

The forked vehicles supply the robot workstations with empty pallets and take full pallets to the scales. When a pallet is ready for shipment the AGV is called to retrieve the pallet. When the pallet is picked up another call is made for an empty pallet to be sent to the cell. While the cell is waiting for a pallet the robot is unable to trim any components.

Vehicle operation parameters:

Velocity = 160.00 fpm
Acceleration = 0.50 fpss
Deceleration = 0.50 fpss
Pickup time = 15.00 sec
Setdown time = 15.00 sec

2.8. AGVS Battery Changing

The vehicle batteries are changed once every eight hours. This is accomplished by having a vehicle randomly pulled out of the system approximately once an hour. The vehicle is held for 30 minutes while the batteries are changed.

2.9. Empty Basket Tracking

New components that enter the system are placed in empty baskets on the wash line input conveyor. These baskets come from the work cells as well as the AS/RS. Empty baskets that are returning from the AGV system will be sent to the wash line input convey. When the basket arrives, if the conveyor section is full the empty basket will then be sent into the AS/RS for storage. When the number of baskets returning from the work cells is insufficient to keep more than four empty baskets on the wash line input conveyor, empties are ordered from the AS/RS.

3. OBJECTIVES OF THE STUDY

The major objective of every simulation study of a new system is "Will it work?" The definition of the criteria of a system "working" is very important. Model construction will be guided by the statistics that are to be collected. The design team wanted information on the following.

"How Many AGVs Would Be Required?"
"What Scheduling Rules Would Optimize the System?"
"How Big Should the Process Storage Area Be?"

4. DESCRIPTION OF MODEL DEVELOPMENT

Model development was accomplished using a family of software tools designed for modeling manufacturing systems. Figure 1 shows the integrated modeling environment.

4.1. InterFaSE - Material Flow and Processes

InterFaSE uses a data base of process plans for parts, orders, machines, operators and tools to simulate production schedules. The resulting production schedules what every machine and operator should work on during the scheduled period. InterFaSE produces a time stamped load movement file that can be used to control the movements in a material handling simulation model of a facility.

4.2. AutoMod - Material Handling Equipment Definition

AutoMod is an English-like simulation language; the terms and expressions in AutoMod are the same as the terminology used by manufacturing engineers to describe physical systems. Minimum programming skills are required for the use of AutoMod. Embedded in AutoMod's subroutine library are routines to model common components of the manufac-

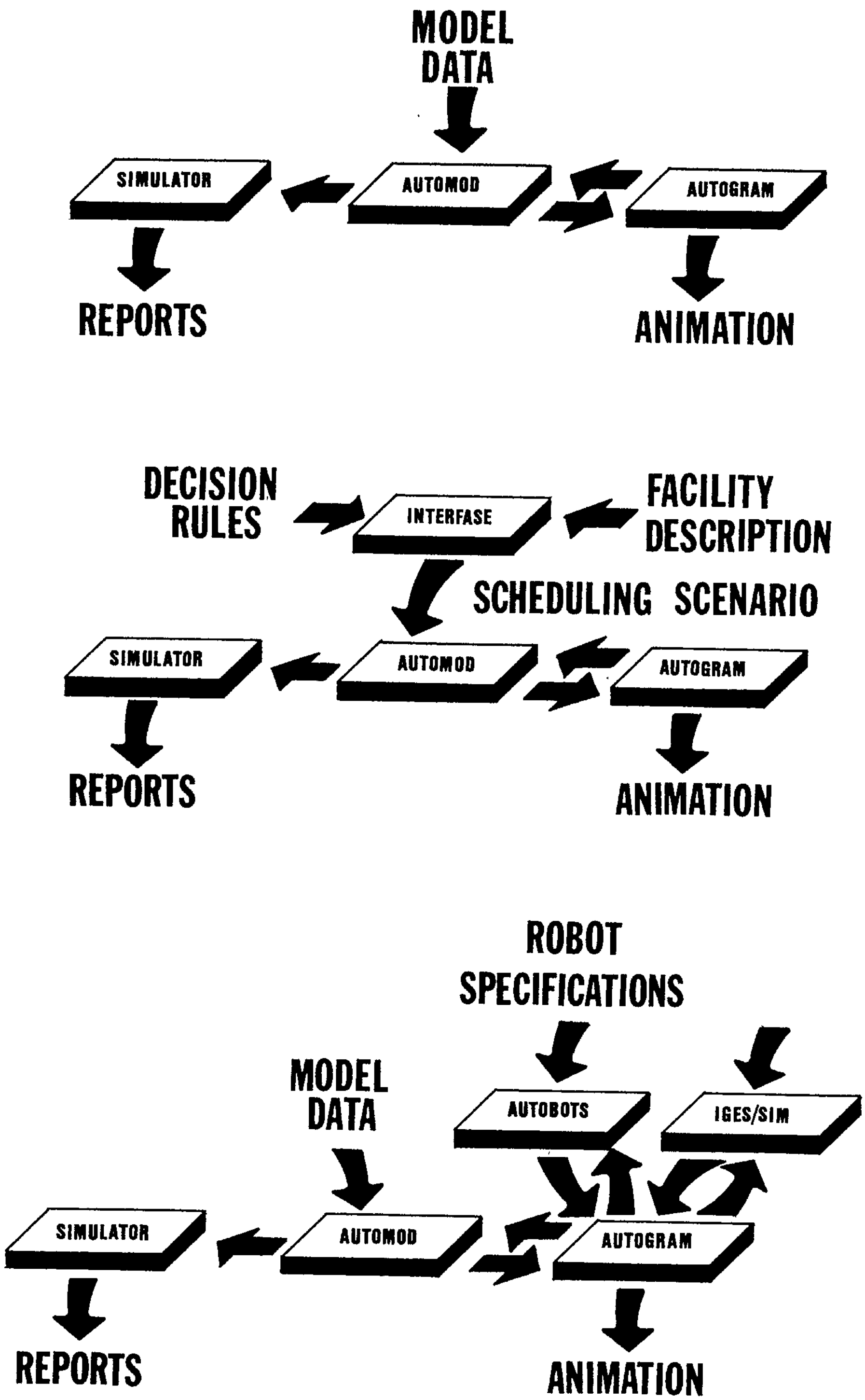

Figure 1 Integrated Simulaton Environment

turing environment. AutoMod model descriptions are translated into GPSS/H models. GPSS/H is used as the modeling language because of its ease of use and its extremely fast execution times.

4.3. AutoGram - Geometry Definition

AutoGram is a companion system to AutoMod. AutoGram allows the modeler to graphically describe the system to be modeled. This definition of the geometry of a manufacturing system is translated into the appropriate simulation statements. After the model has been run, AutoGram can be used to create an animated three dimensional display of the simulation results.

4.4. Level of Detail in the Model

Accurate manufacturing models must be detailed. Models must include details of all physical entities in the system and details of the control and operating rules for the facility and subsystems. As an illustration the following presents the required detail to accurately model automatic guided vehicles.

4.4.1. Modeling AGVS. In modeling automatic guided vehicles three components of the system affect system performance: vehicles, guidepath and controls.

Vehicles - Vehicle performance is affected by the following:

- Number of Loads Carried per Vehicle
- Speeds
- Acceleration
- Deceleration
- Load Pickup Time
- Load Deposit Time
- Fine Positioning Time
- Control System Communication Delays

Vehicle Guidepath - The guidepath the vehicles follow affects performance. The following characteristics must be considered:

- Physical Layout
- Control Point Placement
- Mechanical Interferences
- Control Point Usage
  - When Claimed
  - When Released
  - Enroute Counters

System Controls - Empty vehicles are considered to be the critical system resource. The control of vehicles affects performance in the following ways:

- Empty Vehicle Scheduling
  - Load Assignment
  - Parking
- Vehicle Deadlocks

5. VALIDATION

The validation of AutoMod models is simplified because the underlying model for each material handling system component is based upon a proven module that represents the component. Three techniques were used to validate other model features.

5.1. Move One of Each Part

The model was executed once for one instance of each part number to test the process flows and processing times. In AutoMod each entity that moves is called a load. All loads move from process to process either directly or via a movement system. Because every load has a load type individual parts may be tracked through the system. The standard AutoMod reports list the count of load types entering and leaving every process with the load's corresponding previous processes and destination processes listed.

5.2. Trace a Vehicle Route

To insure that vehicle guidepaths have been defined correctly two techniques are valuable. The first runs the model with only one vehicle in the system. AutoMod collects statistics on the transit time between control points. By running the model with only one vehicle the time between each control point will be tabulated and the speed of the vehicles and the distance between control points can be validated. Secondly, in the analysis of model runs, courses of vehicle runs should be summarized. A course would be from a pickup point to a deposit point. Discrepancies between observed transit times and estimates based upon system drawings must be resolved.

5.3. Graphics

Three dimensional animated graphics offers a powerful capability for model validation. The ability to see the movement of loads through a manufacturing systems "proves" that the model is performing as expected.

6. ANALYSIS OF RESULTS

No statistical computations were made to compute confidence intervals for model statistics. Two techniques were used to gain an "eyeball" verification of the stability of the model statistics. Both techniques were used to identify the appropriate length of simulated time to model for all experiments.

6.1. Extended Run Times With Snap Shots

Runs were made for extended periods of simulated time with multiple snap shots of model statistics. It was observed that the statistics from each snap shot were reasonably similar.

6.2. Multiple Runs with Different Random Numbers

Multiple runs of identical models were made changing only the seeds for the different pseudo random number generators. It was observed that the statistics from each snap shot were reasonably similar.

7. EXPERIMENTS

This section will describe the experiments made to the base model.

7.1. MODEL EXPERIMENTS

The following experiments were run on the base model:

EXPERIMENT OPTIONS TABLE

	Model Name																	
	GYL2	GYL3	GYL4	GYL5	GYL6	GYL7	GYL8	GYL9	GYL10	GYL11	GYL12	GYL13	GYL14	GYL15	GYL16	GYL17a	GYL17b	GYL17c
# FORKED AGV	3	3	3	3	3	3	-	3	3	2	3	4	3	3	3	3	2	3
# ROLLTOP AGV	7	7	6	5	5	4	-	5	5	5	5	5	5	5	5	5	5	5
IN CONVEYOR CAP.	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	2	2
OUT CONVEYOR CAP.	4	4	4	4	4	4	4	3	2	3	3	3	3	3	3	2	2	2
MIN. PARTIAL SIZE	6	6	6	6	11	6	6	6	6	6	6	6	6	6	6	6	6	6
MIN. BASKETS/SET	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1
MANUAL BAT. CHANGE	No	No	No	No	No	No	-	No	No	No	No	No	Yes	No	No	Yes	Yes	Yes
RELEASE SET AT	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	AVG_P	CELLS	AVG_P	AVG_P	AVG_P	AVG_P
FULL ALWAYS FIRST	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes

8. CONCLUSION

This paper has described a case study of a manufacturing simulation. In analyzing a simulation study, we have described a simulation environment that allows simulation to be efficiently applied to manufacturing problems.

AUTHOR'S BIOGRAPHIES

VAN B. NORMAN, vice president of AutoSimulations, Inc., received a B.S. in Mathematics at the University of Utah in 1969. He was a senior systems analyst for Eaton-Kenway Co. and the Utah Board of Education, for which he developed a state-wide computer network. At AutoSimulations, he supervises all simulation modeling and graphics development.

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THEODORE A. NORMAN, vice president of AutoSimulations, Inc., was chairman of the Computer Sciences Department at Brigham Young University. He received a B.S. in Mathematics from the University of Utah (1962), an M.S. in Information Science from Washington State University (1968), and a Ph.D. in Information Science at Washington State Univeristy (1970). He was a Systems Engineer for IBM and a consultant in simulation and controls design. He is currently involved in the development of new scheduling tools for manufacturing applications.

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