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AIRLINE-CATERING PLANT MATERIAL HANDLING SYSTEM ANALYSIS WITH SIMULATION AND SCALED ANIMATION

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ABSTRACT

This paper discusses the applications of simulation and scaled animation at Sky Chefs Inc, particularly highlights the analysis of complex Power and Free (P&F) Material Handling Systems (MHS). It also includes the result of analysis performed in design and validation of the system.

1 INTRODUCTION

The large investment of a Modern Material Handling System (MMHS) demands that the system designers "get it right the first time". The increased complexity of today's system, however, makes the evaluation and prediction of the performance of the designed systems very difficult.

Although simulation is associated with systems analysis [3][6], it is still not a simple task to prodivide feedback of the analysis findings in a timely and effective way to the design engineers, operations, and the other key management personnel. This is due to the difficulties of communicating the abstract concept of modeling and statistical analysis of the data obtained from the simulations.

All of these require more powerful techniques in simulation studies. In Sky Chefs Inc, this necessity becomes urgent. Several Sky Chefs facilities have decided to install Power & Free conveyor system as the major material handling system in their plants in order to improve production efficiency.

Since the investment of P&F systems are substantial, and the layout of these systems could become quite complex, there is an immediate need to evaluate and validate the functionality of the layouts and production flow strategies. On the other hand, there are many factors which influence the system's performance and frequently change during the design stage. Every new parameter change may trigger an entirely new set of conditions to the entire system. Before finalizing the system, therefore, it is necessary to predict the system's performance under the various real world "scenarios" and respond to the " WHAT-IFs".

It has been known that not all conventional methods of solving system planning problems with the "rules of thumb" approaches can satisfy the requirements of today's MMHS. This type of approaches often provide an inefficient allocation of resources and reduce the overall system's performance.

The approach presented in this paper is one of the efforts combined with using simulation and scaled animation techniques to solve MMHS planning and analysis.

A detailed simulation model is developed with GPSS/H language for the Power and Free conveyor system for Sky Chefs Miami (MIA) facility. Graphic animation is interfaced to the simulation model with a general animation software "PROOF". With scaled system animation, virtually experimental data will drive the factory operation via computer simulation. This makes it possible to see and study how everything impacts the entire system. Therefore, systems optimization becomes easier.

2 SYSTEM PROCESS DESCRIPTION

The primary objective of the in-flight catering facility is to cater aircrafts with an appropriate level of service. Catering involves the preparation of meals, beverages, kits and delivery of the airline equipment/carts to the planes. Just-In-Time delivery is an important criteria in order to avoid any flight departure delays.

Figure 1 shows a simplified flow chart of the process in an airline-catering facility.

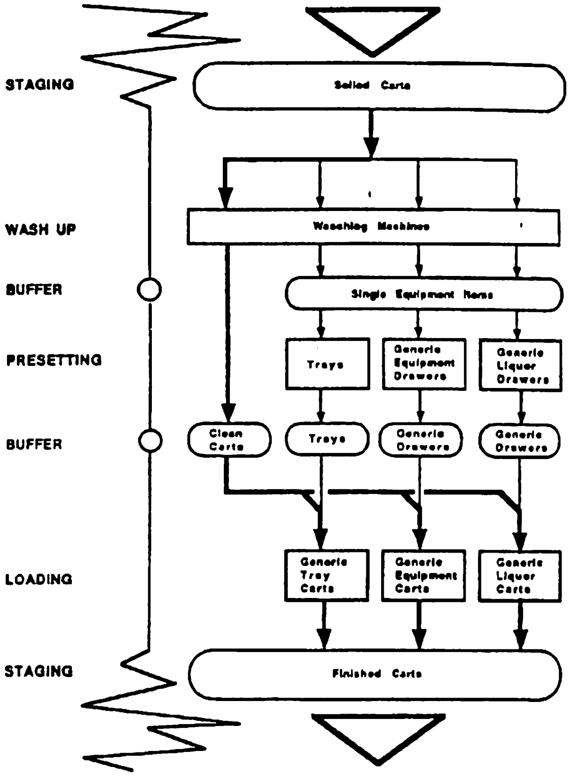


Figure 1: Process in Airline-Catering Plant

Carts are transported to and from the airline catering facility by the special high lift-trucks. In MIA's new facility,the received cart to the inbound dock will be put onto the P&F system to be sent to the subsequent processing workstations. Partial layout of the MIA P&F system is shown in Figure 2.

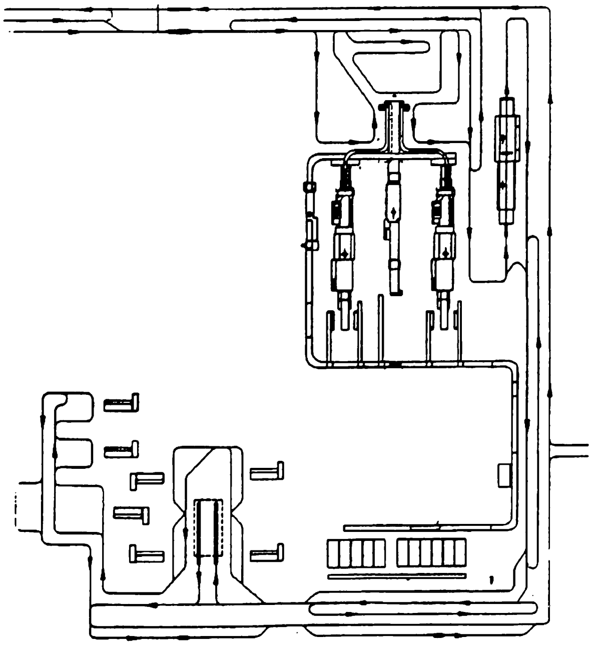


Figure 2: Partial System Layout

It consists of the P&F conveyors that transport carts to the processing areas in the system. Each platform, or delivery device on the system, carries two carts and has an associate routing depending on the cart product attributes. The routing identifies the processing stations for the platform. After the last processing station, the carts are discharged from the platform and the platform is routed back to the charging point for re-utilization.

Table 1 depicts a list of the factors which may effect the system's functionality. The numerous potential combination and interactions among these variables make it extremely difficult, if not impossible to predict and evaluate the performance of MHS's design statically. Therefore, dynamic analysis provided by computer simulation can give a reliable indication of how a complex system will work under a wide variety of operating conditions.

Table 1: Design Factors of System

Factors	Details
Flight Schedule	Inbound cart quantity & distribution Outbound cart quantity & distribution Level of service Flight equipment type/mix
Work Station	Number of workstation Workstation processing rate Workstation layout pattern Routings within the workstation
Conveyor System	Conveyor speeds Pusher-dog distances Buffer sizes Control logics

3 SIMULATION MODEL DESCRIPTION

The GPSS/H simulation model for MIA P&F system is built using facilities, storages, functions, queues, and logic switches. The "Transactions" are used to simulate the platforms (entities) moving throughout the system. Each transaction is tagged, for the processing time at a certain workstation according to the cart (entity) attribute. Each workstation is modeled as a "Facility". All the buffers between the workstations are modeled with queues. Carts stay in the buffers (queues) until they are captured by the workstations (facility). Each buffer represents a physical section of the conveyor.

As mentioned before, MIA P&F system is a complex system, including 11 drive chains, 25 logical decision points, 54 switches, and interfacing with 20 workstations.

Therefore, the logic of the simulation model consists of more than 2000 GPSS/H blocks. It is not necessary to describe every detail of this model here, however, several issues will be discussed in the following sections.

3.1 Inbound/Outbound Schedule

To simulate the operation of the airline-catering factory, the inbound/ outbound schedules (input/output) are the key factors. They have several unique characteristics as shown below :

- ✓ During the airport off-hours, there will be no inbound and outbound activities.
- ✓ During the airports operation, the inbound/outbound schedules fluctuate significantly during each complex.
- ✓ The inbound/outbound schedule can be changed at any time by the airline customer without prior notification.

Figure 3 displays an inbound/outbound schedule graphically.

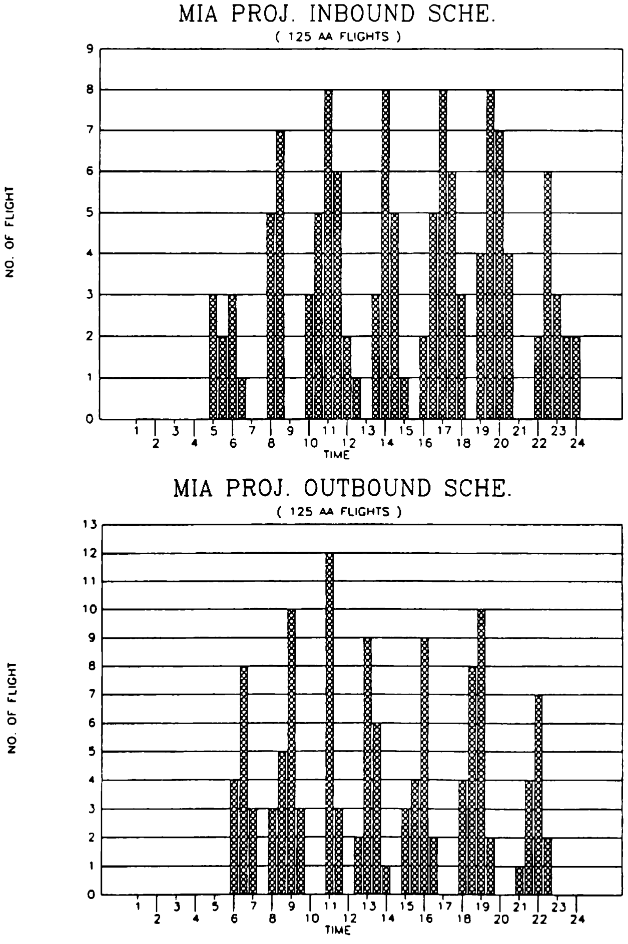


Figure 3: Inbound/Outbound Schedule

The GPSS/H's built-in exponential distribution function RVEXPO is utilized to model the interarrival times during the each time complex. Considering that the expected values of the interarrival times in each time period are significantly different, the C,D operands of "GENERATE" block in GPSS/H language are utilized to control the time periods and the number of cart/entities arriving to the inbound area during each time complex. Figure 4 illustrates the concept we have utilized here. The ampervariables &TIME(I), &CNUM(I) in Figure 4 are obtained from the ASCII schedule file. This file can be easily modified to reflect the schedule changes.

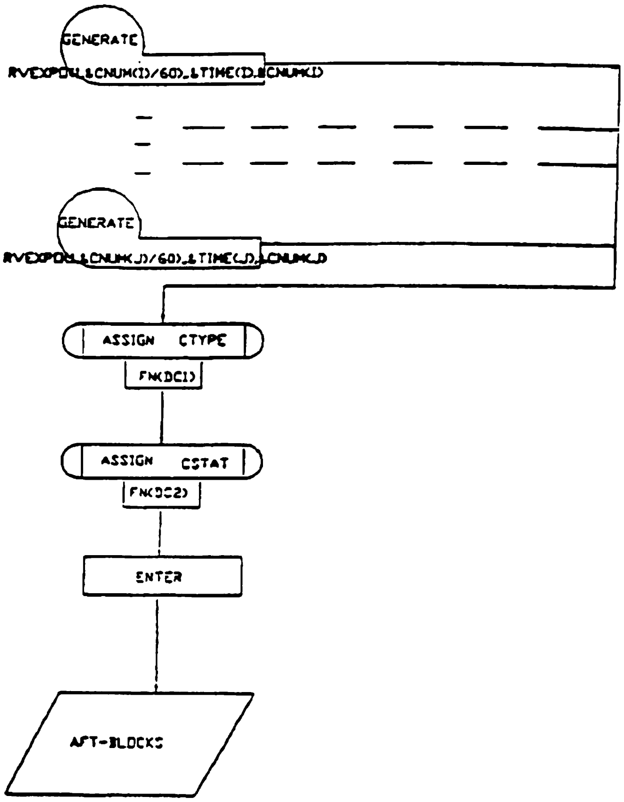


Figure 4: Schedule Simulation Flow Chart

In ASSIGN blocks, the mix of the input products will be defined. The attribute CTYPE is used to represent the cart type. The attribute CSTAT is used to represent the status of the cart. The types and status of the carts are distinguished as Table 2.

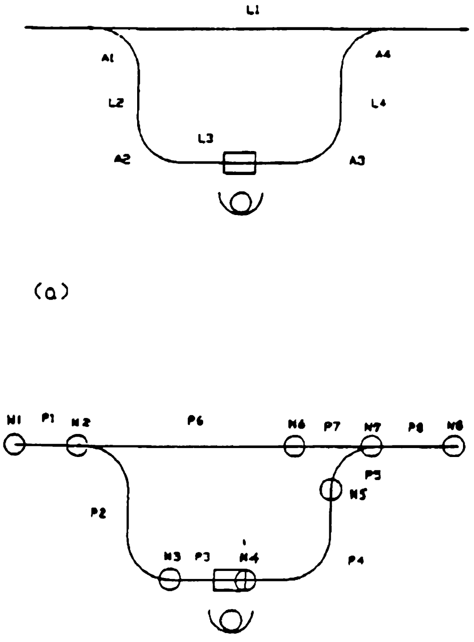
Table 2: Carts Attributes

CTYPE	1	International	Y/C	Cart
	2	International	F/C	Cart
	3	Domestic	F/C	Cart
	4	Domestic	Y/C	Cart
	5	International	L/B	Cart
	6	International	D/R	Rack
	7	Domestic	L/B	Cart
	8	Domestic	D/R	Rack
	9	Domestic	S/A	Cart
	10	International	S/A	Cart
	11	Bounded	L/B	Cart
CSTAT	1	Soiled	Cart	
	2	Cleaned	Cart	
	3	Washed	Cart	
	4	Loaded	Cart	
	5	Bounded	Cart	
	6	Unload	Cart	

3.2 Logic in Typical Section and Identical Job Workstation.

In spite of the complexity of the P&F systems, it is always possible to break down the entire system into several simpler sections.

A typical section layout of P&F system is shown in Figure 5.



(a)

(b)

Figure 5: Typical Section Layout

In this section, the transactions are separated at node N2 based on the parameters of the transactions. Path P2 expresses the buffer before processing. After being processed in workstation (N4), the product is going to merge to the main highway of the P&F system. However, at the intersection (N7), only one platform can pass through. Therefore, if two platforms approach the intersection at the same time, one of them must be stopped at N5 or N6, until intersection N7 becomes clear. This type of traffic control section will be frequently used in P&F system. Figure 6 shows the block diagram in GPSS/H for modeling this typical logic.

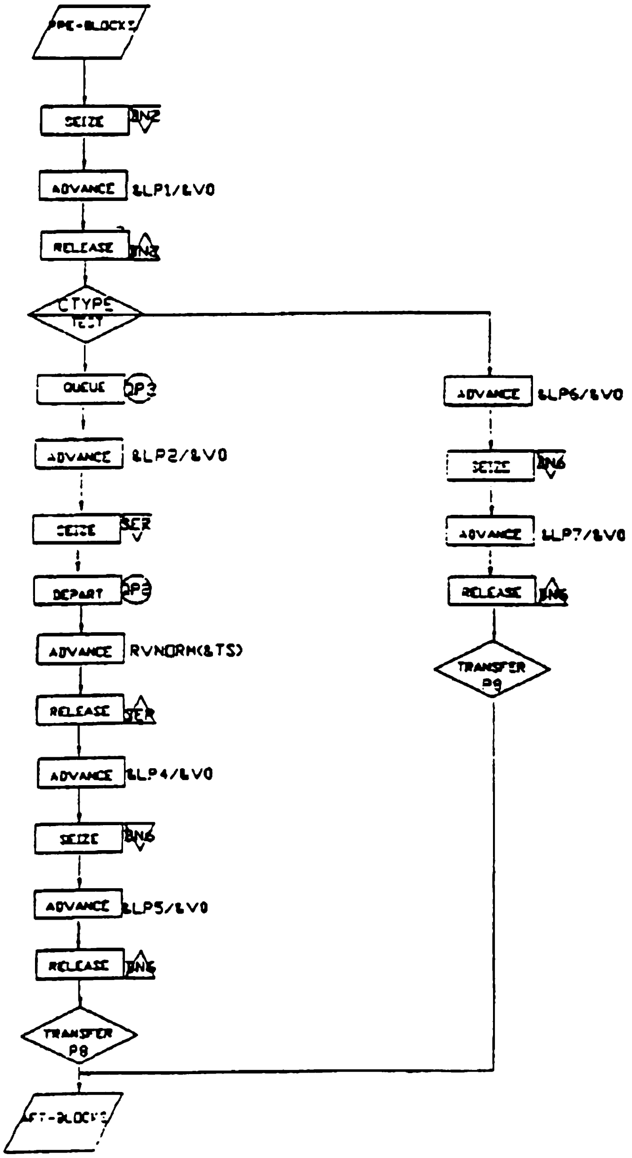


Figure 6: Flow Chart of Typical Section Modeling

The simulation results will show the bottlenecks of the system. In order to resolve the bottleneck situations, as a possible solutions we can increase number of the servers in the workstation. Figure 7 shows a situation with three possible layout arrangements for an identical work scene using two servers. In MIA P&F system, we use case(b) and (c) due to the locations of assembly lines.

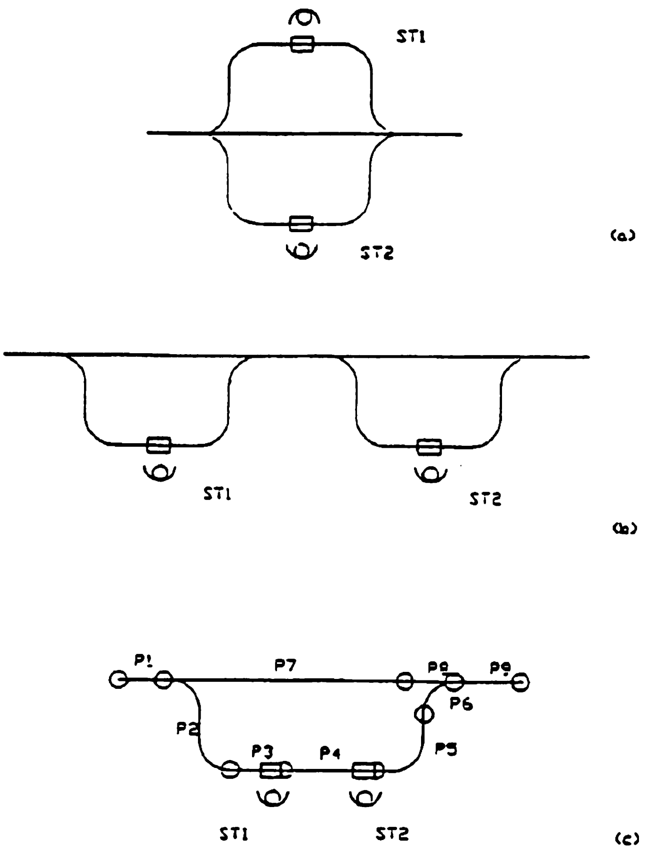


Figure 7: Workstation Layout for Two Servers.

The advantage of the case(b) layout is that there is no interference between the two servers. However, we also use case (c) due to the space limitation in some environments. There are certain relationships between the two servers in the workstation using case (c) layout:

- ✓ When ST2 finishes the process and releases the platform, it is not possible for this server to receive another platform for processing since the platform in ST1 blocks the path.
- ✓ ST1 can not release the platform until ST2 finishes the processing also.

The block diagram of GPSS/H that is modeling this logic is shown in Figure 8.

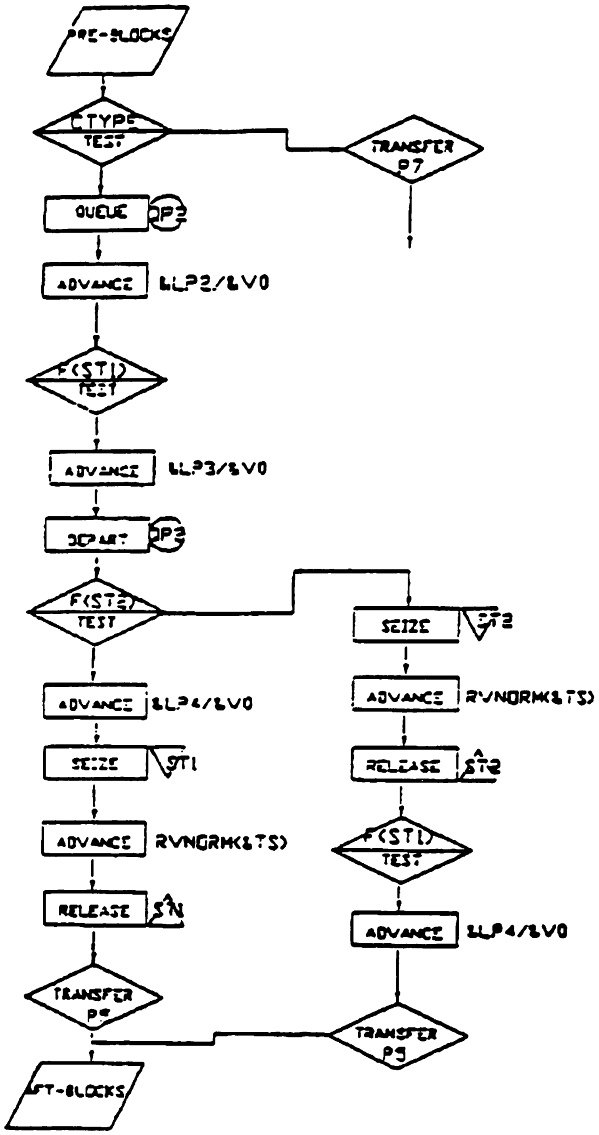


Figure 8: Two Servers Workstation Modeling

3.3 Custom Input/Output File

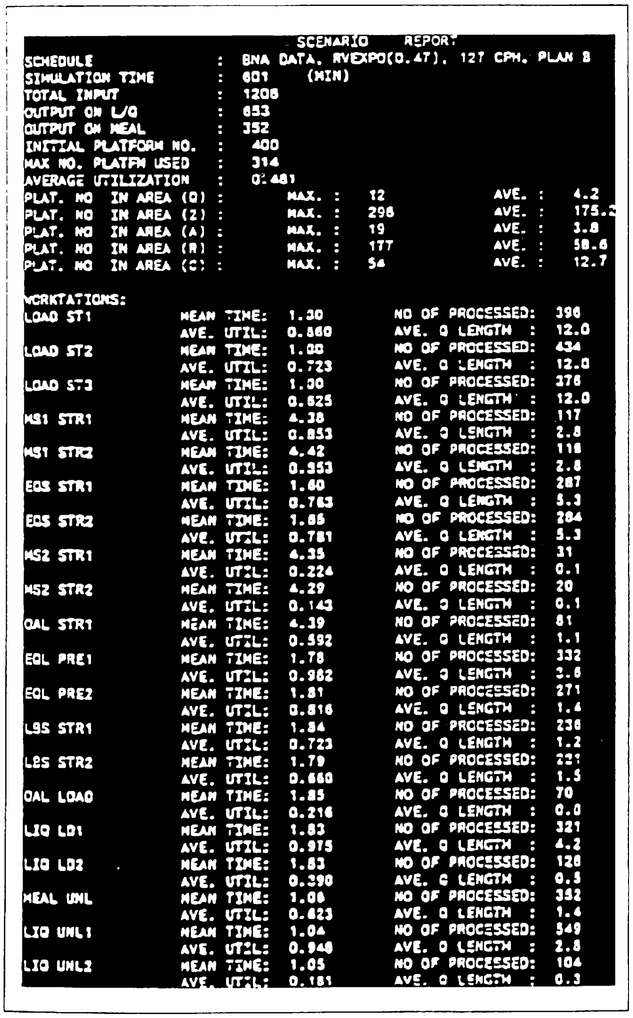
One important issue in development of the MIA simulation model is the user interface. It is more convenient to directly input data from external files in stead of editing the GPSS/H source codes. Similarly, it is desirable to directly output customized reports instead of searching for the required information from the GPSS/H list summary report.

In most simulation languages, outside program languages (eg. FORTRAN, C) are required to read in external file or generate customized output file [2] [8]. In GPSS/H, the new features of (B)GETLIST and (B)PUTPIC can be used for reading from and writing to devices such as terminals as well as files [4] [9]. In MIA simulation model, most of the variables (eg. path names and lengths, drive speeds, schedule data, process rates, etc.) are input from the external files. An example follows:

```
CLT3     FILEDEF 'CLT3.PRN'
         GETLIST
         FILE=CLT3,(&LA(&I),&I=1,30)
```

Where, file "CLT3.PRN" is an ASCII file output from LOTUS (.PRN). The user can easily modify the data in the spreadsheet environment. The data in this file is read in to an array &LA(30) to be used later in the simulation program.

An example of a customized report generated in this simulation program is shown in Figure 9. As people want to employ simulation on a day-to-day management tool, simulation programs face the need to be used by non-simulationists. The approach in MIA model implemented a data-driven model with custom-tailored output, which is very helpful.



```
                                SCENARIO    REPORT
SCHEDULE              :  BNA DATA, RVEXPO(0.47), 127 CPH, PLAN 8
SIMULATION TIME       :  601     (MIN)
TOTAL INPUT           :  1208
OUTPUT ON L/Q         :  653
OUTPUT ON MEAL        :  352
INITIAL PLATFORM NO.  :   400
MAX NO. PLATFM USED   :   314
AVERAGE UTILIZATION   :   0.481
PLAT. NO  IN AREA (Q) :         MAX. :   12              AVE. :   4.2
PLAT. NO  IN AREA (Z) :         MAX. :   296             AVE. :   175.2
PLAT. NO  IN AREA (A) :         MAX. :   19              AVE. :   3.8
PLAT. NO  IN AREA (R) :         MAX. :   177             AVE. :   58.6
PLAT. NO  IN AREA (C) :         MAX. :   54              AVE. :   12.7

WORKTATIONS:
LOAD ST1           MEAN TIME:  1.30        NO OF PROCESSED:  398
                   AVE. UTIL:  0.860       AVE. Q LENGTH  :  12.0
LOAD ST2           MEAN TIME:  1.00        NO OF PROCESSED:  434
                   AVE. UTIL:  0.723       AVE. Q LENGTH  :  12.0
LOAD ST3           MEAN TIME:  1.00        NO OF PROCESSED:  378
                   AVE. UTIL:  0.625       AVE. Q LENGTH  :  12.0
MS1 STR1           MEAN TIME:  4.38        NO OF PROCESSED:  117
                   AVE. UTIL:  0.853       AVE. Q LENGTH  :  2.8
MS1 STR2           MEAN TIME:  4.42        NO OF PROCESSED:  118
                   AVE. UTIL:  0.953       AVE. Q LENGTH  :  2.8
EQS STR1           MEAN TIME:  1.60        NO OF PROCESSED:  287
                   AVE. UTIL:  0.763       AVE. Q LENGTH  :  5.3
EQS STR2           MEAN TIME:  1.66        NO OF PROCESSED:  284
                   AVE. UTIL:  0.781       AVE. Q LENGTH  :  5.3
MS2 STR1           MEAN TIME:  4.35        NO OF PROCESSED:  31
                   AVE. UTIL:  0.224       AVE. Q LENGTH  :  0.1
MS2 STR2           MEAN TIME:  4.29        NO OF PROCESSED:  20
                   AVE. UTIL:  0.143       AVE. Q LENGTH  :  0.1
OAL STR1           MEAN TIME:  4.39        NO OF PROCESSED:  81
                   AVE. UTIL:  0.592       AVE. Q LENGTH  :  1.1
EQL PRE1           MEAN TIME:  1.78        NO OF PROCESSED:  332
                   AVE. UTIL:  0.982       AVE. Q LENGTH  :  3.6
EQL PRE2           MEAN TIME:  1.81        NO OF PROCESSED:  271
                   AVE. UTIL:  0.816       AVE. Q LENGTH  :  1.4
L2S STR1           MEAN TIME:  1.84        NO OF PROCESSED:  236
                   AVE. UTIL:  0.723       AVE. Q LENGTH  :  1.2
L2S STR2           MEAN TIME:  1.79        NO OF PROCESSED:  221
                   AVE. UTIL:  0.660       AVE. Q LENGTH  :  1.5
OAL LOAD           MEAN TIME:  1.85        NO OF PROCESSED:  70
                   AVE. UTIL:  0.216       AVE. Q LENGTH  :  0.0
LIQ LD1            MEAN TIME:  1.83        NO OF PROCESSED:  321
                   AVE. UTIL:  0.975       AVE. Q LENGTH  :  4.2
LIQ LD2            MEAN TIME:  1.83        NO OF PROCESSED:  128
                   AVE. UTIL:  0.390       AVE. Q LENGTH  :  0.5
MEAL UNL           MEAN TIME:  1.08        NO OF PROCESSED:  352
                   AVE. UTIL:  0.623       AVE. Q LENGTH  :  1.4
LIQ UNL1           MEAN TIME:  1.04        NO OF PROCESSED:  549
                   AVE. UTIL:  0.948       AVE. Q LENGTH  :  2.8
LIQ UNL2           MEAN TIME:  1.05        NO OF PROCESSED:  104
                   AVE. UTIL:  0.181       AVE. Q LENGTH  :  0.3
```

Figure 9: Example of Customized Report

4 SCALED ANIMATION DEVELOPMENT

Animation is a powerful addition to any simulation effort [5] [7]. In the simulation study presented in this paper, we have used animation software "PROOF". The main reason for using "PROOF" rely on its flexibility of connection with simulation languages and the functions to interface with .DXF file of CAD systems.

4.1 P&F System Animation Layout File Generation

To run animation under "PROOF", two files must exist: the layout and trace file(s) [1]. In preparation for generating an animation layout file for a P&F system, the following should take place:

- ✓ Draw the animation background
- ✓ Define the paths which guide the objects moving.
- ✓ Define the objects which will move in the system according to the logic of system simulation model.

With the DXF2LAY module of PROOF, the animation background for a P&F system can be directly transformed from the .DXF format of the engineering drawings. This provides a scaled and realistic communication basis for all the personnel involved.

In defining animation paths, be aware of the differences between the CAD drawing element and the animation path. The relations between the drawing elements and animation paths in Fig. 5 is shown in Table 3. The differences originate from the fact that there was almost no communication requirements between the designer and the simulationist in the past. Therefore, the current CAD drawing does not contain the real logic of the system. In the future, however, this situation should be changed in order to meet the requirements of the fast simulation.

Table 3: Drawing Segment vs. Simulation Path

CAD Drawing Segment	Simulation Path Element
Line: L1, L2, L3, L4 Arc: A1, A2, A3, A4	Path: P1, P2, P3, P4 P5, P6, P7, P8
L1	P1 + P6+ P7 + P8
A1 + L2 + A2	P3
L3/2	P3
L3/2 + A3 + L4	P4
A4	P5

4.2 Trace File Generation

Animation trace file is the core of PROOF. During an animation, PROOF reads this trace file, one line at a time, using the time information embedded in the animation trace file to determine when to read and process the next line.

The commands used in PROOF are basically to manipulate the objects on the positions or the paths which have been defined in the layout file. In MIA P&F system animation, the basic object is the platform.

The method for creating the animation trace file is to have a model or program, separate from PROOF, generate the ordered list of PROOF commands that comprise the trace file. In the simulation software packages, GPSS/H has a distinguished advantage due to the ability of writing customized output files. The macro command of GPSS/H has been frequently used to take advantage of performing the repeated coding.

Figure 10 shows a scaled animation screen generated by the simulation and animation model.

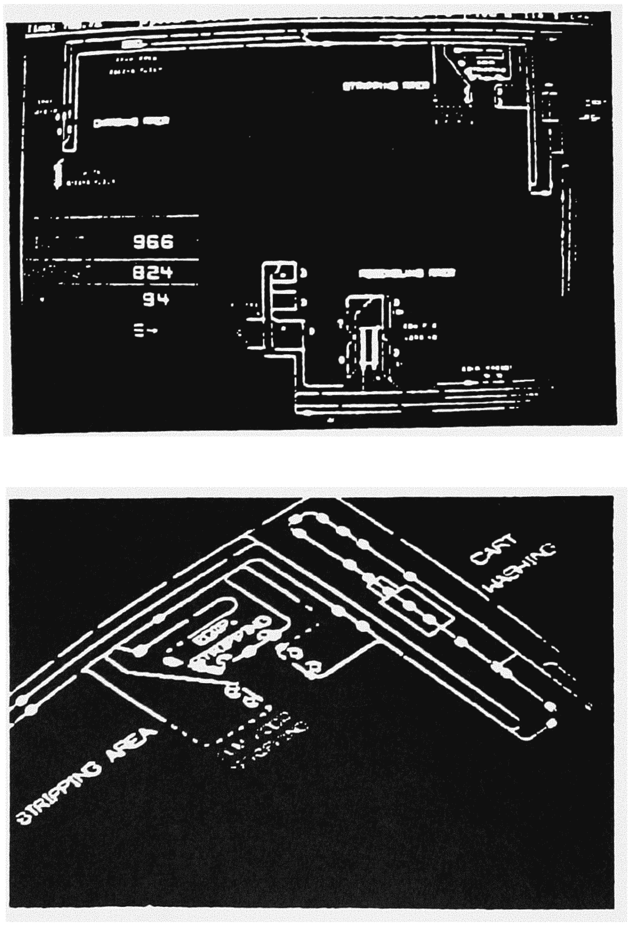


Figure 10: Example of Animation Screen

5 RESULTS AND DISCUSSION

Common experiment results provided by this simulation model include system's throughput, production capacity, facility utilization, buffer size requirement, etc, under the given "scenarios". Nevertheless, other issues for the system's optimization can also be addressed in this model by the proper experimental design under the simulation environment.

One of the issues in optimizing the system requirements is to determine the optimum number of the platforms used in the system. It is clear that there should be enough platforms in order to satisfy the production requirement. Meanwhile, it is not desirable to have too much platforms in a low utilization environment.

Determination of the reasonable range of the conveyor speed is another issue to be addressed. The speed of the platforms traveling in the system depends on the speed of the chain drives which will be fixed after the system's installation.

Partial experiment results on above two issues are shown in Figure 11 (a), (b). The results of Figure 11 (a) shows that the optimum number of platforms is between 165-180 under the given schedule and system process rates. More platforms may provide some flexibility in system management. It can be observed from Fig. 11 (a), however, by increasing the platforms, the accumulation of platforms in stripping area increases. The throughput of the system does not increased since the process rate remain the same. Therefore, increasing the number of platforms in the system does not enhance the production capacity. The potential disadvantage of too much platforms in system is that it may cause the system to jam.

Figure 11 (b) shows that there is no significant change with the increase of the chain speeds from 45 (FPM) to 60 (FPM). When the conveyor speed reaches 65 FPM, the platform requirements can be reduced. However, from the safety stand point, conveyor speed of 65 FPM will not be a suitable choice. Therefore, the optimized speed of this system is decided upon 50-55(FPM).

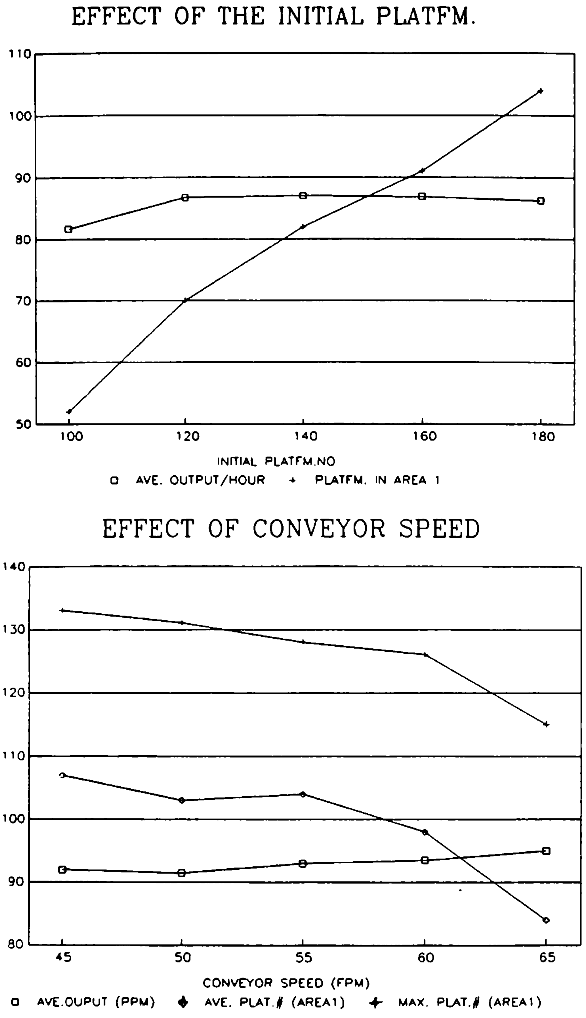


Figure 11: Examples of Experiment Results

6 CONCLUSION AND FUTURE WORK

Optimized system layout and system working parameters are defined by experimental design on the detailed simulation model developed with GPSS/H. With the aid of "PROOF", the scaled animation trace file generated from the GPSS/H simulation model made it possible to "see" the behavior and performance of the designed system in a realistic, smooth and dynamic environment during the entire life cycle of the system's development.

Animation also gives the systems engineers operational experience with the system and improves the communications between internal/external supplies/customers. It also provides the system engineers with quality data from which they can negotiate system component characteristics. As a benefit, the estimated savings due to the use of simulation was in excess of $400,000 in total for MIA P&F system design and installation.

There are two major areas which are worth further developing. One is the intelligent simulation environments for P&F system modeling. A rapid simulation program generating tool is being developed since project start up. However, at this time, this program generating tool is not yet capable of generating programs in some special decision points, where the complex control logic has been associated with it. In future approach, we might solve this problem by summarizing and analyzing all the possible control logic which can be employed in P&F system.

The second area involves the user interface with the .LAY file of PROOF. Although the path information has been included in .LKG file of PROOF, it is not convenient yet to define point information, which is very important to express the relationships among the paths for an intelligent simulation environment. The point information has been included in .LAY file, but it is not flexible enough. A proper parse program needs to be developed in order to abstract those information.

If the areas mentioned above had been improved, it would extend the application as a general and strong analysis tool to an even wider range of user for this specific problem domain.

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