Proceedings of the 1984
Winter Simulation Conference
S. Sheppard, U. Pooch, D. Pegden (eds.)

SIMULATION OF FACILITY DESIGNS ON A MICRO-COMPUTER

Gerald T. Mackulak
Assistant Professor of Engineering
Arizona State University

Neil Glenney
President, The CONFACS Group

The design of a high technology production facility quite often hinges on the successful design of a material handling system to integrate the various automation centers. Traditionally, management has been reluctant to invest the capital necessary for high technology material handling equipment since they have no guarantee of the performance potential. Simulation of a proposed facility design, with a special emphasis on the material handling system is illustrated as a key method for evaluating the proposed design prior to the purchase of production process equipment.

I. Introduction

The cost associated with the design and installation of a high technology manufacturing facility can be prohibitive. Justification for a new manufacturing facility must therefore be extensive and must consider, as completely as possible, all aspects of facility performance. In the electronics industry (and other high technology manufacturing facilities) the key to manufacturing productivity, quality and control is the optimization of the equipment housed in the facility and fed by the material handling system. The material handling system can provide security, integrity and integration of the automation required for the products being manufactured. The facility itself must also provide flexibility to the extent that products can be selectively mixed through the facility while still maintaining overall control.

Material handling is a critical consideration with respect to the automated factory because in it, great amounts of in-process material are or will be moved at a high velocity from place to place, stored for future use or fed into operations that add value. Material handling provides the movement, machine tools the precision assembly, and computers the direction. It is the balancing of these, however, that is the most difficult to accomplish.

The key role of the systems integrator will be recognizing the best practices available for minimizing inventory and maximizing the utilization of assests. For example, there may be a need for a unit-load warehouse stacker if the real problem is simply inventory out of control another situation may be a new machine producing a number of parts the system can neither feed to the machine nor take away.

Traditionally, management has found difficulty in committing resources to the area of material handling due to the uneasy feeling that are generally associated with large capital expenditures for untested or unproven systems. American management has seen fit to gear toward short term profitability as opposed to long term survial. Seymour Melman, Professor of Industrial Engineering at Columbia University shows that over 2,000,000 jobs have been lost to foreign competition from 1979 through 1980 due to managements lack of commitment toward modernization. [1] Melman further states that the goals of management have shifted from long term, manufacturing commitment prior to World War II to now one of short term, subcontract to overseas facilities. The author contends that this lack of commitment comes from management's inability to understand how total system integration can occur. Further, simulation is one of the tools available to demonstrate just how profitable the integration will become. Through system analysis and design with simulation, management is able to regain the confidence necessary to make commitments for future survial.

Surviving in the 80's requires that management utilize it's most basic tool - strategic planning. Manufacturing's strategic planning must be both a guide and a control mechanism for improving the productivity of the manufacturing system. The model of a manufacturing system for the 80's (Figure 1) suggests how strategic planning (specifically strategic planning through simulation) can guide and control the balanced integration of the distinct subsystems into a productive manufacturing system.

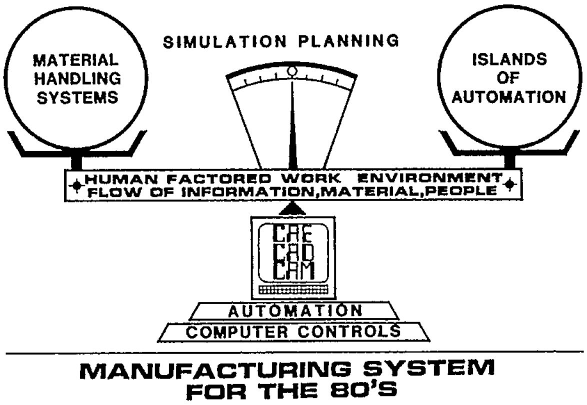


Figure 1: The System Model

The component parts of the model include all of the major factors which must be included in a productive automated manufacturing environment:

1. The human-factored work environment
2. The automation/computer controls
3. The islands of automation
4. The material handling systems

None of these components may be allowed to overpower any of the others, yet all must be included for the manufacturing system to perform to its expectations.

Increased capital spending for automation equipment has often been touted as a panacea to the productivity problems and the mechanism for making the company a low-cost producer. Yet with all of our advances in robotics and numerically controlled machines, we have not yet solved the problem. In fact, these automated machines may have added to the problem by creating "islands of automation". These "islands of automation" often create suboptimizing situations because they have not been integrated into a total manufacturing system.

The computer has altered the way we work in almost every aspect of business and many of the productivity improvements we have made would be impossible without it. In manufacturing, computers aid in the design of products (CAD) and in the control of automated manufacturing processes (CAM). However, successes in linking CAD and CAM into a truly integrated system are particularly lacking in electronics. The computer, therefore, has not yet met its full potential in answering the productivity issue and, in many cases, has itself become an "island of automation".

Material handling has been suggested as one of the areas where great productivity gains can still be obtained. This is probably true, but as with the linking of CAD and CAM the necessary integration of material handling with the manufacturing process has often been neglected.

The key to integration of the material handling system into the manufacturing facility is the use of simulation. Simulation permits the examination of different manufacturers types of equipment. Simulation is a key ingredient to insure balance has been brought to the total facility design process.

The concept of producing a system design for a high technology facility relates to the artistic sense of the designer in terms of new advancements for facility flow, experience and dedication of sound engineering practice. Simulation must be performed on the proposed design to determine whether the desired aspects of the design can be met. Simulation of a hypothetical facility can answer questions pertaining to:

1. Will the flow meet the needs of the specified facility?
2. Will the equipment maintenance requirements hinder production, or have they been successfully designed into the overall process?
3. Are the staffing levels and resource allocation correct?
4. Will the facility produce and control at the quality levels required by management?

Many of these questions can be answered through analysis of the system with simulation.

With ever increasing demands on the high-technology industries' needs of its growing field of customers, and its desire to fulfill the changing expectations of its non-traditional work force, a manufacturing environment must be created to sustain innovation.

A strong emphasis must be placed not only on stabilizing facility square footage and manpower, but also on maintaining balanced growth and meeting the requirements of increasing production schedules. The need to improve the flow of production can be established with the tools attributed to computer-integrated manufacturing (CIM) systems, thus allowing production personnel to be concerned only with their production tasks, not with physical movement and tracing of materials. [2] The principals of CIM integration need to be sensitive to all functions within the manufacturing organization. Their inputs are critical to developing the simulation data-base. (See Figure 2)

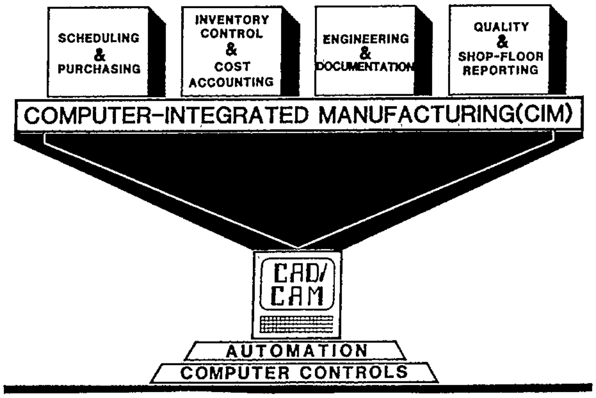


Figure 2

II. Design Issues in Facility Planning

A system that triggers positive responses from those who use it must be built from components that meet a wide range of needs. It should be easy to change, with individual parts that can be replaced or expanded with a minimum of disturbance to the system. When each component or subsystem has a spectrum of uses, a modular approach to problem solving is utilized and flexibility in decision making is achieved. The structural changes made possible by the modular approach will allow the industrial environment to keep pace with increasing demands for change at reasonable cost.

The material flow pattern is the basis for the entire facility design as well as the success of the enterprise. Too much emphasis cannot be placed on the importance of determining the most efficient plan for the flow of materials, information and people.

The importance of flow pattern in any facility as it influences production can be analyzed in advance for cost, quality and time using various means of measurement. [3] The simulation analyst can integrate these factors into an overall simulation model to evaluate the facility design. Top management will demand justifications for automated material handling systems. A simulation model will be necessary to show how the proposed system will operate in all situations. In addition, a tactical material handling plan can indicate the most efficient routing of material through the facility using routing analysis as well as illustrate queues that may be required between certain operations. This technique will allow the material handling engineer to increase his effectiveness by using computer-aided plant layout. Systems will be designed using computer-aided plant layout routines, integration with simulation models, equipment design routings and interactive computer graphics. This equipment and data analysis will soon become a widely accepted planning tool in the automated facility as the animation will be an effective means in presenting alternative concept designs.

Material handling is to some extent an art, however, and creative solutions often come from first-hand experience in dealing with actual situations. Production simulations and sophisticated MRP systems will help, but the final answer must come through analysis and implementation by a trained and experienced professional who is familiar with all the resources available in order to make critical decisions in this area.

The primary design objectives of the simulated material handling system are:

1. Reduce initial building cost
2. Reduce construction time
3. Reduce contingency investment
4. Increase efficient utilization of space over the life of the building
5. Reduce change and relocation costs
6. Reduce energy consumption
7. Increase comfort, efficiency and satisfaction of users
8. Utilize independent production units for use separately in any sequence
9. Centralize storage of inventory/work-in-process
10. Increase speed of the distribution system that provides material to independent production units just-in-time (J.I.T.)
11. Modular containerization for storage and handling stardarization
12. Total "real-time" distributed process control

Simulation is the key to evaluation of the integration of these objectives. [4]

The remainder of this paper will discuss the application of micro-computer simulation to three case studies for facility design. The first case study was an examination of an existing layout, the second, a proposed move to a new building/layout and the third, was a total building and site planning effort. In all three cases simulation was a key integration tool in the design effort.

III. Facility Design Scenarios

All of the analysis discussed in this paper was conducted on an IBM-PC using the SIMAN simulation language. [5] SIMAN is a general purpose simulation language that executes on personal, mini and mainframe computers. The advantages of the SIMAN language pertains to the fact that SIMAN is user friendly, FORTRAN based, upward compatible from personal computers through mainframes and oriented toward manufacturing situations. The use of SIMAN as a "what if" decision tool permits the system designers to investigate how the actual design will perform prior to purchasing any individual equipment items. SIMAN also permits lower first cost simulation capability since it runs on a personal computer. SIMAN and simulation eliminate many of the risks associated with the more traditional approach of statically designing a facility and hoping the integration of dynamic system components will perform to the desired specifications. This paper will now discuss the application of the SIMAN IBM-PC language to the design of three high volume electronics board assembly shops.

Scenario One - Existing Layout Analysis

This case study consisted of analyzing an existing layout. The layout was designed according to industrial engineering techniques where the major emphasis was placed on a scheduled cycle time so that the desired number of units would be produced over the given production period. The involvement in this project occurred after the machines and material handling system had been procurred, but not yet delivered. Management was concerned with the fact that the layout was designed according to static parameters and did not consider the dynamics and interactions of the various pieces of equipment as well as the material handling system design.

The material handling system consisted primarily of an extensive network of conveyors linking the various machines to one another. Because of this particular design criteria, there was virtually no room for queing within the production facility.

This necessitated a very fine balance between the various pieces of equipment so as to not produce queues, of items that would never be removed from the production process.

The production process also consisted of dealing with products one unit at a time through this in-line assembly process. The product, however, started in lots of approximately 60 units, were then converted into lots of 30 units, and then were finally subdivided into individual units and handled uniquely. This necessitated critical scheduling of the production process so that the product would not develop queues. Sufficient racks and storage devices were not available to hold the various items at key points of the process.

The size of the production facility necessitated dividing the model into two sections. The first section consisted of the in-line board production process while the second section consisted of the assembly process from which the final device was released.

The simulation model was developed and validated from existing data. The data indicated that there were several problems that existed in the original facility design. The major problem was that the production process was not balanced when dynamics of non-deterministic machine times were included in the simulation analysis. This meant the queue levels would build at at certain points in the production process and never be alleviated.

The simulation analysis indicated at best approximately 66% of the anticipated production level could be met with the given facility design. Unfortunately, the manufacturer had a contract to deliver product where the deliverable quantity must be met according to the terms of the contract. Had a simulation analysis not been performed prior to installation of the equipment, the manufacturer would have found that the contract would have become default. A newly constructed layout, based on the SIMAN simulation outputs, was the result of this program.

However, the simulation analysis did point out several interesting management interactions in that the managers in charge with the original facility design forced themselves to stick with the concept of the original design and disagree with the results of the simulation model. Since simulation is a technique that does not guarantee an exact one to one correspondence with every detait of the existing facility management would strive towards that particular realization and state that the results of the simulation model were therefore, not necessarily valid. After a seminar that taught the finer points of simulation, however, the analysts in charge reflected to their management that indeed the results of the simulation model could be relied upon to illustrate the fact that the existing material handling design and process layout was not adequate for the production level's desired.

The sample process flow diagram (Figure 3) of a Printed Circuit Board Assembly (PCBA) opertion illustrates throughputs/hour, yield rates, rework loops and machine requirements. Figure 4 shows a section of the expansion of process flow diagram to a sequence of blocks for translation of the simulation model to computer code in SIMAN.

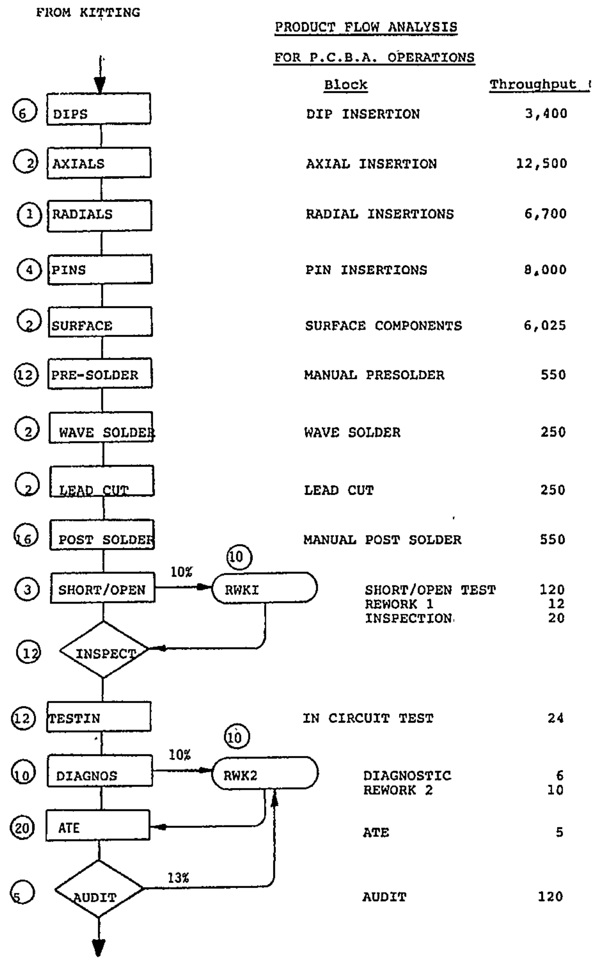


Figure 3

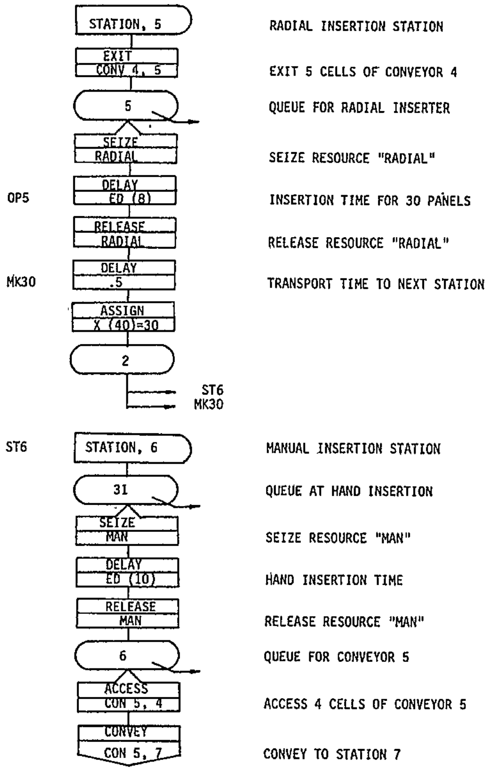
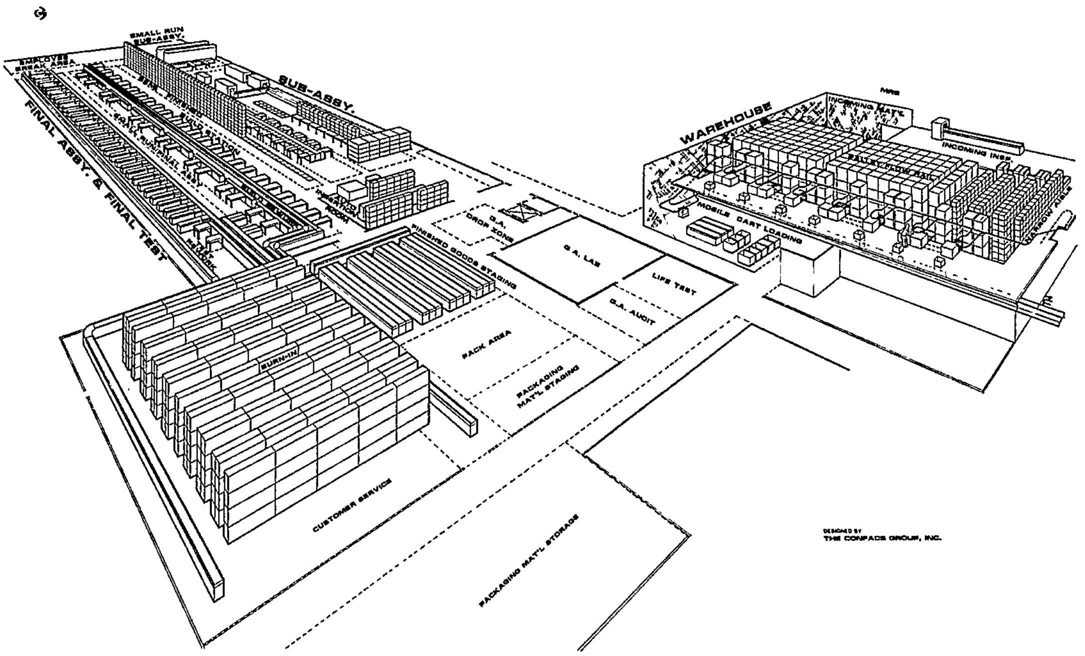


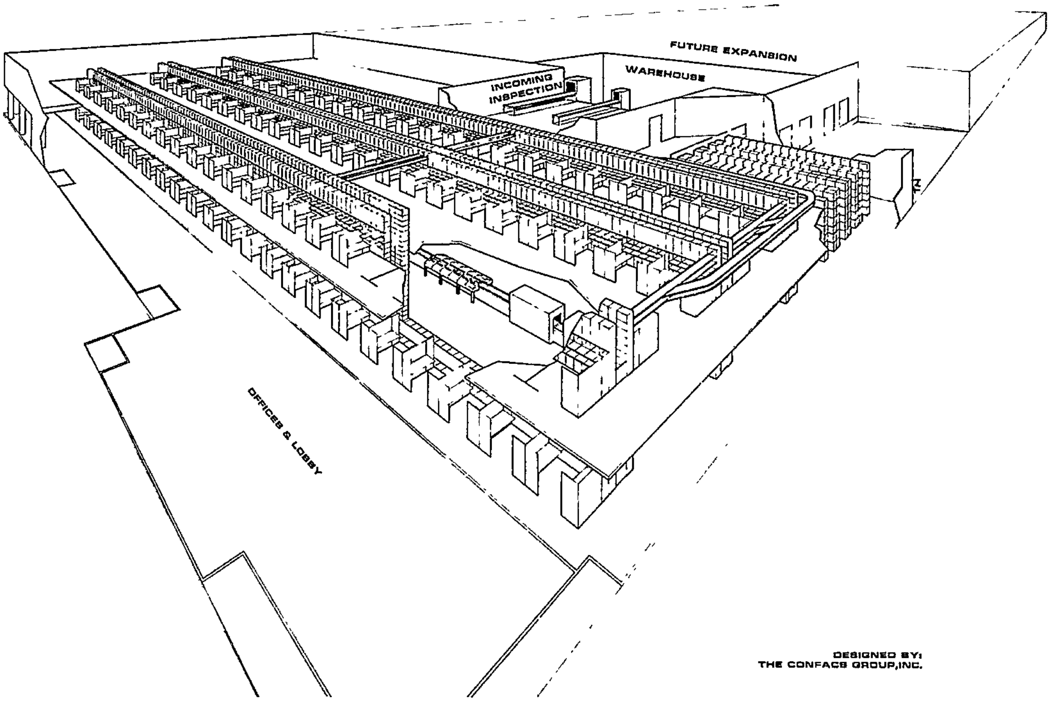
Figure 4

Scenario Two - Proposed Building Layout Plan

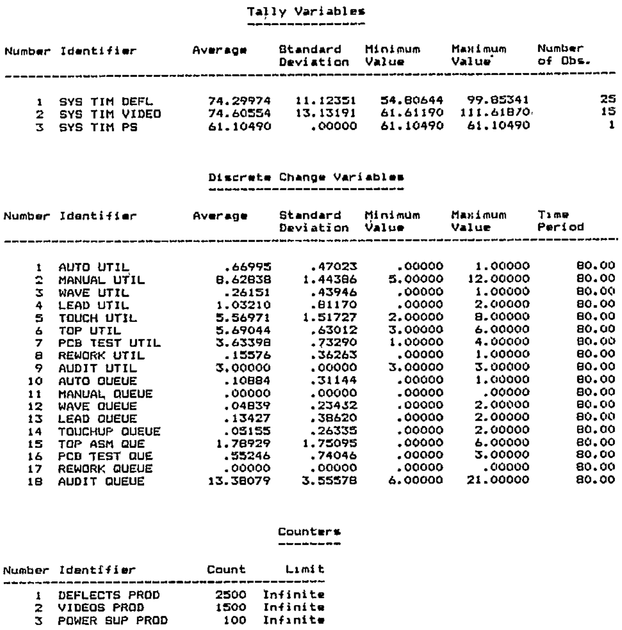
This case study consisted of analyzing a situation where management was examining the production capability of their particular facility in the future. Management was concerned with the fact that volumes and product mixes were changing and they were trying to determine whether their particular facility could be redesigned within an existing three building complex or whether they would require relocation to a larger new single building site. The project consisted of simulating the entire production environment of the existing electronic board packaging assembly shop. Utilizing a similar format to the initial steps in scenario #1, as the basic building blocks, a program based on the SIMAN simulation language was constructed for the Tally and Discrete Change Variables as shown in Figure 5. The simulation was run on an IBM-PC and was encapsulated in one model.



SCENARIO ONE



SCENARIO TWO



```
                            Tally Variables
                            ---------------

Number Identifier          Average    Standard   Minimum    Maximum    Number
                                      Deviation  Value      Value      of Obs.
---------------------------------------------------------------------------

  1   SYS TIM DEFL         74.29974   11.12351   54.80644   99.85341       25
  2   SYS TIM VIDEO        74.60554   13.13191   61.61190  111.61870       15
  3   SYS TIM PS           61.10490     .00000   61.10490   61.10490        1


                        Discrete Change Variables
                        -------------------------

Number Identifier          Average    Standard   Minimum    Maximum    Time
                                      Deviation  Value      Value      Period
---------------------------------------------------------------------------

  1   AUTO UTIL              .66995     .47023     .00000    1.00000    80.00
  2   MANUAL UTIL           8.62838    1.44386    5.00000   12.00000    80.00
  3   WAVE UTIL              .26151     .43946     .00000    1.00000    80.00
  4   LEAD UTIL             1.03210     .81170     .00000    2.00000    80.00
  5   TOUCH UTIL            5.56971    1.51727    2.00000    8.00000    80.00
  6   TOP UTIL              5.69044     .63012    3.00000    6.00000    80.00
  7   PCB TEST UTIL         3.63398     .73290    1.00000    4.00000    80.00
  8   REWORK UTIL            .15576     .36263     .00000    1.00000    80.00
  9   AUDIT UTIL            3.00000     .00000    3.00000    3.00000    80.00
 10   AUTO QUEUE             .10884     .31144     .00000    1.00000    80.00
 11   MANUAL QUEUE           .00000     .00000     .00000     .00000    80.00
 12   WAVE QUEUE             .04839     .23432     .00000    2.00000    80.00
 13   LEAD QUEUE             .13427     .38620     .00000    2.00000    80.00
 14   TOUCHUP QUEUE          .05155     .26335     .00000    2.00000    80.00
 15   TOP ASM QUE           1.78929    1.75095     .00000    6.00000    80.00
 16   PCB TEST QUE           .55246     .74046     .00000    3.00000    80.00
 17   REWORK QUEUE           .00000     .00000     .00000     .00000    80.00
 18   AUDIT QUEUE          13.38079    3.55578    6.00000   21.00000    80.00


                               Counters
                               --------

Number Identifier          Count     Limit
------------------------------------------
  1   DEFLECTS PROD         2500  Infinite
  2   VIDEOS PROD           1500  Infinite
  3   POWER SUP PROD         100  Infinite
```

Figure 5

The model was flexible from the standpoint of rework yield rates and production rates on a per unit basis. Attributes of the particular production unit were the times required at various production processes in addition to the yield experienced on different products through the various test areas.

A major problem associated with this particular case study was that the manufacturer was analyzing the change from the current manufacturing process to the new production process of surface mounted device (SMD) technology. The challenge was the development of a production facility that would meet the needs of current production requirements at minimum cost and yet still be flexible enough to meet the future needs of the production process out to the year 1990. The problem of switching from a current technology to a new technology is that both production processes will be in existence in the facility at one time thereby necessitating a larger space than either production process would require by itself. Eventually, the new production process will require less square footage but, unfortunately, few manufacturers are able to entirely halt production and start up with a new production facility when the new technology has advanced to where they will begin using it. The simulation data/facility design proved this out.

Several other goals of this particular facility design were to eliminate traditional warehousing and kitting methods, to standardize tote container sizes, and to perform lot tracking. The concept was advanced to the level that the automated storage/automated retrieval system (AS/AR) would deliver tote-containers directly to the work station. The facility was required to be able to react quickly and efficiently to chaning production schedules. All of these aspects were incorporated into the simulation model and an extensive simulation analysis indicated the production performance of the facility as designed for three buildings verses the single building layout. The study indicated that the three building approach would be insufficient in terms of the desired production quantities and technology required for this manufacturer's facility. Therefore, the single building layout was the particular facility design that was the final outcome of the overall layout project.

In this particular instance, the management reacted to the results of the analysis and simulation outputs and indeed procurred a single building where the prodcution process could be relocated so as to meet the needs of projected requirements out to the year 1990.

Scenario Three - The Facility Planning for a Proposed Building on a New Site Plan

In this partciular case study a company has been experiencing rapid growth over the last four to five years and had been growing into many different building locations. This company wanted to consolidate under the "one roof" concept. A 30 acre panel of land was available for construction and an adjacent 10 acres was also available, but several other parties were interested in this parcee. A critical decision had to be made by the company in order to determine whether appropriation of the additional 10 acres was required for parking or additional growth over the next three to five years. The study began by examining existing processes and product mixes. This study was performed in order to develop a data base that would be used as the foundation to evaluate future processes and product mixes that would be housed under the one roof building concept.

The objectives of the facility design itself were ones that would allow just-in-time delivery from the warehousing operations to the assembly functions within the manufacturing operations. The first step in the process of accomplishing these goals was determination of the size of the warehousing function.

The warehouse analysis began with a simulation study to determine the number of dock doors that would allow for more frequent deliveries of trucks bringing inventory into the facilities and the number of docks required for shipping products out of the facility. Once the number of dock doors has been established, the method of removing vendor packaging as soon as possible was also determined through simulation. Requirements in the number of standardized containers for the detrashed material was also analyzed as well as the number of random storage locations that would be needed to house the product in mini-load and other AS/AR systems. The simulation output reports determined the throughputs of these systems as well as assisted in determining the proper application of conveying the raw materials to the various assembly areas. Due to the capabilities in the program for sizing of the future warehouse needs a design for expansion and flexibility was planned for this critical area of the facility.

The sub-assembly area was developed through extensive sensitivity analysis surrounding material flow, resource levels and product mixes. Production projections through the year 1989 were loaded into the model and a quarter by quarter analysis of resource utilizations, throughput times and queue levels were produced. Figure 6 is a samle output for analyzing the utilization at a particular machine. A similar study was performed for the final assembly process.

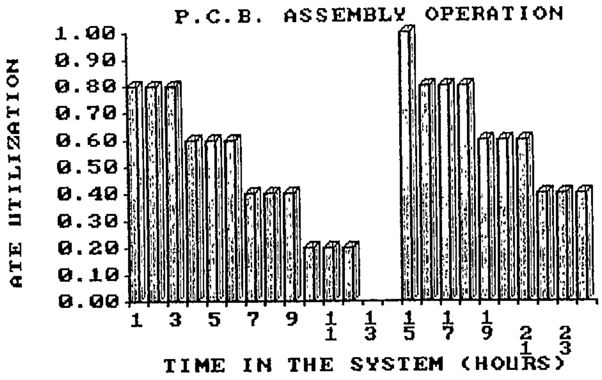
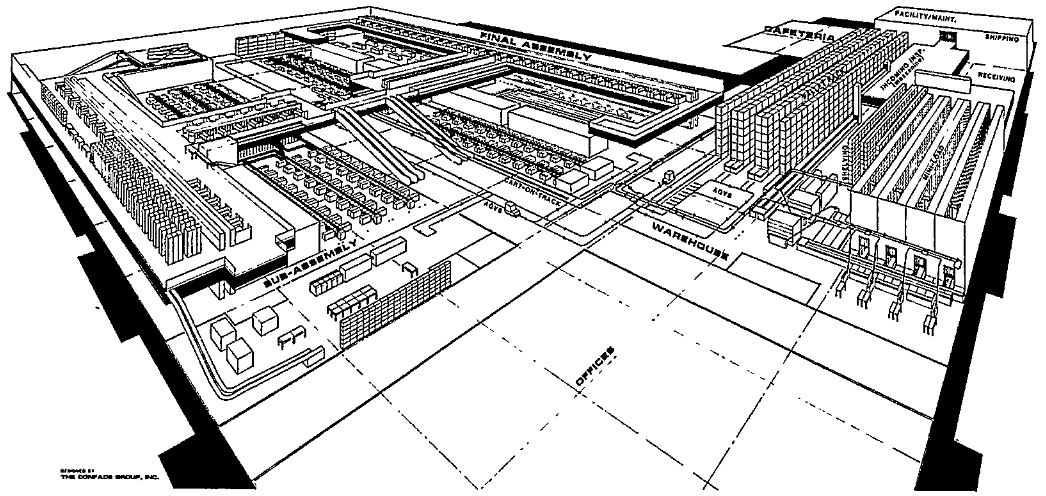


Figure 6

The final analysis stipulated a production area requirement of a litte more than 200,000 square feet, housing manufacturing process equipment, material handling systems and personnel. This manpower requirement in turn enabled calculation of the packing requirements for the facility. The result was that effective and efficient design avoided the purchase of the initially proposed 10 acre adjacent parcel, resulting in extensive cost avoidance.

IV. Concluding Remarks

SIMAN was found to be an effective and low cost analysis tool to aid in the design of material handling and facility systems for these three scenarios and other high technology manufactures. The process of facility design has been greatly enhanced through these simulation modeling techniques. Management can finally have confidence in the given design since it has been "tested" on the computer. In addition, simulation on a micro-computer permits nearly everyone to utilize simulation since the cost of the language and computer are no longer prohibitive.



SCENARIO THREE

REFERENCES

[1] Melman, Seymour, "The High-Tech Dream Won't Come True", INC. Vol. 6, No. 8, pg. 13-14, August, 1984

[2] Mackulak, Gerald T., "Planning Techniques for Computer Integrated Manufacturing" (CIM), National Productivity Review, Vol. 3, No. 3, pg. 315-333, Summer, 1984

[3] Glenney, Neil E. and Rylander, Robert, "Real Time Shop Floor Control", Production and Inventory Management, Vol. 23, No. 4, pg. 121-138, Fourth Quarter, 1982

[4] Glenney, Neil E., "Modular Integrated Material Handling System Facilitates Automation Process", Industrial Engineering, Vol 13, No. 11, pg. 118-124, November, 1981

[5] Pegden, Dennis C., "Introduction to Siman", Systems Modeling Corporation, State College, Pennsylvania, 1982 pg. 258