Proceedings of the 1987 Winter Simulation Conference
A. Thesen, H. Grant, W. David Kelton (eds.)

ANALYTICAL FACTORS CONCERNING THE USE OF MICRO-MINI STORAGE DEVICES AS MATERIAL MANAGEMENT SYSTEMS

Paul C. Caruso
Advanced Manufacturing Engineering
New Process Development Section
The Saline Plant
Ford Motor Co.
7700 Michigan Avenue
Saline, MI 48176
(313) 429-6903

Maged M. Dessouky [1]
Bell Communications Research
331 Newman Springs Road
Red Bank, NJ 07701
(201) 758-4148

KEYWORDS: FLEXIBLE ASSEMBLY SYSTEM, MATERIAL MANAGEMENT SYSTEM, SIMULATION

ABSTRACT

As part of the design stage, a simulation model of a flexible assembly system is developed to determine the system's operating characteristics. The results show that the Micro-Mini Automatic Storage and Retrieval System (ASRS) is a critical resource in the system. The function of the ASRS is to be the material manager for the system. In this capacity it serves as the inventory manager, storage device, and the subassembly component distribution manager of the system. In applying simulation to this problem, four factors that affect performance of the ASRS are identified: (a) material ordering policies, (b) storage strategies, (c) job priorities, (d) and changeover capabilities. This paper discusses each of these factors as applied to an actual flexible assembly system.

INTRODUCTION

The primary purpose of a material management system is to distribute materials to work areas where value is added to a product. A material management system performs the functions of inventory manager, storage device, and subassembly component distribution manager of the system. As an inventory manager the material management system must order the materials required by the process that it is servicing so that the materials will be available when demanded. This function involves keeping track of part counts and evaluating the inventory control strategy. The material management system must also provide storage if a buffer is required between the supplying operations and the system being serviced. Finally the material management system delivers materials to the appropriate work areas when required.

Traditionally a material management system has consisted of a warehouse, manual or semi automatic delivery systems, and manual or semi automatic inventory management systems. ASRS's can be utilized to fully automate these functions. The hardware in an ASRS consists of storage racks, automatic cranes placed between the racks, totes that accommodate unit loads, and a computer control system. The computer system utilizes special software to perform the control functions of the system.

The performance of an ASRS applied as a material management system is influenced by many controllable factors, foremost among which are material ordering policies, storage strategies, job priorities, and changeover capabilities. The purpose of this paper is to analyze the performance of an ASRS as a function of these factors. Because of the complexity of the relationships between the performance criteria and the factors, mathematical or statistical models cannot capture these relationships, and simulation modeling presents itself as an effective tool for analysis. An actual flexible assembly system is used for illustration, where the values of the controllable factors are chosen, and the proposed model derives the values of the performance criteria. The performance criteria are system throughput, crane utilization, and wait time for the crane. The values chosen were based on experience with the system. The proposed methodology can be applied to different values of the controllable factors in an attempt to obtain improved designs.

THE CONTROLLABLE FACTORS

Material Ordering Policies

The inventory control policies can have a significant effect on the manufacturing process. A policy specifies a combination of the following decisions: ordering time, reorder point, and order quantity. The complete specification of a policy requires the selection of an appropriate policy and the determination of the values of the control parameters. The ordering policy used in this study is (s,S) where s is the reordering point and S is the stock control level. The order quantity is S-s.

Storage Strategies

ASRS systems are capable of random storage and zoned storage. Zoning is the partitioning of storage racks so that loads can be stored in a predetermined area. Typically loads are stored close to their respective delivery point. Three problems face system designers relative to storage strategies: (1) the number of zones, (2) the distribution of parts within a zone, and (3) zone overflow storage strategies. The more zones that are used the closer the zone will be to the delivery point, but the higher probability that a given zone will be overloaded. Therefore, overflow strategies need to be defined.

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[1] This study was performed while Mr Dessouky was employed by Pritsker & Associates.

Job Priorities

In it's simplest form the ASRS performs two movement functions, input and output of loads. The determination of a decision rule to select the next unit load to be moved can have an important effect on system performance. Three possible priority decision rules are input units first, output units first, and first-in-first-out. The determination of a decision rule is important especially if loads are manually input to a queuing device which serves as an input to the system. In this case, interarrival times on the input side can be highly variable resulting in large queues and performance peaks and valleys. When a system's requirements become more extensive encompassing priorities on additional factors such as part number or changeover state the selection of job priority becomes increasingly important.

Changeover Capabilities

Changeover from one product type to another brings into consideration the need to reassess the values of other factors, including inventory control policy parameters, storage locations within zones, and movement priority rules. Furthermore additional factors should be considered such as timing of ordering those parts which are required for the new product but which are not currently in the ASRS.

SYSTEM DESCRIPTION

A flexible small parts assembly system will be modeled. Twelve unique product types (final assemblies) will be assembled on the system each consisting of forty to sixty subassembly components. There are approximately ten subassembly component types in the system. The subassembly components are stored in the micro-load device. Other major components of the system are the tote input station, the tote delivery conveyor, the work-in-process conveyor, and the assembly cells.

There are ten assembly cells in a line of which 5 are contained in a module. Hence there are 2, 5 cell modules per line. The two modules are identical and independent and can produce any of the twelve products being produced on the system.

The subassembly components are stored in totes that arrive to the system stacked on pallets. The totes are depalletized at the tote input station where they are placed on the tote delivery conveyor. The totes travel on the tote delivery conveyor to the micro-load device where they wait for the crane to transfer them to storage. Upon demand from an assembly cell the crane removes a tote from storage and transfers it to the work-in-process conveyor. The tote then moves on the conveyor to the assembly cell. When the assembly cell has emptied a subassembly component tote the empty tote travels along the work in process conveyor to the empty tote handling area where it leaves the system.

Product assemblies are carried through the system in a build pallet that is delivered to the ASRS in the same manner as the subassembly component totes. These pallets are delivered by the crane to the first assembly cell in a module and move along the work in process conveyor through the four successive assembly cells. A product is completely assembled when it leaves the fifth assembly cell and proceeds to inspection.

The operational sequence for the system is shown in figure 1. The boxes represent operations and storage locations, and the arrows represent the material handling system.

At the beginning of each day a schedule for each assembly module is determined. Once an assembly module finishes it's schedule it becomes idle for the rest of the day. If an assembly module does not finish it's schedule the remaining orders are carried over to the next day's schedule. Inventory in the ASRS at the end of the day is carried over to the next day.

An inventory review of the ASRS occurs after every delivery of a subassembly component tote to an assembly cell. When the inventory level of a subassembly component falls below the reorder point, a replenishment order is sent to the warehouse.

MODEL FORMULATION

The computer simulation model of the flexible assembly system was developed using the SLAM II simulation language. SLAM II was selected because of it's Material Handling Extension feature which enables the user to model material handling systems such as the micro-load device easily.

A combined network-discrete event model was developed. The network portion was used to model equipment in the system (conveyors, micro-load device, tote input station, and assembly cells). The discrete event portion was used to model the control logic of the system. The control logic of the system includes scheduling the assembly cells, ordering the materials, assigning storage locations, assigning job priorities, and controlling changeover at the assembly cells.

The entities in the model are the subassembly component totes and the final assembly pallets. The attributes of these entities are shown in table 1. The conveyors, tote input station, and assembly cells are modeled as RESOURCE blocks.

The SLAM II Material Handling Extension statements used to model the ASRS are AREA, PILE, CRANE, GWAIT, and GFREE/MOVE. The storage locations in the ASRS are defined by AREA and PILE statements, and the cranes are modeled as CRANE resource blocks. The requests for cranes and storage locations wait at a GWAIT node, and crane movement is modeled using the GFREE/MOVE node.

The four factors that effect the micro-load device are modeled in discrete event code. At the beginning of each simulation run the reorder points for all subassembly components at the ASRS are selected randomly from a uniform distribution in the range (150,275) which falls within the range of lead times to deliver an order. The reorder points are assigned to a random variable to insure that the subassembly components reach their reorder points at different times. The stock control level for each subassembly component is equal to

Attributes	Description
1	Storage location number
2	Current resource number
3	Last resource number
4	Final resource number
5	Assembly cell number
6	Area number
7	Desired pile number in ASRS
8	Final assembly number
9	Subassembly component number
10	Entry time to system

Table 1. List of Attributes

the reorder point plus a pallet load. This assignment guarantees that the order quantity is a pallet load. An order quantity larger than a pallet load is undesirable because it ties down the tote input station to a particular subassembly component for too long of a time period.

The storage strategy divides the storage racks into four zones. Figure 2 shows the zone assignments within the ASRS. The first zone stores the product pallets which are used by the first two assembly cells in module 1. The second zone stores the subassembly components that are used by the last three assembly cells in module one.

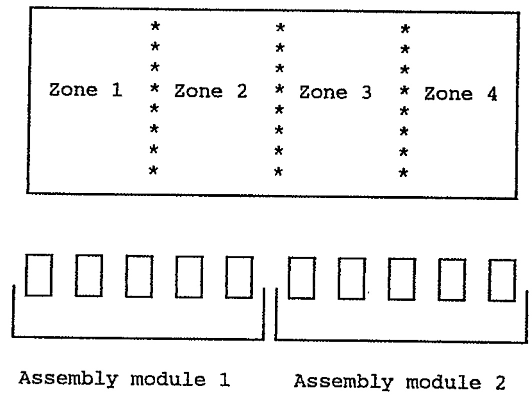

Figure 2. Zone assignments within ASRS.

Zones three and four are defined using the same logic except in this case it applies to module two. The storage strategy within each zone is to load totes from left to right. If a zone is overloaded the totes that are assigned to that zone overflow into the adjacent zone.

The job priority for the crane is first-in-first-out (fifo). Thus, input and output job requests have equal priority.

Table 2 shows the logical changeover steps. The changeover logic is exercised when the first assembly cell in each module completes an assembly cycle. In step 1, the current production levels and an estimate of the remaining production time are determined. If the estimated remaining production time is less than the lead time to replenish an order, a pallet load of all subassembly components in the new bill of material that are not currently in the system is ordered.

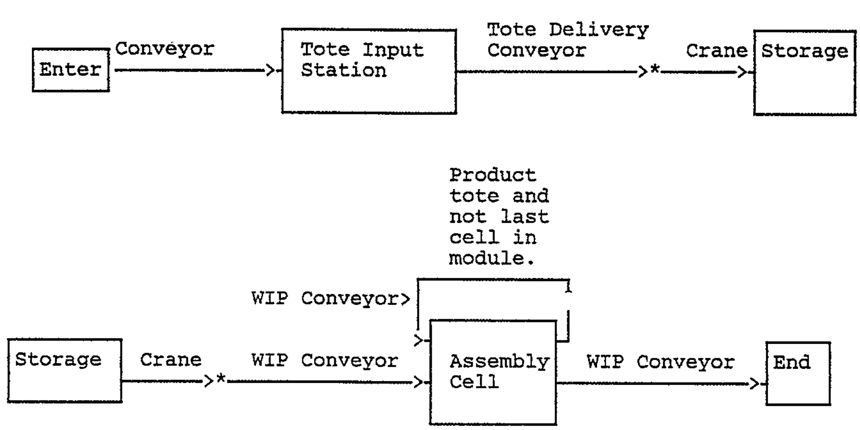

Figure 1. Operational Sequence

Step three checks if the production requirement for the current final assembly is met. If the production requirement is met, step four checks if any more products are in the schedule for this module. If there are no more products to assemble the assembly cell is set to idle. If there are more products to assemble, step five determines if the subassembly components in the bill of materials for the new final assembly are in the ASRS. If all subassembly components are not in the ASRS, the assembly cell waits for delivery of the subassembly components to the ASRS. If all subassembly components are in the ASRS, the assembly cell starts production on the new final assembly.

Step #	Description
1	Estimate remaining production time.
2	Order required parts if production time is less than lead time to deliver new parts.
3	Determine if production requirement is met. If not continue production.
4	Get outstanding build order.
5	Check inventory for required parts and begin production of new product.

Table 2. Changeover logic.

ANALYSIS OF RESULTS

A day's schedule was simulated and the results are presented in Table 3. With the controllable factors at the specified levels, the system assembled 5295 products. Since the system production requirement was 5200 products per day, the daily production requirements can be met by operating the system at the current levels of the controllable factors.

Wait Time for Crane (min)	.52
Utilization	75.00%
Daily Production	5295

Table 3. Results of simulation run.

As the table shows, the crane utilization is 75%, and the wait time for the crane is .52 minutes. These results were considered acceptable to the design engineers.

At this point an effort was made to simplify the control logic of the system by reducing the number of zones from four to two. The results from the simulation run show that the crane utilization increased to 84% and the wait time for the crane increased to .75 minutes. The reason that the wait time for the crane increased is because decreasing the number of zones increases the average distance that a subassembly component needs to travel from the storage position to the delivery point. Thus the crane utilization is increased. In this case the simplification of the control logic does not justify an increase of 50% in the wait time for the crane.

Other embellishments to the levels of the controllable factors were made. Some embellishments improved system performance while others did not. The point that needs to be made is that the simulation study helped identify base case levels of the controllable factors that can operate the system at acceptable levels of performance. Once those are established one can fine tune the performance of the system with further testing of the simulation model.

CONCLUSION

When a system designer is faced with the task of analyzing designs that do not yet exist he is constantly faced with the problem of deciding what design parameters are significant. Often the most significant factors are discovered only after numerous less significant factors are examined. This dilemma is particularly true in systems that are software intensive. The controllable factors identified in this paper also will be significant in many systems that utilize similar equipment performing similar tasks. The most significant benefit of this study to the authors is that it developed a procedure of analyzing a system beyond the traditional points of how many machines are required or what the downtime implications of the equipment are.

This study also revealed the fact that it may not be possible to find commercial equipment that will meet all of the requirements specified in an initial design. This is particularly true for software intensive equipment such as an ASRS. Therefore it is important to understand the software capabilities and limitations of available equipment and account for these limitations during the analysis phase of the system design.

The system discussed in this paper is currently in the implementation phase. The simulation model is being used extensively to aid in the fine tuning of the operational parameters. The system is scheduled to be in full production in the fourth quarter of 1988.

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Maged M. Dessouky

Maged M. Dessouky is a Member of Technical Staff at Bell Communications Research. His work involves developing operations systems plans to support telephone company operations. Prior to joining Bell Communications Research Mr Dessouky was a Senior Systems Analyst at Pritsker & Associates. He received his Bachelors of Science and Masters of Science degrees in Industrial Engineering from Purdue University. He is a member of IIE, Alpha Pi Mu, Omega Rho, and Phi Kappa Phi.

Paul C. Caruso

Paul C. Caruso is a Manufacturing Development Engineer at the Ford Motor Company, Plastic Products Division. His work involves the development of automated manufacturing and support systems. He received his Bachelors of Science degree in Mechanical Engineering from Michigan State University.