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MODELING TECHNIQUES FOR MANUFACTURING CONVEYOR SYSTEMS USING GPSS

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Computer simulation has long been recognized as a valuable tool for designing and analyzing manufacturing systems. In particular, the transaction flow basis of the GPSS (General Purpose Simulation System) simulation language is well suited for the part flow nature of many manufacturing processes. This paper will describe the simulation of a proposed crankshaft machining line using GPSS with emphasis on coding techniques for modeling various commonly found elements of manufacturing and material handling systems.

Computer simulation has long been recognized as a valuable tool for designing and analyzing manufacturing systems. In particular, the transaction flow basis of the GPSS (General Purpose Simulation System) simulation language is well suited for the part flow nature of many manufacturing processes. This paper will describe the simulation of a proposed crankshaft machining line using GPSS with emphasis on coding techniques for modeling various commonly found elements of manufacturing and material handling systems.

The system under analysis was the crankshaft machining department of a new automobile engine plant. The department has 16 operations and a varying number of machines in each operation for a total of 46 machines. Within an operation, all machines are identical. A description of the department is given in Fig. 1. Between operations, crankshafts are transported via monorail conveyor systems. This monorail conveyor is a powered, closed-loop chain from which equally spaced carriers or "buckets", each capable of holding one crankshaft, are suspended. Associated with each machine are entry and exit accumulating conveyors. When a full bucket passes the end of the entry conveyor, an iron arm automatically lifts the crankshaft from the bucket and places it on the entry conveyor for delivery to the machine. Similarly, when an empty bucket passes the end of the exit conveyor, an iron arm removes a crankshaft from the end of the exit conveyor (if one is present) and places it in the bucket for delivery to the next operation. A schematic of the monorail-conveyor-machine interfaces is given in Fig. 2.

<u>Machines Per Operation</u>

Operation Number	Machines In Operation
10	2
20	4
30	3
40	2
50	4
60	2
70	2
80	3
90	2
100	4
110	8
120	3
130	3
140	2
150	1
160	1

Fig. 1

The general flow of parts through the department is as follows. Rough crankshaft castings from a foundry are manually loaded onto the monorail preceding the first operation, distributed to the machines of the operation, machined, automatically loaded onto the monorail feeding the

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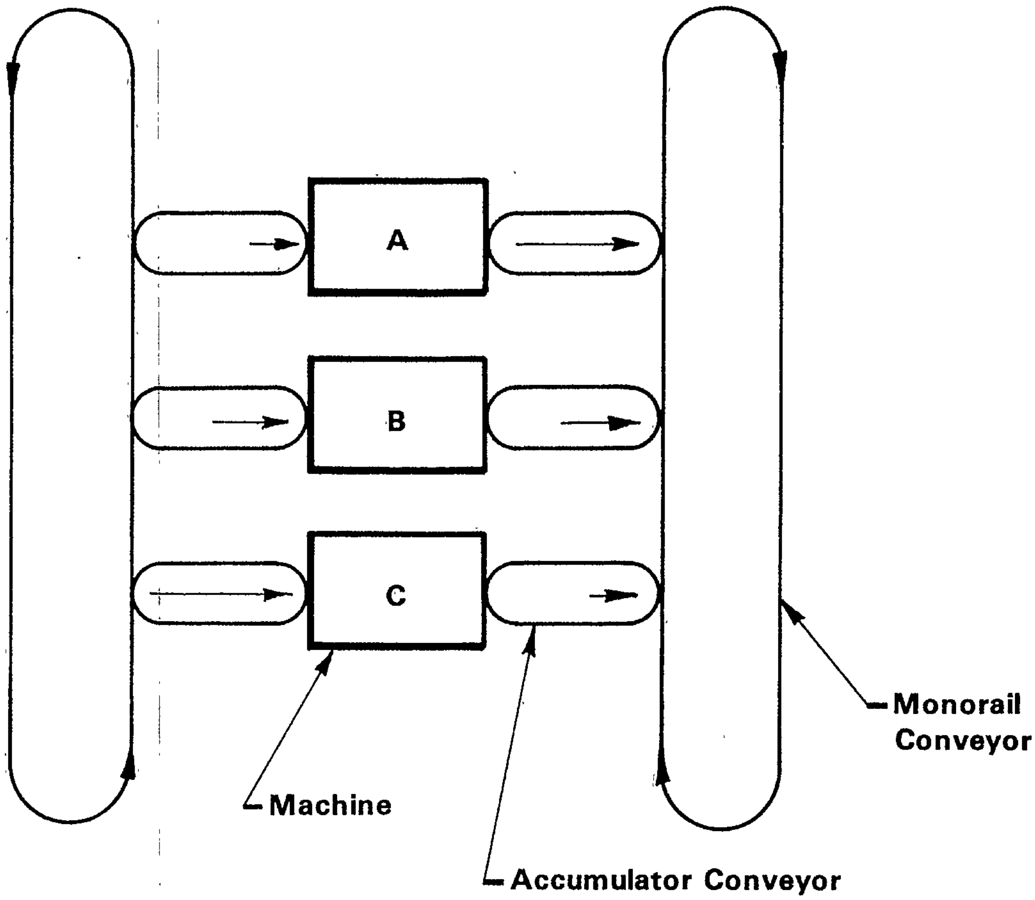


Crankshaft Material Handling System
Figure 2

second operation, and so on. Completely machined crankshafts leaving the sixteenth operation are stored awaiting their use in the engine assembly department.

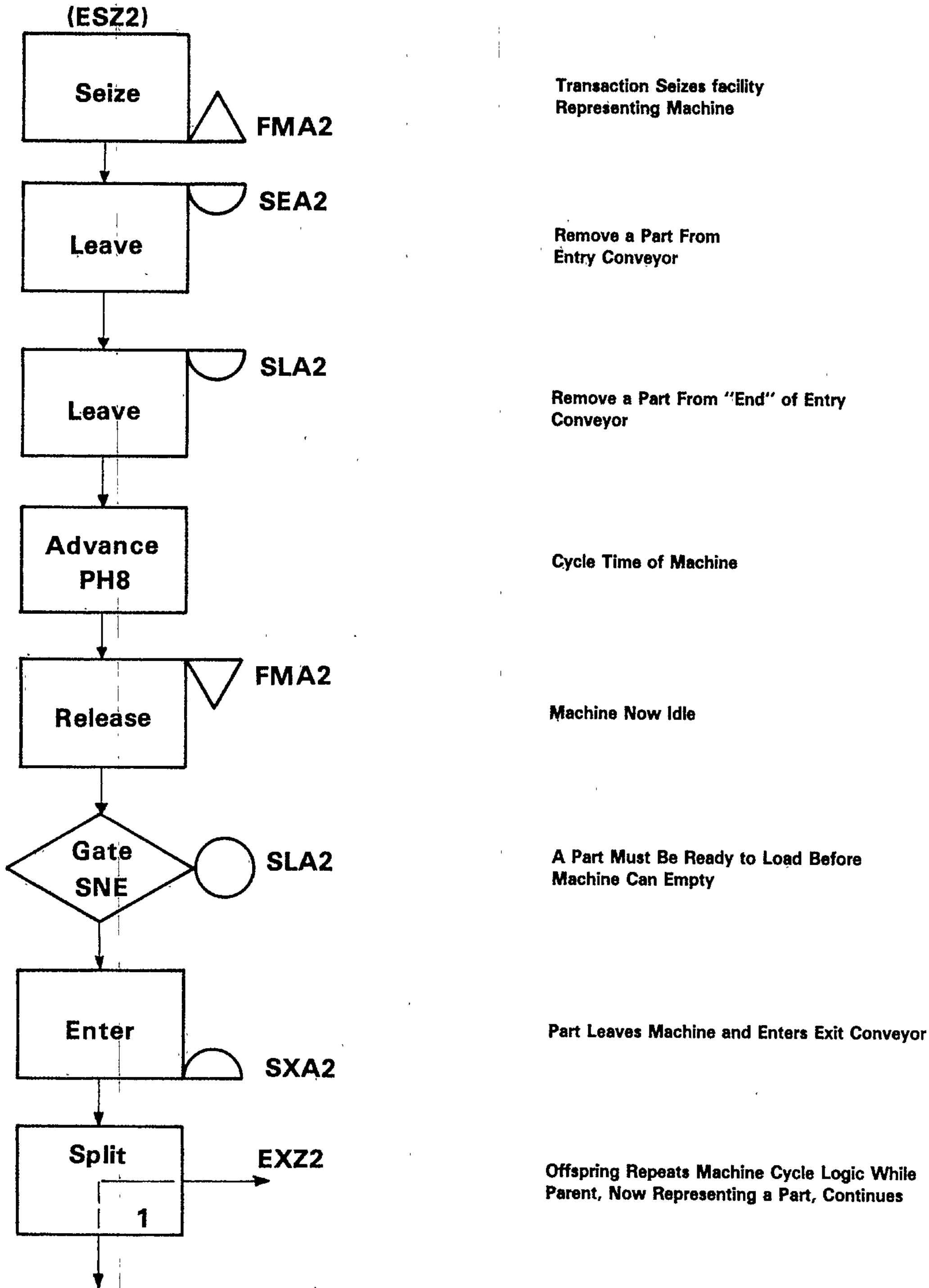
The simulation project was divided into two phases. In the first phase, only the automatic equipment in the system would be modeled. Under investigation were such factors as the number of machines per operation, capacities of machine entry and exit conveyors, lengths and capacities of monorail conveyors, and monorail-to-machine distribution algorithms. Data relevant to this phase of the analysis included such items as monorail speeds, machine cycle times and tooling requirements, which were taken from equipment specifications, and machine inter-breakdown and repair distributions obtained from historical records of similar operations. Significant breakdowns of monorails were considered rare and not included in the model.

The second phase of the simulation project dealt with analyzing the effect of operating policies, particularly task priorities, on department productivity. Labor utilization influences productivity in such a department in primarily two ways: machine maintenance, both repairing random breakdowns and performing scheduled tool changes, and material handling. Because of the limited storage capabilities of monorail conveyors, it is often necessary, during periods of excessive machine downtime, to manually load parts to floor storage from the monorail in front of the affected operation and manually load parts onto the monorail after the affected operation. Two classifications of labor were modeled for this department, material handlers, who perform only material handling duties throughout the department, and job setters, who, while assigned to specific machines, perform tool changes, assist skilled tradesmen in machine repairs, and handle material if necessary. The numbers and assignments of material handlers and job setters were the primary factors under analysis in the second phase of the simulation study.

Certain aspects of a GPSS program to model such a process are immediately evident. GPSS transactions are used to represent crankshafts moving through the system, although for storage and processing time efficiencies, every effort is taken to minimize the number of "live" transactions present in the model. GPSS facilities are used to model machines. This representation enables us to incorporate individual part processing and the interruption of processing, that is, machine breakdowns, into the model. GPSS storages are used to represent machine entry and exit conveyors. In order to minimize the number of live transactions in the model, two storages are used to represent each of these accumulating conveyors. When a crankshaft is taken from the monorail, a transaction passes through an ENTER block for the entry storage, an ADVANCE block representing the travel time on the conveyor, another ENTER block for the machine load storage, and then TERMINATES (see Fig. 4c). Then, when the machine is ready to begin the next processing cycle, this machine load storage is checked for positive contents. (A flow diagram of machine processing code is given in Fig. 3.) Thus, transactions remain in existence only while the crankshafts they represent are undergoing change (movement or processing). Similar logic is used for the machine exit-monorail load conveyor.

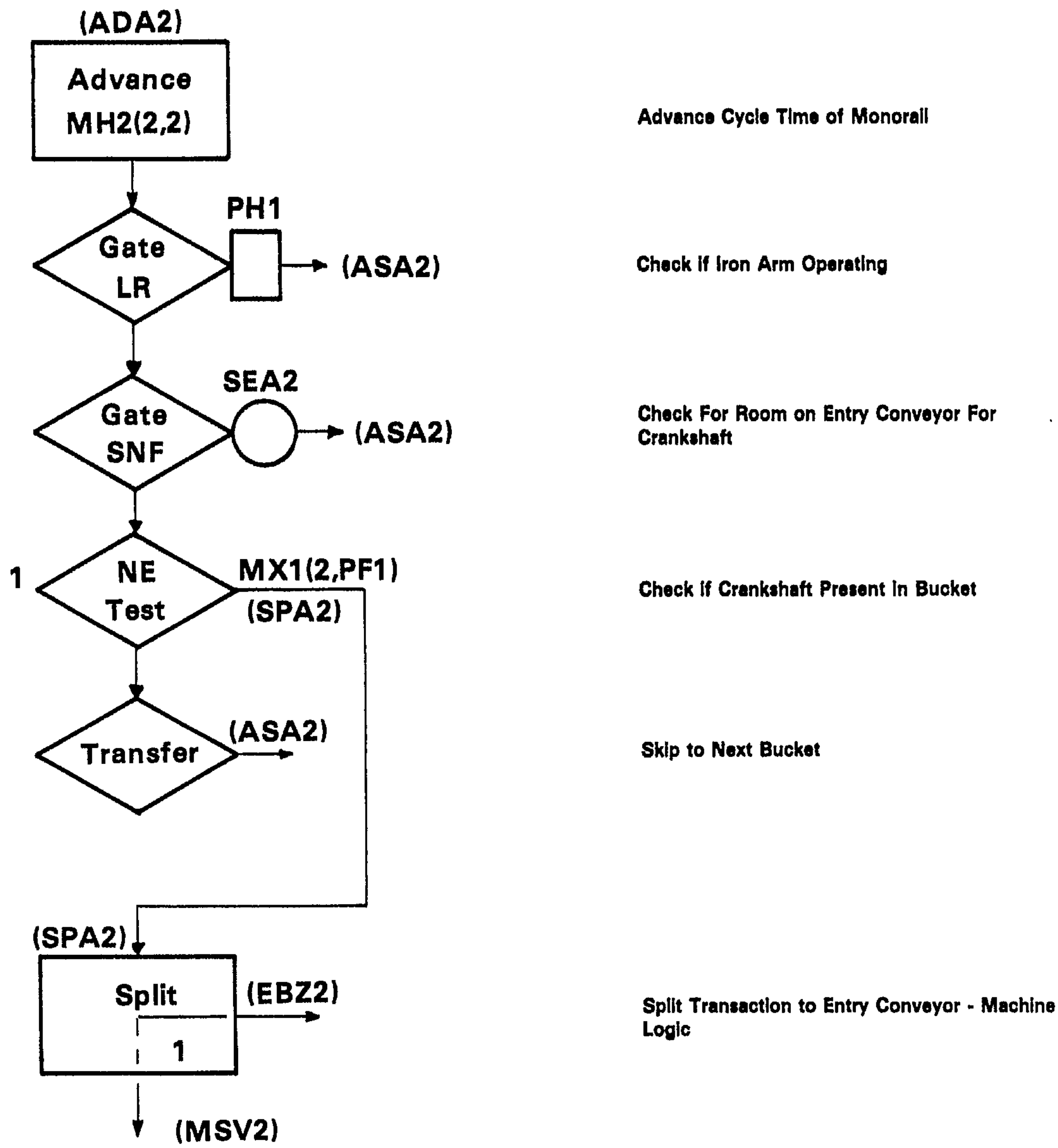
The monorail conveyors presented the need for an alternative part movement representation. On a monorail, the crankshafts are continually in motion. As a loaded monorail bucket passes the end of a machine entry conveyor, a check is made to determine if space for a part is available on the conveyor, and if so, the transfer is made. During times of congestion, it is possible for a crankshaft to pass all the machines in an operation and loop back toward the preceding operation. To model this using the logic described earlier for accumulating conveyors would be awkward and inefficient. One of the more obvious ways to model a process such as this is to use a row of a matrix savevalue to describe the contents of the monorail. Buckets on the monorail are represented by cells in the matrix, and the value of the matrix cell describes its current state. A zero value can be assigned to an empty carrier and a non-zero value, such as one, to a full carrier. A given monorail is accessed by the exit conveyors for one operation and the entry conveyors for the succeeding operation, and so a method of indicating which bucket is currently being accessed by a conveyor was needed. This was accomplished by having one monitor transaction for each conveyor pass through a segment of code modeling the monorail-conveyor interface with a parameter holding the appropriate value. A flow diagram of this interface for monorail 2 is given in Fig. 4. Notice that the current access bucket (held in PF1) is decremented at discrete points in time separated by the monorail cycle time (held in MH2(2,2)). When the access bucket value is decremented to 0, it is reset to be the total number of buckets on the monorail (held in MH2(2,1)). Note that this modeling concept can be easily modified to include the cases of monorails that carry multiple types of parts or multiple parts per bucket.

An overall description of the model is now given. Essentially, the model is composed of separate code segments representing various aspects of the real system. These segments interact by referencing common GPSS entities used to model particular system elements, such as the facilities representing machines. This makes the evaluation of alternative modeling techniques and overall model verification easier. This also makes the models simpler to understand which enhanced the communication process with our users. Often, only one monitor transaction loops continuously through a segment performing some system function and creating new transactions whenever necessary to model part movement or initiate another system function. In other model segments, several transactions were present, representing distinct but identical entities in the system. Specifically, machine processing segments, as shown in Fig. 3, monorail-machine entry conveyor segments, as



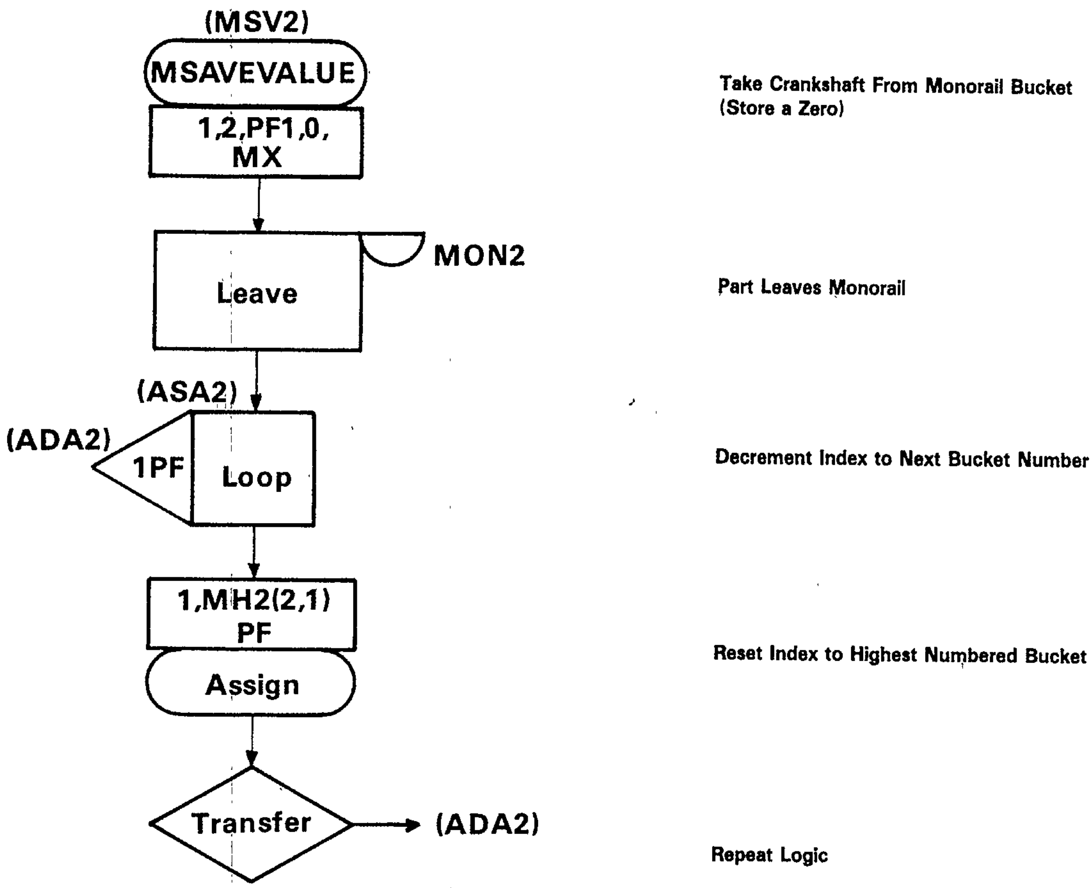
Machine Processing

Figure 3



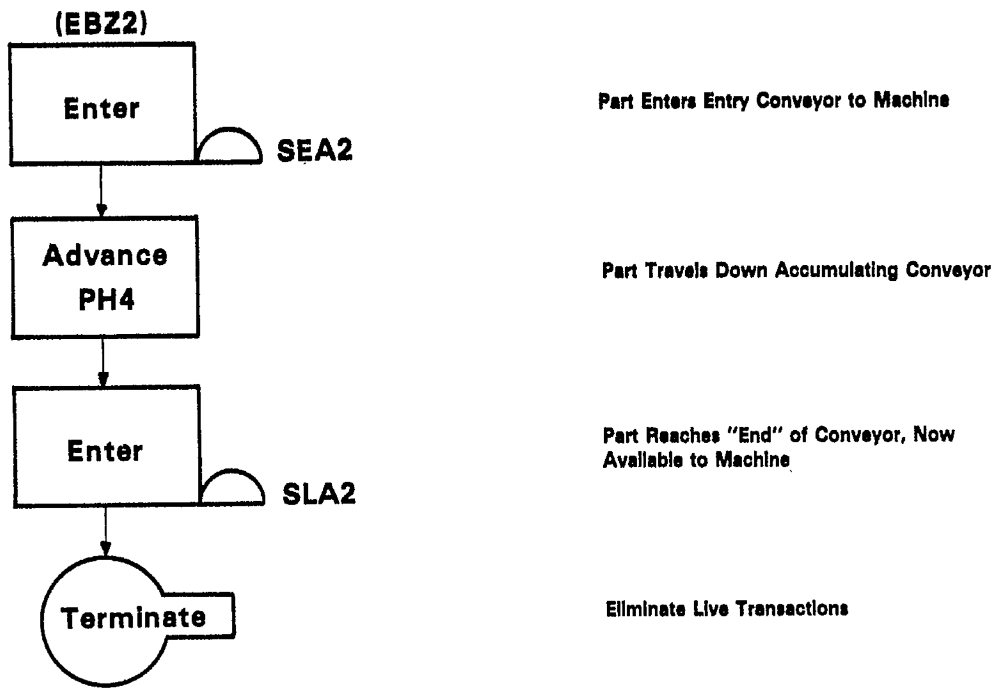
Monorail - Entry Conveyor Interface

Figure 4a



Monorail - Entry Conveyor Interface

Figure 4b



Monorail - Entry Conveyor Interface

Figure 4c

shown in Fig. 4, monorail-machine exit conveyor segments, and machine breakdown segments were included in the model for the first phase of analysis. In order to study the influences of labor policies for the second phase of the project, some modification of the machine breakdown segments and a material handling segment was added. This material handling segment monitored the contents of the monorails and of floor storage areas and initiated the proper system response to correct storage imbalances.

These two models, the manufacturing and labor models, were used extensively in designing the proposed department. As mentioned earlier, the manufacturing model was used to analyze the effectiveness of the automatic equipment, such as storage and monorail capacities and machine utilization. One interesting aspect of the analysis involved studying the effect of various part distribution or "picking order" algorithms by which the iron arms on each machine entry conveyor take parts from the monorail. The alternatives are given in Fig. 5. It was found that although alternative 3 caused machine utilization to be balanced for a given operation, alternative 1 yielded the highest overall system throughput and, hence, was adopted. Significant savings were realized through the elimination of under utilized machinery. Using the labor model, significant productivity improvements were obtained by balancing manpower workloads. Also, by selectively locating and sizing critical floor storage areas, in-process inventory levels were substantially reduced from those found in current similar departments.

Picking Algorithm

1. Grab every crankshaft.
2. Allow N number of racks to pass.
3. Allow N number of racks with crankshafts to pass.
4. Check contents on the buffer accumulator conveyors.

Fig. 5

REFERENCES

Schriber, T. J. (1974), Simulation Using GPSS, John Wiley & Sons.