GPSS STUDY OF WORK-IN-PROCESS INVENTORY

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Summary

This paper reviews the use of two GPSS models to verify effects of changes in an inventory control system. Selected model output, general descriptions of the models, summarization of output and discussion of results are included. The GPSS models were essentially inventory models which determined the work-in-process inventory (WIP) variations under two different methods of controlling and disbursing a high cost inventory item. Reductions in the amount of WIP required to meet production, control of WIP and amount of exposure to inventory obsolescence were measured by the GPSS models.

Introduction

Early in 1968 a successful simulation study was made of the keypunch assembly line at the IBM Systems Manufacturing Division plant in Poughkeepsie, N.Y. Based on the success of this experimental simulation study, IBM established a division-wide simulation project for the Systems Manufacturing Division (SMD) in March 1968. This project was intended to acquaint the SMD plants with management science techniques in inventory management.

The General Purpose Simulation System (GPSS) was chosen as the management science tool to study inventory management. GPSS was chosen because it is an IBM Type II program, fully supported by the IBM Data Processing Division; training courses are available at IBM education centers; some plants already had personnel trained in GPSS; and it provided a common language which facilitated exchange of information.

The simulation project had two main purposes for being established at the IBM Boca Raton plant:

1. A training vehicle to acquaint plant personnel with GPSS as an analysis tool.

2. To provide data to support or disprove proposed changes in inventory management of a high-cost computer part at Boca Raton.

In May 1968, the IBM Boca Raton facility, having no personnel trained in GPSS and none of the required computer hardware or software, embarked on its first simulation project. The study was conducted over a nine-month period and was successful in meeting its objectives.

The following discussion will describe: objectives of the simulation, the GPSS models that were used, results of the simulation and the presentation to management. All of the data presented in the following discussions of results of this project is simulation data. For example, the plotted output in Figures 3 and 4 contains data from GPSS simulation, not actual inventory quantities.

Objectives

As mentioned, one of the main objectives of the simulation at the Boca Raton plant was to test a proposed change in inventory management procedures for one of the high cost parts of a computer.

The "high dollar" parts studied were pluggable integrated circuit boards called "cards." Each card contains many electrical circuits and several hundred cards are used in (plugged into) each computer assembled at the Boca Raton plant. Although the cards are small and relatively easy to store, each one is expensive and many dollars can be invested in inventory of these cards. Typically, some of the cards are subject to rework before they can be used because of engineering changes. This rework expense can be reduced by proper control of card inventory.

Without any analysis it seemed logical that reducing the amount of in-process and warehouse inventory would lower the dollar investment in inventory for the plant and also reduce the rework expense associated with the cards. However, the following "unknowns" required answers:

1. How much could the inventory of cards be reduced without jeopardizing production schedules?

2. Would manufacturing efficiency be affected?

3. Would the dollar savings be realized for some products and not others?

4. How much would the dollar investment in inventory be at any point in the production cycle?

5. Would more or less manpower be required?

Simulation of the so-called "present" method of operation and the "proposed" method was performed to provide answers to these questions and others. The existing method will be referred to in this paper as the "present" method, and the new method as the "proposed"

method. The engineering group proposing the inventory changes and the simulation analyst both approached the project objectively. This understanding between the simulation analyst and the engineers was important so that the analysis could be performed without prejudice and "hidden objectives."

The GPSS Models

Two different simulation models were built:

1. A model of the existing method of card inventory and usage on the computer assembly lines.

2. A model of the proposed method of card inventory control and associated assembly procedures.

Representations of the present and proposed methods of card inventory procedures and associated assembly activity are shown in Figures 1 and 2, respectively. In the present method, cards are stored in a "card crib," which is controlled by Production Control (PC). According to a lead time set by Production Control, cards required for production are sent to an inventory point on the assembly line. Maintenance of this "line" inventory is also under control of PC. As computers move down the assembly line to the card installation station, assembly personnel go to the line inventory of cards, choose those needed, and install them in the computers. All of the computer assembly lines in the present method require the above described procedure with a manufacturing line inventory of cards as well as cards stored in the Materials Distribution Center.

The proposed method of card inventory (Figure 2) requires only one inventory of cards for all of the computer assembly lines. It was proposed that this inventory would be stored in a card crib on the assembly floor. Then the computers would come to the card crib for installation of cards.

It was thought that this procedure would provide the following advantages which simulation would prove or disprove:

1. The need for a duplicate inventory of cards at each assembly line would be eliminated.

2. The number of inventory control personnel would be reduced.

3. Efficiency of the card installation personnel at each card-installation operation would be increased by having these personnel install the cards in more than one type of machine.

4. The proposal would provide other benefits such as reduced space requirements and reduced exposure to card rework (as previously described).

The GPSS models used in this study are basically simple in contrast to complex models sometimes built to demonstrate the analyst's expertise. It was decided to keep the models simple so that the engineers and managers involved, who were not programmers, could understand the general workings of the models. Their understanding was important since this was the first application of simulation techniques to an existing plant situation at Boca Raton.

Flexibility was purposely designed into the models through the use of variables and functions so that many experiments could be conducted with the models. For example, different lead times, production schedules, and inventory operating rules could be changed or inserted by simply adjusting the variables or functions. The ease with which experiments could be performed aided acceptance of the simulation by the engineering groups.

The real world was accurately represented in the models. This was especially true for the inventory control procedures being studied. The models simulated the daily production for two years of four different computers. The models were designed to constantly check the level of inventory in the Materials Distribution Center and on the assembly lines against not only current production at any time, but also against future production requirements. All of this activity had to meet the prescribed inventory control operating rules of the present and proposed methods. The ability of the models to accomplish these tasks was important to Production Control and Manufacturing management.

The real world was approximated in some cases, however. For example, the following real-life situations were not simulated:

Stock out (or not stock) situations

Overtime conditions

Production reschedules

Varying skill levels of assembly personnel

Analysis of the output showed that these limitations did not jeopardize the validity of the results.

Most of the data required in the simulation was readily available since these were essentially inventory models. However, one of the four computers that was involved in the simulation was new and not in production at that time. Data for this computer was estimated by development engineers using current computer models as a basis. Meetings were held to obtain agreement on the required cost data to be used. The agreements on data that resulted from these meetings also aided other studies regarding the new computer.

Simulation Results

The output of the simulation models produced the following kinds of data:

1. Manpower required for card inventory control and card installation on the assembly lines.

2. Efficiency of card installation in assembly.

3. Inventory amounts:

   - Average inventory of cards required per computer
   - Maximum and minimum quantity of cards required by inventory control and manufacturing to meet schedules
   - Dollar investment in card inventory for each computer
   - Maximum order lead time for card inventory

The position of card inventory, required by manufacturing and inventory control, for each computer type at two-week intervals for two years was plotted.

The output of simulation was to be used to show management the feasibility of making the proposed inventory control changes. After simulation provided data to prove the soundness of the proposed method to the engineers studying the problem, it was decided that plotted output would best represent the proposed method. These plots of the level of card inventory in the assembly area and in the Materials Distribution Center were shown to management. Examples of the plots are shown in Figures 3 and 4.

By use of the plotted output, management could "see" the levels of card inventory every two weeks during the two years of the simulation for every computer type. The plots also dramatically showed the difference in card inventory required under the present method versus the proposed method of inventory management. All of this was accomplished by showing the plotted output directly as it came from the GPSS without any additional embellishments.

Computer resources used for debugging the simulation models were different from computer resources used for the final output. For the first few months while the models were being constructed and tested the Boca Raton plant did not have the hardware or software required to run GPSS. During this phase of the project the models were input to an IBM 2741 communications terminal over telephone lines to an IBM System/360 Model 50 in San Jose, California. The Model 50 in California would immediately queue the Boca Raton simulation with the other jobs on the system and process it as its turn came up. The results of the Boca Raton simulation would be automatically stored in the computer in California to await retrieval over the 2741 terminal in Boca Raton. This system provided an excellent method of debugging since turnaround was fast and the 2741 terminal allowed direct access to any line of the printed output without looking at the entire output. Thus the computer in California was asked to search the stored simulation output for the words "error in block number..." Then the computer would print just the information associated with the error.

The models were validated with data from Production Control, Manufacturing Engineering, and Industrial Engineering. The model of the present method was used not only for comparison with the proposed method but it was also used as the validation model. Output from the model of the present method regarding quantity and dollar investment in card inventory was compared to the current planning of Production Control. It was found that the card inventory being projected by the simulation was 96% of the amount being projected by Production Control planning.

The results of the simulation studies fully supported the proposed changes in inventory management of cards. The results showed dramatic reductions in average and maximum amounts of card inventory with the proposed method in comparison to the present method. The percentage reductions in card inventory are summarized below.

Table I. Summary of simulated card inventory reductions.

Average Card Requirement Reductions

Computer Type	Year 1	Year 2
I	66%	64%
II	67%	55%
III	71%	58%
IV	94%	90%

Maximum Card Requirement Reductions

Computer Type	Year 1	Year 2
I	53%	52%
II	33%	18%
III	43%	36%
IV	91%	91%

The "average card requirement reduction" above refers to the amount by which the median card inventory was reduced by the proposal. In the same manner, the "maximum card requirement reduction" shown refers to the amount by which the highest card inventory requirement point was reduced in the simulation of the proposal. Furthermore, simulation showed that the above reductions in card inventory could be achieved with no loss of efficiency in the assembly lines.

The dollar investment in card inventory at the end of each month of simulated production was calculated by the models. Following are the projected reductions in card inventory investment resulting from the proposed changes in inventory management.

Table II. Simulated card inventory investment reductions.

Computer	Year 1	Year 2
I	48%	84%
II	32%	81%
III	75%	87%
IV	92%	92%

Presentation to Management

The simulation project group had agreed to reveal the results of the study to selected management first and then in a group meeting of all management later. The results were not publicized until these formal presentations.

It was decided following the presentations to management that a committee should be formed to implement the proposal as it was simulated. This committee was made up of representatives from a half-dozen different functions that would be affected by the proposal. The objectives of the implementation committee were several: establish a target date for implementation; construct a schedule of events for all the required implementation activity; and determine the costs of implementation.

At this point the simulation analyst's job was completed and he stepped out of the picture, so to speak. He consulted with the committee but was not a committee member. To date the proposal has not been implemented because of external conditions beyond control of the Boca Raton plant. The mode of operation at present is essentially that simulated in the so-called present method previously described.

Conclusion

This simulation study provided the means for an organized analysis of a recognized problem. Simulation provided the data necessary for a rational decision based on the objectiveness of facts.

In retrospect there is some question concerning the appropriateness of simulating inventory problems. There are other less costly and less time consuming methods of analyzing inventory problems. In addition, simulation can be such a powerful tool that it may pre-sell the solution of relatively simple inventory problems.

In this case, however, simulation was worthwhile because of the ease of experimentation and analysis of various "what if" situations after the models were built. Also, this ease of experimentation probably resulted in the analysis of more different situations than would have been attempted with other analysis tools. The simulation provided the information required to aid management in analyzing the advantages and disadvantages of the two methods of operation.

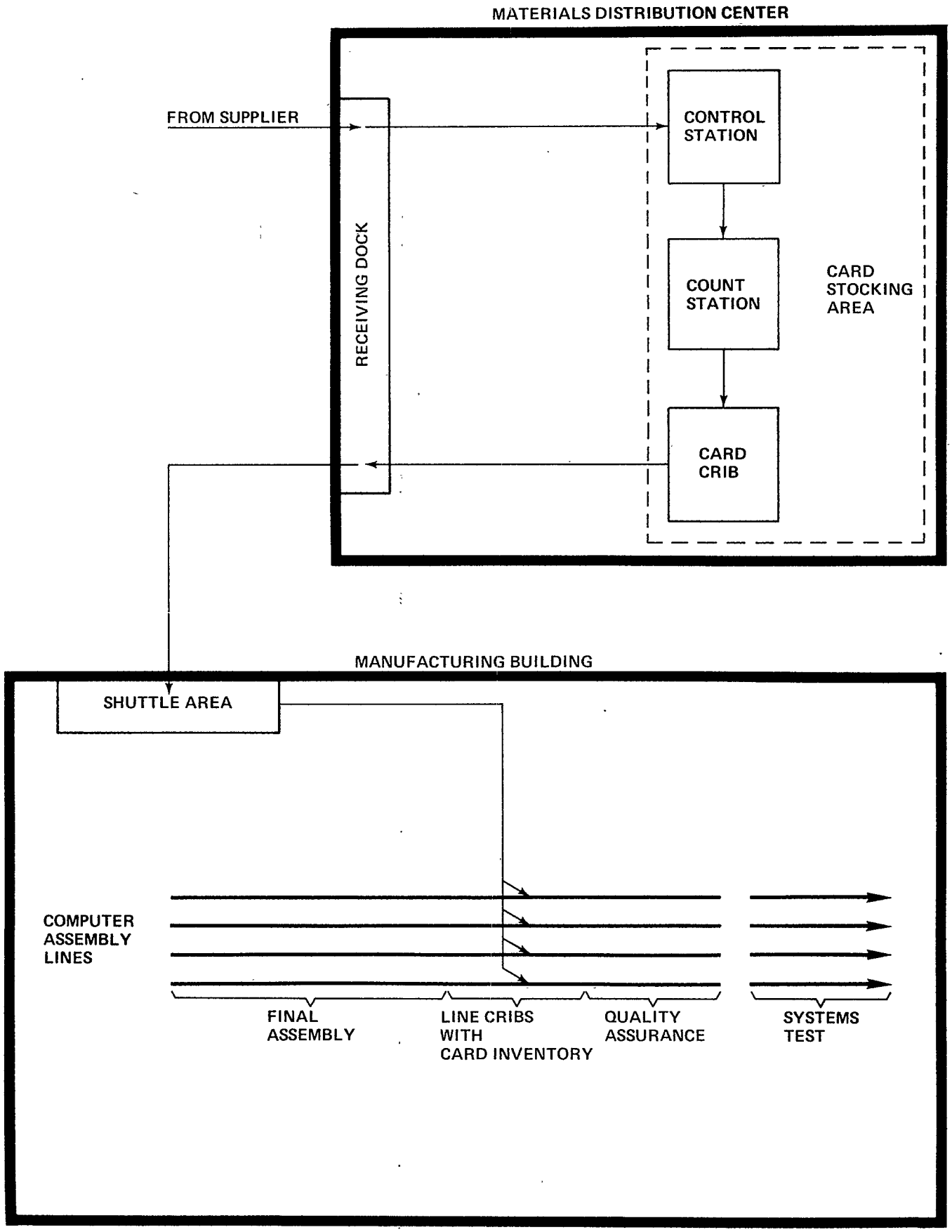

Figure 1. Present method.

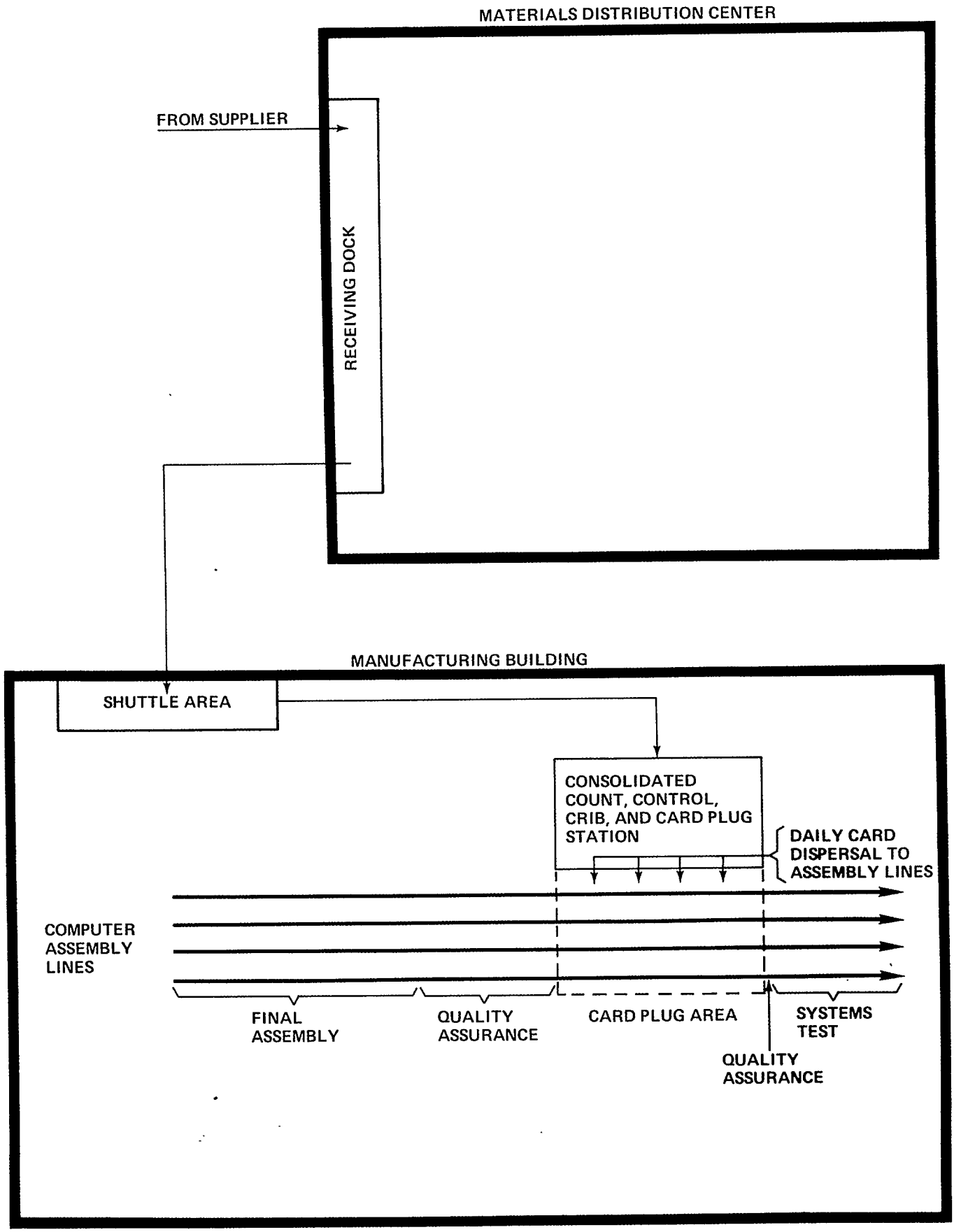

Figure 2. Proposed method.

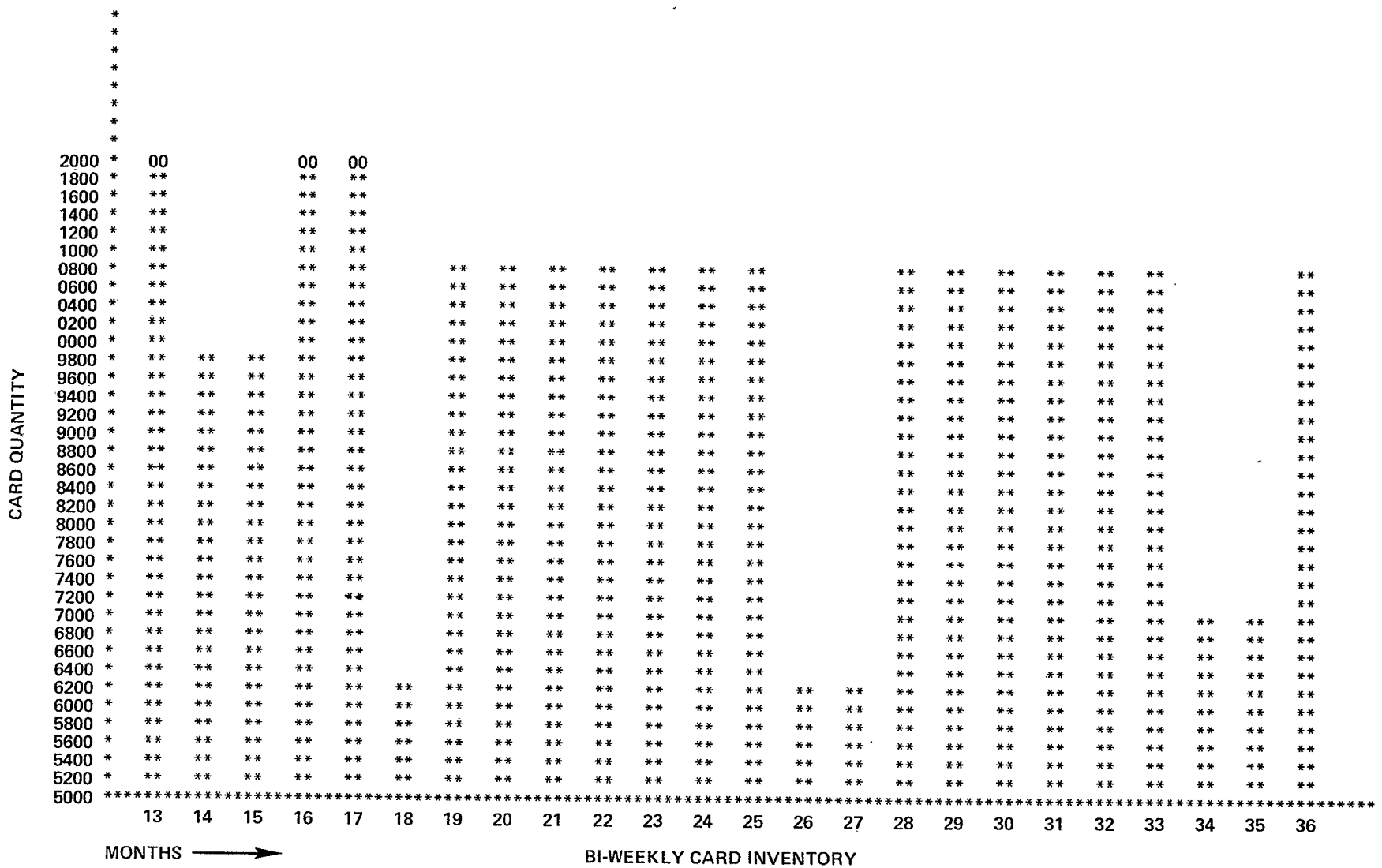

Figure 3. Computer I card inventory requirements, present method.

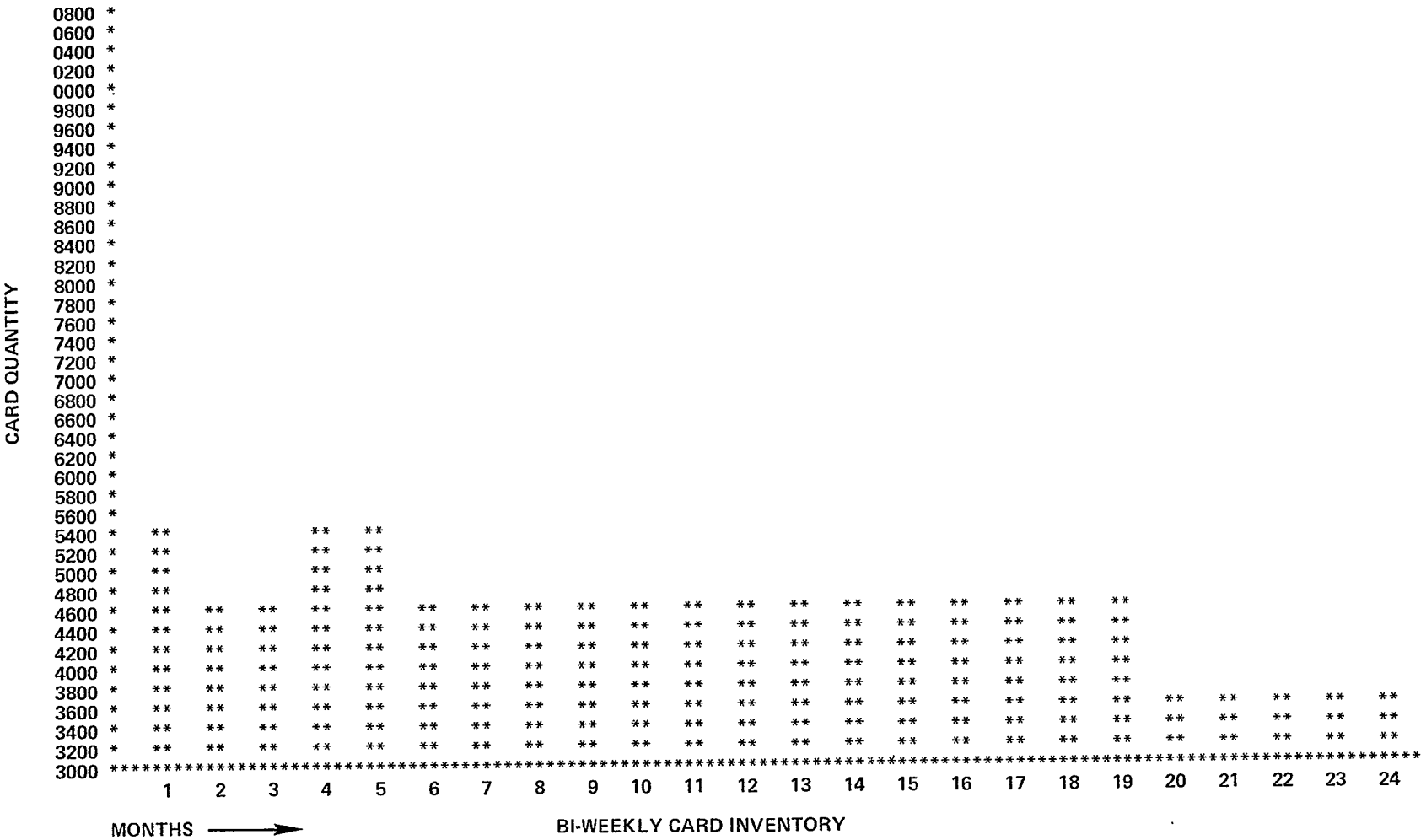

Figure 4. Computer I card inventory requirements, proposed method.