ANALYSIS AND DESIGN OF A MATERIAL DISTRIBUTION CENTER CONVEYOR NETWORK THROUGH GPSS SIMULATION

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ABSTRACT

GPSS simulation was used to evaluate the design of the proposed pallet handling conveyor system. The discrete conveyor system will be installed in a new warehouse to move material from dock to stock, manufacturing and shipping. This paper describes how simulation proved to be an invaluable tool in solving the complex problem of designing a feasible system and ensuring the efficiency of design.

INTRODUCTION

This study describes how the simulation technique was used in designing the conveyor network for the proposed Material Distribution Center (MDC) at the IBM Corporation, Endicott, New York. The MDC will be used for receiving, inspecting parts, storage, processing or filling production orders for parts and meeting customer parts requirements. The items handled include frames and cover kits, small parts, and sub-assemblies used in the manufacture and maintenance of IBM products.

The proposed MDC building is quite different from the present warehouse at Endicott. The MDC will have a total area of over 200,000 square feet, part of which is two stories. This building will contain areas such as docks, count and backorder, inspection, bins, Automatic Storage and Retrieval System (ASRS), sort and accumulate and shipping. The conveyor network under consideration will transport palletized loads from one section of the MDC to another and also to the manufacturing area.

Industrial Engineering worked with a consultant on the problem of proposing a conveyor network. The present warehouse activity was studied to determine the flow of pallets from one area to another. Requirements to be met by the conveyor system were also defined. The conveyor network proposed is shown in Figure 1.

The question to be answered was, how will the proposed system perform under real operating conditions? No previous experience existed to guide us in answering the above-mentioned question.

It was not known how the operations of one area would affect the flow of pallets in other areas. We were not sure how fast the lifts and the conveyors should run, how many spurs would be needed in the count/backorder area and how long they should be. There was one particular conveyor section which, if it were full could stop pallet flow in the whole network. With a significant amount of investment at stake and a critical need for the smooth flow of pallets, we had to know what to expect. The fluctuation in the rate at which pallets enter the network from different areas, the variation in the operation time from pallet to pallet at different work stations, numerous merge points, single lift serving input and output activity of up to three areas; all these made the problem too complex to be solved by analytical techniques. Before making a large investment, it was necessary to know if the system was going to work. The only way to find out was to use simulation to predict the performance of the system. So, we decided to simulate. Our goal was to design a conveyor system which could efficiently handle the pallet flow activity in the MDC. The proposed network was just the starting point.

DESCRIPTION OF THE SYSTEM

The flow of pallets in the MDC is shown in Figure 2.

The material received on the dock is processed through a receiving department which provides the paper work associated with each receipt. Once the paper work has been made available, the material is sent to the count/backorder area. From this point the material can either go to a storage location or to the inspection area. If inspection is not required, back orders are filled and sent to an order staging department. If inspection is required, back orders are filled after the parts have been accepted. Those parts which are not used to fill back orders are placed into storage. This can be in one of several areas. The bin section will contain parts that do not require a great deal of space. Bulk parts are stored on pallets in the automated storage and retrieval system (ASRS). Once placed into the ASRS, the pallets can be pulled out to fill requisitions. The requisitions are then sent to the order staging department, and the parent pallet will be returned to the ASRS. Parts stored in the bin area are sent to the order staging area in conveyor pans, to fill requisitions.

The order staging department directs the orders to one of two locations: (1) The shipping dock for disbursement to other plants or to consigned vendors, or (2) the manufacturing facility for use in assembling the finished product.

The Manufacturing Facility, in addition to being a customer of the MDC, also supplies parts manufactured in plant. These parts enter the MDC and are directed to the count/backorder area from where they will be processed as are the parts coming from the receiving area.

Referring to Figure 1 for a sketch of the conveyor network, some of the characteristics of the system which are relevant to this study are described below:

1. The pallets are of two different sizes.
2. Each area has its own rate of feeding pallets to the network. The number of pallets per hour entering the network from the receiving area, for example, is a function of the hour of the day. This function is shown in Figure 3. It shows how the arrival rate of pallets in the receiving area varies with the time of day. The arrival rate reaches its

highest peak roughly in the middle hour of the day. The maximum arrival rate is five times the minimum.

3. There are eleven spurs in the count/backorder area. They are used for the operation which involves counting, selecting a sample, and filling backorders. This operation time varies from pallet to pallet. Some pallets may take only two minutes, whereas others may take forty minutes. Each of these spurs accomodates up to six pallets. The pallets enter Section 4-3 after the operation is over.
4. Each pallet going to the count/backorder area waits at point 8 for paperwork which must accompany it. It is then sent to any of the eleven spurs if space is available. If all spurs are full, the pallet waits. The waiting time for paperwork varies from pallet to pallet.
5. Backorder Lift: This lift is used for two purposes:
   a. It takes pallets from the first floor to the second floor. These pallets originate at receiving and count/backorder areas. They are traveling to order staging, shipping and plant.
   b. It takes pallets from the mezzanine conveyor to the first floor and unloads them on Section 7-1. These pallets come from the plant and manufacturing spur and go to count/backorder.
6. ASRS Lift: This lift takes pallets from the first floor to an ASRS input station.
7. Mezzanine Lift: This lift takes pallets from the second floor to the mezzanine floor. These pallets either go to count/backorder or to shipping. Pallets going to count/backorder enter the backorder lift which takes them to the first floor.
8. Plant Lift: This lift supplies pallets to the third and fourth floors of the plant. It also brings pallets from these floors to the second floor, where they join the pallets coming from the second floor of the plant and are conveyed to the MDC.

DESCRIPTION OF THE MODEL

A model of the system was constructed in GPSS/360. GPSS/360 was chosen because it provided us with the capability of completing the study in a short time and it also provided sufficient modeling flexibility. The input to the model consists of the following:

1. The distribution of inter-arrival time of pallets at each of the entrance points to the conveyor network.
2. The number of pallets traveling from one area to another for all the areas. This determines the point at which a pallet enters the conveyor network and the point at which it leaves the conveyor network.
3. The speeds of the lifts and time for loading and unloading the lifts.
4. The speeds of each branch of the conveyor network.
5. The time to take a turn at each branch and merge points.
6. Distribution of operation time at count/backorder area.
7. Delay time at all points where a pallet has to wait for dispatching or any other operations.
8. Priority rules to be used at merge points and for dispatching the lift.

The output from the model was statistical information on the facilities, queues, storage and rate of flow of the pallets. The following information was of major importance in measuring the performance of the system:

1. Utilization of all the lifts.
2. Utilization of manpower in the count/backorder area.
3. Maximum and average accumulation of pallets on each branch of the network.
4. Maximum and average number of pallets in queue at count/backorder area.
5. Maximum and average number of pallets in queue for the lifts.
6. The distribution of arrival rates of pallets to different areas in MDC.

The special feature of the program is its ability to model different operating conditions of the conveyor system. The model was built so that we had the capability of testing various alternative operating conditions by making minor changes such as changing a variable or a function or a boolean variable. The GPSS feature MACRO was used to enable us to easily make changes in the network. Just by adding one or two statements, the program can be altered to incorporate minor changes in network flow or to add additional conveyor sections.

Some of the important features of the program are as follows:

1. Each conveyor section can have a different speed.
2. Each area can have a different distribution of inter-arrival time.
3. Priority rules at merge points and for the lifts can be changed to represent different operating rules.

These features were desirable because each area in the MDC had unique requirements and characteristics.

Data on conveyor speeds, lift speeds, lift loading and unloading time was obtained from the equipment manufacturers. The present warehouse activity was analyzed to obtain the other input data such as the operation time at the count/backorder area, pallet flow from one area to another, etc.

The program was run on IBM System/360, Model 65. It required 140K bytes of core. Fifteen minutes of run time were required to simulate the operations of the conveyor system for one week.

SIMULATION EXPERIMENTS AND RESULTS

The first experiment was designed to study the performance of the system with a "first come, first served" priority rule at all merge points and the backorder lift. The lift speed selected was 120 feet/minute.

Simulation results showed that the conveyor section 7-1-2-3-5-6 (shown in thick lines in Figure 4 below) would become blocked in such a way that no pallets can move.

This would cause clogging of the entire network and the conveyors would have to be stopped. The model was run again with the following modifications: (See Figure 4)

1. At point 1, always give priority to pallets in branch 7-1.
2. The backorder lift should not pick a pallet at the mezzanine floor if 7-1 is full. This was tried because all such pallets are taken to the first floor by the lift and enter 7-1, thus causing congestion in branch 7-1.

With this modification there was no blocking of

Section 1-2-3-5-6-7. The utilization of all the facilities was acceptable. It had not been anticipated under the first come, first serve priority rule that the network would become congested and force the warehouse to shut down. We thought that an adequate lift speed would be sufficient to handle the activity without causing congestion. Simulation gave us the ability to identify and solve this problem, before we designed the control system for the conveyor network. Simulation prevented us from making a wrong judgment, which may have caused redesign, replacement and delay cost.

The most important result of simulation was that it proved the feasibility of the system. Also, the simulation provided us with statistical data for measuring the efficiency of the design.

The people working on the design of various areas of the MDC were greatly benefited by the results of simulation. The simulation predicted the arrival rates of pallets in the different areas. This was used to plan the manpower requirements and in estimating the storage space required in the different areas. The arrival rate information was critical for the Automatic Storage-Retrieval System because of capacity constraints.

Another important result was that simulation indicated that only ten spurs were required in the count/backorder area; whereas 11 had been proposed. When this was realized, it was recommended that the count/backorder area and the inspection area operations be reexamined to see if this spur could be used to improve their operations. At present, the simulation model is being modified to test a proposal in which the 11th spur could be used to send pallets from inspection to count/backorder. If this proves to be feasible, the space required in the count/backorder area would be reduced by approximately 5% and the performance of this area would greatly improve. If this is not feasible, we would eliminate one spur and reduce the investment in conveyors.

In summary, simulation helped us to determine a feasible system and improve the design of the network.

CONCLUSIONS

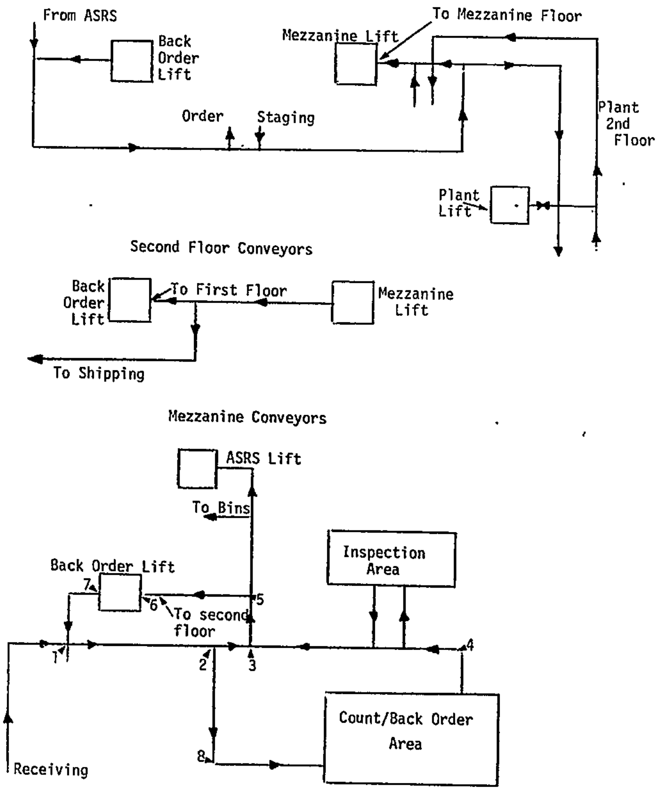
This paper discusses how simulation was used to design the conveyor network for a material distribution center. Simulation pinpointed the potential bottleneck areas and their cause. This helped us in modifying the proposed network and arriving at a system which will satisfy our requirements. Results of this study were used in planning the operations, space and manpower in the different areas of the Material Distribution Center. The results also predicted the performance of the system. The proposed conveyor system will be installed in the new Material Distribution Center now being built at IBM Endicott.

In the computer manufacturing industry, the warehousing activity is very dynamic. We will continue to use the simulation model to predict how the designed system will perform when the requirements change in the future. We believe that simulation is a valuable tool for designing and a reliable method of predicting the performance of conveyor systems.

BIOGRAPHY

Mr. N. N. Tendolkar holds a B. S. degree in Mechanical Engineering from Indian Institute of Technology, Bombay, India, and a M. S. degree in Operations Research from Cornell University, Ithaca, New York. He joined the Systems Manufacturing Division of IBM Corporation in September, 1967. He has been working on developing and designing systems for solving manufacturing and planning problems using the techniques of Operations Research.

MDC CONVEYOR NETWORK



First Floor Conveyors
FIGURE - 1

PALLET FLOW IN MDC

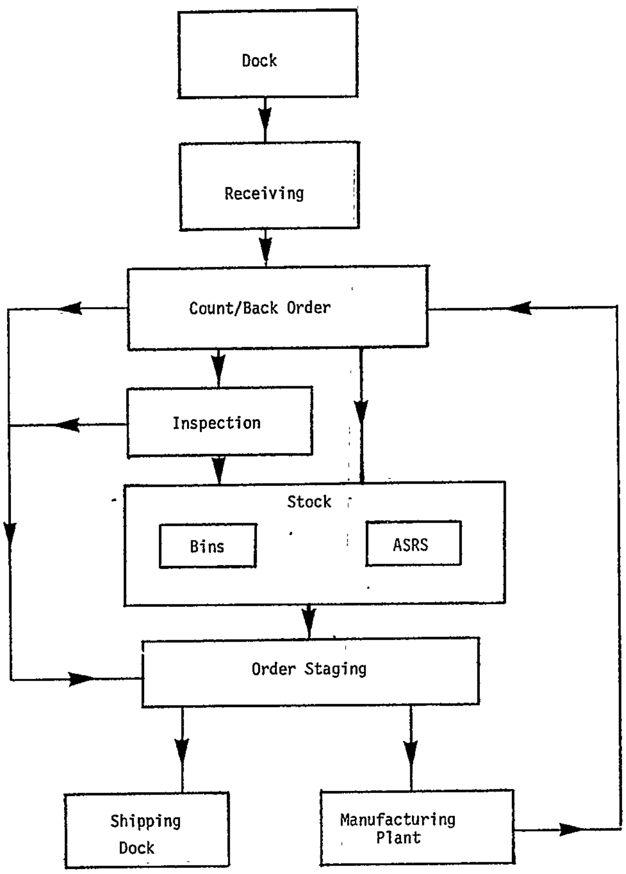


FIGURE - 2

PALLETS RECEIVED IN AN HOUR VARIES WITH THE HOUR OF THE DAY

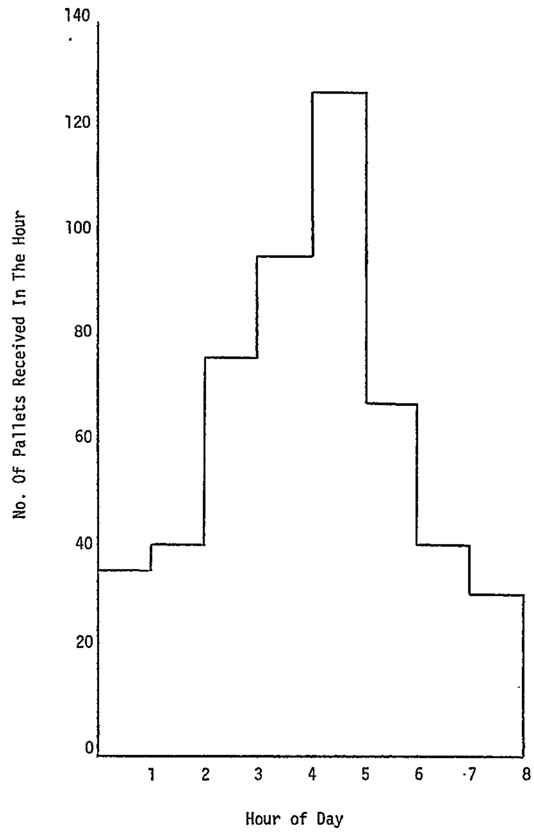
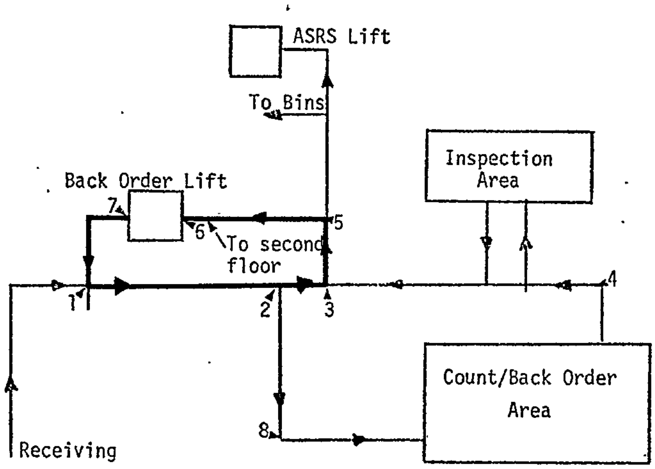


FIGURE - 3



First Floor Conveyors
Figure 4