"AUTOMATIC DATA PROCESSING
IN LARGER MANUFACTURING PLANTS"

by

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If you have ever tried to drag a small child through a toy department, while trying to catch a train, you will have some feeling for the troubles of the Production Control Manager. He is faced with a never ending stream of unexpected troubles, all of which tend to keep him from making good his schedule. Development of ingenious methods to solve this problem has helped some, but in many cases, both the problem and ulcers remain.

The authors are engaged on a research project at the University of California, Los Angeles, on how to improve scheduling. The objectives are to provide quantitative methods as a basis for management decision, instead of the present predominantly intuitive methods. One main phase of the project is developing the "optimum schedule"--that schedule which makes the best use of plant facilities and materials. A conceptual "model" of a scheduling system has been developed by one of the authors and serves as a conceptual "framework" for this study.

But, in addition to methods for developing an optimum schedule, there is the further problem of meeting the schedule. This problem reaches its peak of bewilderment in the large job shop--where a large variety of products is possible, and production is to customer order rather than to inventory. Parts are made in small quantities, and there is a long time between repeat orders, hence, the learning process is minimized. Because tooling on one operation turns out to be unsatisfactory, the job has to be set aside until proper tools are obtained. Then the reworking of incorrectly made parts can throw off the schedule, and the rejecting of bad parts changes the quantity and necessitates rush orders. The machinist, not clearly understanding the print, decides to make the part his way--and sometimes this isn't the right way. Occasionally whole operations are skipped, by sending the parts to the wrong department. Or an order is lost; it is somewhere within the plant but no one knows where. Sometimes you can't determine the cause of the trouble; the part has been made satisfactorily 50 times before but this time it just can't be made right. And then just when everything seems to be going smoothly on the part, the customer changes his order--more earlier, fewer later, cancels out or other.

What is the result of all of this on the schedule and the man who is responsible for it? A sample survey was made in a local manufacturing plant. Table I shows what was happening to scheduling there. Out of 692 orders in the sample, only one was on schedule, all others either were early or

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late relative to the schedule. This same plant publishes a shortage list daily that is about 300 pages long. Decision-making is indeed difficult with that much data to consider.

<table>
<thead>
<tr>
<th>Number of days actual differed from scheduled completion date</th>
<th>Number of parts completed within the interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 or more</td>
<td>early: 128, late: 114</td>
</tr>
<tr>
<td>17 to 20</td>
<td>early: 84, late: 78</td>
</tr>
<tr>
<td>13 to 16</td>
<td>early: 72, late: 48</td>
</tr>
<tr>
<td>9 to 12</td>
<td>early: 40, late: 56</td>
</tr>
<tr>
<td>5 to 8</td>
<td>early: 21, late: 28</td>
</tr>
<tr>
<td>1 to 4</td>
<td>early: 16, late: 6</td>
</tr>
<tr>
<td>&quot;on schedule&quot;</td>
<td>late: 1</td>
</tr>
</tbody>
</table>

TABLE I

Figure 1 shows the variations in the work load in one department of this plant, a hydraulic press department. The solid line represents the jobs arriving in the department, and due in the future. The upper dotted line represents the past due jobs, and the lower dotted line is the number of jobs clearing the department on that day. Uneven flows and backlogs such as this mean loss of money to the firm, since parts often must be assembled out of the proper sequence; jobs, men, and machine are not available at the same time, etc. In part, this is just like putting the electrical wiring in a new house after the walls are up. This not only costs extra money, it also usually means that deliveries are "off schedule".

The variety of solutions to the production control problem is almost as great as the variety of problems. Probably the most common solution is some variation of the "manual" system. In this system, the problem is broken down into a number of small components, and different men are made responsible for these components. Expeditors are needed to coordinate efforts; it is not uncommon to find 2 percent to 5 percent or more of the employees of a plant working as expeditors. Under such a system, it is almost impossible to predict the load on a given production department even a few days into the future, especially where there is no standardized flow of parts through the plant.

To allow some means of predicting future loads, use has been made in recent years of punched card systems of production control. Punched card systems allow for more centralization. By sorting cards by expected dates and by departments, some estimate of future loads can be obtained. All predictions are based on standard running times, and the only way to enter the day-by-day variations into the cards is by mass key-punching new cards and replacing the obsolete ones. The common method of meeting this problem is to increase the standard running times until you can be sure the parts...
will be made within the allotted time—and consequently, up goes inventory—
raw, finished, and in process, and back into the future go delivery promises.

Electronic data handling systems offer much promise for helping solve such production control problems. Since, if properly designed, data in the system can be changed or erased at will, the system can keep up with the day-by-day variations. Actual running times can be remembered easily, for adjusting standards. Data can be sorted, collated, and transferred, to give different pictures of shop loads according to different needs. In short, an electronic system promises to provide what one of the Navy's top admirals recently asked for—a machine which, upon throwing a switch, would project onto his wall a "picture" of the major problems and bottlenecks confronting his organization at that moment.

To obtain a more concrete picture of requirements for an electronic production control system, our project has sponsored a detailed study at one of the local plants. The company has about 1000 employees, which is near the lower limit in size for companies who can consider an electronic system. They fabricate and assemble small but complex units on a job shop basis. The company at present has an efficient manual method of processing data; an idea of their efficiency is seen from the fact that only 7/10 of one percent of their employees are expediters, as compared to a normal range of 1 percent to 5 percent. A total of 29 people are employed in production control, with such diverse jobs that only about half of them might be replaced by an electronic system. Amortizing this saving over 2½ years, it is seen that the electronic system should cost in the neighborhood of $175,000 to $200,000. Some additional cost might be allowed if the system would provide very desirable scheduling data that are not now feasible. So let us say that $225,000 to $250,000 is the range we must shoot at. A company with such an efficient manual system was picked as a yard stick against which to compare the merits of an electronic system.

Time does not permit consideration of all the possible variations of an electronic system that were considered. For example, the idea of an all-electronic memory throughout was soon discarded, at least until more efficient systems are developed, as the volume of data was too great, and since other forms of memory were quite feasible. Also, not all production centers throughout the plant are tied to the machine by electrical communication circuits, since in general, information is not generated at a high enough rate to justify this.

In the next few minutes, I will hit the highlights of a proposed system that we believe can meet the requirements of this company. At the same time, I want to emphasize that this is not a general purpose system, but is designed for this one company specifically. For another company, many of the same building blocks might be used, but the parameters would be different. However, later in the talk, a design philosophy will be presented, based on our experience, which we believe will apply quite generally.

Figure 2 is a flow diagram of the procedure to be used in posting customer orders and the issuing of purchase requisitions, shop orders, and assembly orders. A typing operation appears unavoidable at the beginning, in order to prepare a standard sales order from the customer's order. Such
items as inspection procedure, renegotiation clause, customer code number, and product code must often be added to the information supplied by the customer. By using an electric typewriter that can punch a paper tape (such as the Flexowriter), data are in a form suitable for direct entry into an Electronic Data Handling Machine, designated here as the EDH. This machine is quite similar to electronic digital computers of today; in fact, it is possible that commercially available machines will meet all requirements. Bills of material are prepunched into punched cards; the appropriate decks are selected by the operator and fed into the machine. Automatic access of Bill of Material data is not essential here in this plant, since only 10 to 50 assemblies are involved each day. The machine combines the variable information (quantities, due dates, etc.) with the standard data and posts these schedules on the Requirements magnetic tape. After all postings are made, the machine scans the requirements data for each part number, compares it with the inventory data from the adjacent magnetic tape, and pulls out those part numbers for which an order may be necessary. The operator scans these printed data and decides which parts to order and in what quantities and enters this information by a keyboard. The machine is then able to prepare the necessary papers.

More tape units, or the newer types of random access memory, probably would be desirable if the cost were not too great, to cut down access time. Allowing only 10 seconds to hunt each part number on the tape, the 1000 to 1200 individual part number entries per day will require about three hours machine time, which is almost at the maximum time limit allowable for this operation.

Figure 3 shows how shipment schedule cards can be prepared automatically, without the need for manual key punching. These cards contain the pertinent data of the customer orders, and can be sorted by delivery due date, by customer name, or other convenient breakdowns. The breakdown by delivery due date will be used in a later figure.

Figure 4 shows the assembly order procedure. Variable data such as quantity and due date is stored in the working magnetic memory; bill of material data, as before, are in pre-punched cards. The electronic machine in conjunction with a summary punch and interpreter combines the two to provide individual requisition cards. The stock clerk, when filling the parts requisitions from stock, separates these cards into two piles—parts disbursed and parts that are short. Day-by-day changes are handled by a Summary Punch with keyboard in the stockroom, or a unit similar to the Talley Register, (made in Seattle). Disbursement cards are read by the machine and entered into the inventory tape previously shown. Shortage cards are read into the Parts Shortage magnetic tape.

Figure 5 shows the method of obtaining and recording shop progress data. As new shop orders are issued, they are recorded on a Shop Order Status magnetic tape. This tape is kept up to date by means of reading the completed move tickets (a pre-punched card), labor distribution cards (already being prepared by the Accounting Department), filled raw material requisitions, and inspection and reject punched cards. The machine is also able to prepare the next move ticket for each job, as the completed one is read in. The method of calculating the due date for this new move ticket will be discussed shortly.
Figure 6 shows the analysis procedure, for using all of the data gathered most effectively. The Production Controller selects shipment schedule cards (mentioned above) by due date; he is primarily interested in past due, due, and about due orders, and the cards have been sorted in this fashion. The machine reads these cards and collates with this information the data from the Parts Shortage tape. The data are graphically presented on a large visual Control Board, and show, for example, which customer orders are past due that have only one part missing. It is on such orders that the Production Controller concentrates his attention.

The machine is next asked to tell specifically which parts are missing on these assemblies, by part number. The Control Board might be adapted to this use by using a transparent plastic overlay on which are written the Bills of Material. Lights are lighted behind those parts which are missing.

The value of a temporary, graphical presentation should be emphasized so that the Production Controller does not have to scan a large number of figures. Details of the Control Board have not been completely worked out but the problems appear to be ones of cost and engineering, rather than new, unique problems. Several alternative approaches appear interesting, also.

Next, the Production Controller calls for the status of the shop orders which are making the missing parts. These data are obtained from the Shop Order Status magnetic tape. The overlay on the Control Board in this case gives the Route Sheets for these parts, and the lights indicate which operations the orders are in.

To get an idea of when these orders might be completed, considering the overall status of the shop, the Production Controller makes use of the Scheduling Machine. This electronic machine works on a principle very similar to the digital differential analyser. It is loaded from the Shop Order Status tape. Then with Route Sheet data at its disposal, it gradually works its way into the future. Whenever a machine tool becomes available, the machine scans the waiting shop orders and picks the one with the highest priority slated for that machine. By changing priorities, the Production Controller can "play" with the schedule, until he gets one that looks good for the next two weeks. Appropriate operation due dates and priorities are transferred to the Shop Order status memory, for preparing the next move tickets. The Production Controller then lets the machine run out for a month or two into the future to get a rough picture of what is ahead. It is estimated that the time scale is about three hours shop time per one minute machine time.

When the machine allocates a shop order to a machine, it causes a card to be punched, with all pertinent data. These cards can be sorted to give future department loads, possible tool conflicts, etc. After the machine has determined the schedule, the Production Controller or an assistant can play with it, testing out different priority rules, scheduling methods, etc. Monte Carlo methods can be used to simulate the conditions of machine breakdown, tooling trouble, inventory policies, and other day-by-day variations, to find a scheduling method that is least affected by these factors.

Also available from the Shop Order Status tape is a running total of shop order cost, as opposed to standard cost. This is a first order
approximation of how much the Production Controller can spend in expediting an order, and still make a profit. This is a value judgment, and often involves more than just the cost of the individual part.

Adding up the estimated costs of the above equipment, and including rental of punched card equipment for 2½ years, gives an optimistic total of about $264,000. Installation charges are not included. So while the electronic system probably costs in the right order of magnitude for this particular firm, it is not a foregone conclusion that it would be desired. However, this was a research study, and we were not trying to sell anything.

Experience at this one plant, plus the other surveys made by the authors, indicate a rather general purpose design philosophy for electronic production control systems. For the next three to seven years, it is likely that most such installations will make use of existing equipment and techniques (such as punched tape, punched cards, electric typewriters) as well as newer electronic devices such as random access memory. The system must be tailored to meet the individual plant's requirements, as we see little hope of a general purpose system. The human operator will still be the main source for important judgments, the machine can only help out on the routine choices (not of a complex nature). Therefore, a good integration of men and the machine must be engineered. Recent studies on information theory in psychology should be of great assistance here. Many results of the data processing for Production Control need only a visual display, and need not be permanently recorded; this will reduce very materially the printed output problem.

The Production Control Center in a plant thus takes on the aspect of a Combat Information Center aboard ship. The machine processes the data and presents it to the humans for decision-making purposes. The plant machine works on a different time scale than does the CIC—hours instead of minutes or seconds, so that the plant machine need not be designed to aid in the minute-by-minute decisions.

From an engineering standpoint, it is quite evident that data should be recorded in machine language as close to the source of data as possible, in order to reduce manual operation bottlenecks to a minimum. The use of existing equipment where possible has the advantage of predicting the level of reliability in advance. Also, this reliability and the accuracy of the system can be improved by providing routine cross checks between Accounting Department data and Production Control data. Finally, an all-electronic system is not necessarily desirable, and depends upon the economics of each specific case. For example, the inter-department mail system may be a completely satisfactory communications channel for some of the data. Similarly, not all data has to be stored in electronic, random access memory. In short, the system should be designed to fit the company, rather than squeezing the company to fit the system.

In this paper, we have presented some of the initial results of our Industrial Logistics Research Project. We are anxious to place these results before business management, as potential users of electronic data handling systems, as well as before electronic equipment manufacturers. It is hoped that we can perform some small service toward a meeting of the minds, between users and producers of this type of equipment. Time has not allowed a detailed
description of the topic of this paper, nor an indication of the other affiliated areas in which we are working. For any such additional information, we extend a cordial invitation to all interested parties to visit us at U.C.L.A.

REFERENCES


Fig. 1- Typical Variations in shop loads (Hydro Press Department).
Fig. 2 - Posting Requirements and Ordering.

Fig. 3 - Sales Order Cards.
To Purchase Reqs, Shop Order, etc. (Figure 2)

Fig. 4 - Assembly Order Procedure.

Fig. 5 - Shop Progress.

Fig. 6 - Control and Expediting.
The activities of the Division of Accounting Operations of the Bureau of Old-Age and Survivors Insurance have been referred to, upon occasion, as one of the biggest bookkeeping jobs in the world. Whether this condition is true or not depends on how it is measured. Certainly, by the yardstick of costs, it would not appear that the job is at all near the biggest. On the basis of comparisons similar to those made in business, the gross costs of operations represent only \( \frac{1}{8} \) of 1 percent of total gross income. Furthermore, the system shows no signs of becoming the biggest in terms of cost. In a ten year period, an approximately 50 percent increase in basic work loads has been absorbed with no significant or compensatory increase in personnel. It is felt, therefore, that if the job qualifies as being one of the biggest in volume, it also might qualify as one of the smallest in terms of proportionate costs.

However, regardless of how it is measured, the job represents a real challenge to those who administer it and to those who would furnish it with suitable electronic paraphernalia. For these reasons, the following problems are presented with pleasure at the opportunity and with confidence in the know-how represented at this conference to solder together whatever combinations of wires, tubes, diodes and transistors that are found to be necessary in each case.

The largest area of mechanical operation within the whole accounting system is in the processing each quarter of approximately 60 million entries received in random order to approximately 107 million accounts which are established in numerical order for ready reference. The end result of this work must permit rapid access to any one of the approximately 107 million accounts at any time except the instant at which a particular account is being posted. Such access is necessary in completing the approximately 755 thousand references made each quarter for such purposes as: processing claims for benefits, issuing statements of account, and making adjustments.

The ideal situation, of course, would be one in which each of the 60 million incoming items each quarter would be incorporated with the related account at the instant the new item is presented to the system. Key depressions by which punched cards now are produced instead would cause pulses to flow over wires to a device which would summon forth the designated account. This device would compare and post the entry or separately record it for clerical investigation if absolute identification of the entry with the account were not possible. Although, we often have seen yesterday's fantasy become today's reality when electronic principles have been established and applied, we cannot wait for as long as might be required to produce equipment suitable to this ideal. Hence, we must contain ourselves with projects of less ambition while the science progresses to this ultimate destination.