Production and Design

Although the major world economies are dominated by service industries, manufacturing is still an important component of many firms. Because of the economic issues, manufacturers in industrialized nations have increased their reliance on machines and robots. Advanced computer capabilities have enabled robots to perform more complex tasks. Other uses of computers in manufacturing include process control, inventory management, and product design.

Process Control

Process control is the use of computers to monitor and control the production machines and robots. Production lines generally use many different machines, each requiring several adjustments or settings. If each machine has to be set up separately, it can take days or weeks to change a production line. Similarly, it can be difficult to spot problems when you have to monitor hundreds of settings. If the machines support standard interfaces, they can be connected to a central computer control facility. The computer can monitor all of the measurements generated by the machines, and some adjustments can be made automatically by the computer. Similarly, engineers can change the entire production line by indicating changes on a computer screen. The computer sends the appropriate commands to set up each machine. These systems are also used to monitor quality control measures.

One important benefit of integrated process control systems is improved quality. Identifying problems requires continuous monitoring of the process. In fact process monitoring is a key component of the ISO 9000 quality standards. The ISO 9000 standards are used to verify a firm's commitment to quality design and production.

The distribution of products is often included as a problem in production. Routing salespeople and delivery vehicles is a complex problem in computer science and production management. The goal of finding the shortest route is a classic problem that is difficult to solve for a large number of stops. Grocery stores have found substantial benefits from computers in improving their distribution systems.

Inventories, MRP, CIM, and JIT

Manufacturing requires raw materials. It also requires products to be tracked through the entire production process to shipment. There are many ways to organize and monitor a production line. Hence, there are many ways to build information systems that support production. One of the oldest production management methods focuses on inventory management. The objective was to maintain sufficient raw materials to keep the line running yet hold costs down by keeping inventories as small as possible.

Many manufacturing companies base their information systems on the manufacturing line. A popular system was based on the operations management concepts of **material requirements planning (MRP)**. In most MRP systems, the production line drives the information system. At each stage in production, the MRP system evaluates the usage rates of raw materials and determines the necessary inventory levels. If managers or designers alter the production lines, they can use existing data and simulations to determine approximate inventory levels for the new production. Production management has traditionally relied on mathematical models from queuing theory, economic inventory theory, and simulation to determine the best flow of production and the required supplies of materials and labor. Modern MRP systems also enable managers to track individual parts back to the original suppliers—an important step in improving quality.

Manufacturing Resource Planning (MRP II) represents an integrated approach to production. It combines materials planning with scheduling and process control. The objective is to build a “demand-pull” system that is based on projected sales. In a demand-pull production line, the sales department provides detailed estimates of production needs for a certain time period. The system then computes the labor and raw materials needed to manufacture the products. It searches for an optimal production schedule and creates inventory orders needed to meet the schedule.

A key feature of most production lines is that they rarely behave exactly as they were predicted. Thousands of things can change, from marketing departments rearranging schedules to meet rush orders, to broken equipment, to labor shortages or engineering design changes. Any change in one part of the process will affect the others. Production management systems such as MRP II are designed to enable managers to evaluate alternative schedules and choose the most cost-effective solutions.

Led by Toyota of Japan, a popular manufacturing technique is to rely on **just-in-time (JIT)** production, where the raw materials arrive at the manufacturing line just as they are needed, so the manufacturer saves money by holding less inventory. However, JIT requires that the suppliers know exactly how much to deliver. If you change production schedules, the suppliers have to be notified. Likewise, if a supplier cannot make a shipment on time, you need to find an alternative supplier. Hence, JIT requires more communication between suppliers and manufacturers. Computer communications, such as EDI, can be used to transfer the orders quickly with less chance for mistakes.

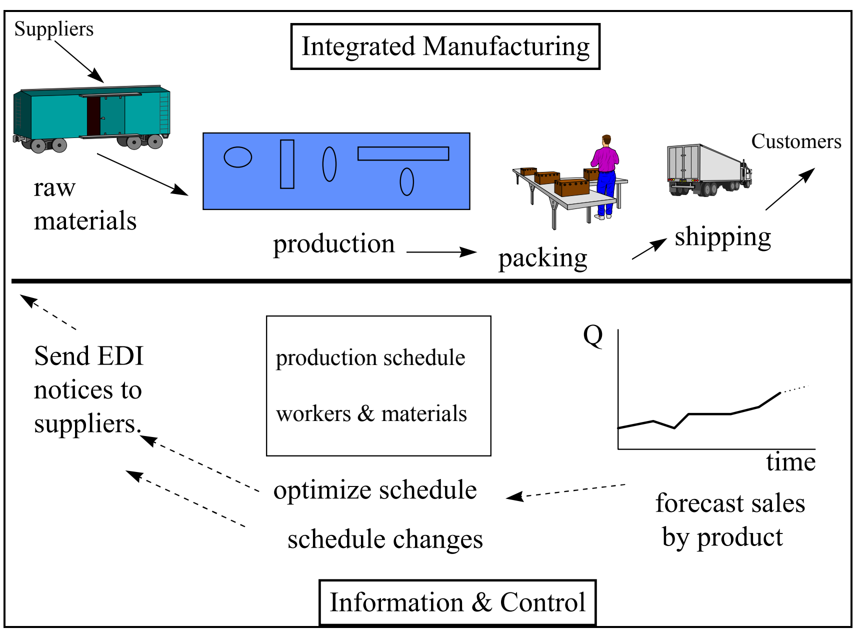

Figure 1

Production models. Production requires careful control over purchasing, inventories, scheduling, ordering, and shipping. Optimization models and forecasts play an important role in reducing costs. Integrated manufacturing systems enable companies to produce products on a demand-pull basis. Based on customer orders or forecasts, optimal production schedules are computed and raw materials are automatically ordered through EDI systems.

Increased flexibility is another major consideration facing producers today. Yet each change in schedule or product feature requires realigning suppliers and optimizing the production line. To support the new manufacturing systems, many producers have invested heavily in sophisticated information systems. The computer-integrated manufacturing (CIM) technique was introduced in the mid-1980s. In a truly integrated environment, every element of the production would be monitored and controlled through the computer system. Figure 1 illustrates the basic concepts of a computer-integrated, demand-pull manufacturing system. The sales department estimates sales of each product. The information system uses past manufacturing data to create a production schedule that produces the desired products for the least cost and best quality. The computer then generates just-in-time orders for the suppliers. If there is a change in demand or problems in the production line, changes are made in the information system. The computer then reschedules the jobs and issues new orders to the suppliers. As supplies are delivered, they are recorded and the computer directs them to the appropriate production area. Many claims have been made for the potential capabilities of CIM, but to date, few companies have managed to create a truly integrated environment.

Product Design

Computer aided design (CAD) programs are used to create engineering drawings. CAD programs make it easy to modify drawings. They also make it easier to keep track of material specifications. They can perform spatial and engineering estimates on the designs, such as surface or volume calculations. Individual pieces can be tested on the screen to be sure they fit together correctly. The diagrams can be used by modeling software to examine structural features or perform initial wind-tunnel tests. Machines are also available that will take the diagrams directly from the computer and produce prototypes of the parts. For instance, an engineer could create a replacement gear. The prototype is too soft to be used for real work, but it can be tested to be sure the design is correct. The amazing aspect of these tools is that the prototypes often can be produced in less than an hour.

Example

Queuing theory is a tool that is often used in production management. It can be used to model problems such as service lines for retail checkouts, the number of medical personnel needed in an emergency room, or even the number of bathrooms needed in an office building. A useful example in manufacturing is the number of repairpersons needed to maintain a group of machines.

Consider a company that has 10 machines that produce the same product. Typically they use only eight of the machines; the other two are kept as backups. When a machine breaks down, the work is transferred to the backups, and a repairperson fixes the broken machine. On average, any given machine will function for 15 days before a malfunction, and it typically requires 2 days to make the repairs. Using this information, plus an assumption that the breakdowns follow an exponential distribution, the queuing theory model generates the probability that any number of machines will be broken on a given day. These probabilities also depend on the number of repair workers available. For example, if two machines fail at the same time, one worker could be assigned to each machine.

There are six input parameters to this model: number of backup machines, number of repair workers, mean time to failure, mean repair time, cost of the workers, and cost of lost production. The primary output of the model is the sum of the costs from lost production and the cost of the repair workers. The objective is to hire the number of workers that leads to the lowest cost. With the base data in this example, the least cost point is to hire two repair technicians. The model enables the manager to examine the input data more closely. For example, it is easy to see what happens if the average failure time is closer to 25 days instead of 15, or if it takes 3 days to repair average breakdowns.

		Production Queuing Model					
		Number of Repair Persons					
Backups	2	Mean time to failure		15	days		
Loss per	$ per day	Mean repair time		2	days		
Machine	500	Avg daily repairer cost		150			
		# repairers	1	# repairers	2	# repairers	3
Machines Waiting to be Fixed	Cost of Lost Production	Probability # machines wait to fix	Expected $ loss	Probability # machines wait to fix	Expected $ loss	Probability # machines wait to fix	Expected $ loss
0	0	0.1324	0	0.3162	0	0.3422	0
1	0	0.1413	0	0.3373	0	0.3650	0
2	0	0.1507	0	0.1799	0	0.1947	0
3	500	0.1607	80	0.0959	48	0.0692	35
4	1000	0.1500	150	0.0448	45	0.0215	22
5	1500	0.1200	180	0.0179	27	0.0057	9
6	2000	0.0800	160	0.0060	12	0.0013	3
7	2500	0.0427	107	0.0016	4	0.0002	1
8	3000	0.0171	51	0.0003	1	0.0000	0
9	3500	0.0046	16	0.0000	0	0.0000	0
10	4000	0.0006	2	0.0000	0	0.0000	0
			747		137		68
		worker cost	150	worker cost	300	worker cost	450
		total	897	total	437	total	518

Figure 2

Production model to determine optimal number of repair persons. The goal is to minimize total costs. Parameters include number of repair workers, number of backup machines, mean time to failure, mean repair time, the cost of additional workers and the cost of lost production. For one to three repairers, the spreadsheet uses probabilities to estimate the number of machines waiting to be fixed to get the expected loss. Varying the parameters leads to different outcomes.

Several specialized programs make it easier to evaluate more complex queuing theory models. However, it is possible to evaluate this small model in a spreadsheet, as indicated in Figure 2. The only hard part is deriving the probability estimates. The derivation for this example occurs in a separate section of the spreadsheet and is not shown in the example. Although the equations are not overly complicated, they require specialized knowledge. A business manager would rely on an operations research expert to set them up. The box discusses some of the problems you might face in setting up this problem with a spreadsheet.

This example also illustrates the concept of choosing a goal as described in Chapter 3. The discussions of the example to this point have assumed that the number of backup machines (two) is fixed, and that our goal is to determine the number of repair workers to employ. However, it might be cheaper to buy more backup machines instead of hiring more workers. The same model can be used to answer this new question. You first need to know how much it costs to acquire more machines. If these machines are large, you might have to build additional space to store them. Then you need to examine the total costs (lost production, workers, machines) for a combination of different numbers of backup machines and repair workers.

Exercises

C09Ex05.xls

1. From the production example, assuming that we currently have one repair worker and two backup machines. The total cost of a machine is $112,500, but it has a useful production life of six years (1,500 days). Assuming we use eight machines for production, how many backup machines and how many repair workers should we employ?