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FOUNDRY:
A FOUNDRY SIMULATION

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ABSTRACT

FOUNDRY is a simulation of a medium-sized gray iron foundry located in central Wisconsin. The simulated foundry has annual production capabilities of about 4,000 tons.

Through promotion efforts, participants obtain requests from customers for price quotations on specific jobs. Using the cost and production information available to them, participants submit quotes for the available jobs. If a quote is within an acceptable range, they will get and hold that job until they are underpriced or they fail to meet production deadlines.

Jobs must be scheduled on the production line which involves participants in inventory control, production scheduling, and personnel decisions. The output of the simulation gives participants information which they then use to prepare financial reports.

INTRODUCTION

FOUNDRY is an interactive simulation based on an operating foundry in central Wisconsin. Participants are expected to make weekly marketing, finance, accounting, and production decisions, including preparing quotes and scheduling jobs. The foundry industry was chosen because: 1) it is an important part of Wisconsin's economy, 2) it is a basic industry and yet one that is not usually familiar to students/participants, and 3) it allows decision-making in a wide variety of areas in an industrial rather than consumer product category.

The primary objective of this simulation is to provide the student with actual decision-making experience, while providing an opportunity to view the impact and the effectiveness of various decisions in a competitive business environment. The industry, itself, is composed of a number of firms, each capable of producing the types of gray iron castings necessary and each able to meet all production requirements of any of the 1,000 possible jobs contained in the simulation. The companies are well established and of equal size in the beginning. All have equal production capacity and initially the only variable will be the management t earns.

The main simulation program, named FDRY, is written in FORTRAN IV and implemented on a Burroughs B-5700 computer under the TSSMCP time-sharing operating system. As the B-5700 is a virtual-memory machine, the utilization of many large one- and two- dimensional arrays within the program is possible without requiring overlay techniques. The program was designed to operate in an interactive mode; thus, all player input/output is via terminal. Internal accessing of data bases is via random-access disk files. A general flow chart of the simulation is presented in the appendix.

PRODUCTION

The production process can be conveniently thought of in terms of four major areas: coremaking, molding, melting and pouring, and finishing and inspection. These areas will be discussed in detail below.

Core-making

Frequently, a complex casting requires ‘cores within the mold. For example, it is impossible to mold a casting containing a through-hole since there would be no way to remove the pattern. To accomplish this, a cylindrical sand core must be placed within the mold prior to closing the cope and drag (top and bottom of the mold). Cores may be made in one or more parts and pasted together to form the finished core. Core box production rate is normally distributed with a mean rate of 17.5 core boxes per hour for experienced operators, with a standard deviation of 1.5 core boxes per hour. The number of cores per box along with the number of castings per pattern is specified in the request for quotation received from each potential buyer.

Inexperienced core makers achieve the mean rate of 17.5 boxes per hour within approximately one month and learn at a logarithmic rate. Core makers are absent at a rate governed by their past absence history. Substitute core makers fill in for those absent but produce at a significantly decreased rate.

Molding

Currently, the molding operation is being carried out on 8 squeezer molding stations. Squeezers can make castings that weigh up to 100 pounds. The average molding rate of experienced molders is 25 molds per hour but depends directly on the flask size and whether or not cores must be placed. Generally, it takes an inexperienced molder about three months to achieve the 25 molds per hour average rate and the learning rate is again logarithmic. Deviations of experienced molders about the 25 mold per hour mean follow a normal distribution with standard deviation equal to 2.0.

Absenteeism can occur at any mold center on any given day depending on the molders past absence history. When a molder is absent, a substitute molder is found who generally produces at about one-half the rate of an experienced molder.

Melting and Pouring

After the completed sand molds reach the pouring area, they are ready to receive the molten metal. Approximately 20 tons of molten metal are poured per shift, although the pouring rates are different for each job depending upon the piece size and number per mold.

Poured molds are allowed to cool, then dumped onto a conveyor which shakes loose the molding sand. The casting then moves by conveyor to the cleaning area.

Cleaning and Finishing

Cleaning castings actually encompasses several operations: cleaning the casting surfaces, inspection of the casting, grinding and shipping.

Castings are 100¾ inspected. Defective castings are discarded to in-house scrap along with gates and risers. The defective scrap rate is presently 7%. At present, one person can handle inspection of all production.

From inspection, the castings travel by conveyor to grinding. Here snag grinders remove all remnants of gates, risers, fins, and parting lines in what might be called a rough grinding process. Next, castings proceed to the pencil grinder for a finish grind and subsequent removal to shipping. Currently, one snag and one pencil grinder are sufficient to handle production on each shift.

The shipping clerk next weighs and counts the pieces (castings) for shipping and the shipping containers are removed to storage where they await shipping carriers. At present, one person handles shift production adequately

Generally speaking, the areas requiring decision making on the part of students are with respect to job scheduling in the coremaking and molding operations. Pouring, cleaning, inspection and shipping are never bottle-neck" operations for the production process and are assumed to need no special scheduling or staffing attention.

At the start-up of the simulation, students have sufficient core sand, molding sand and scrap for two weeks of production. There is a one week lead time on all raw material orders. Insufficient core sand inventory will cause an automatic shut down of the core-making operation. Similarly, the absence of molding sand and/or required cores causes an automatic shut down of the molding operation. Lack of scrap in turn will shut down the pouring operation.

Molding sand is reused with a 99.5% recovery rate. No core sand can be reused.

Job Descriptions

Based on expenditures for marketing, the simulation model will generate a list of job prospects for students to bid on. Each job is identified by number and is followed by a brief description of the pertinent data necessary to make intelligent bids. A typical description of two actual jobs follows.

JOB	TCAR	DD	NO	PAT	WPC	NCC	NCB	WSC
1003	50	5	1.	1	7.0	1.	1.	1.0
		RO	DRO	BOX	NPAT			
		10	2	1	1			
JOB	TCAR	DD	NO	PAT	WPC	NCC	NCB	WSC
1151	10000	4	2.	1	4.0	0.	0.	0.0
		RO	DRO	BOX	NPAT			
		10	24	0	3			

JOB refers to the job number (1003, 1151)
TCAR is the total number of castings required for each order (50 for job 1103)
DD tells the number of days from receipt of the job order until it is due
NO tells the number of castings in each pattern. Thus, in job 1151, 2 castings can be made in each pattern. PAT is the flask size and is used to determine rate of sand usage
WPC identifies the weight of each casting, a key determinant in pricing
NCC refers to the number of cores in each casting NCR is the number of cores that can be made per core box
WSC is the weight of sand used per core RO identifies the number of possible future reorders
DRO refers to the interval in weeks between reorders
BOX is the number of boxes available for producing cores (core stations)
NPAT is the number of patterns needed or allowed for producing castings (molding stations)

Thus, job 1003 requires 50 castings, is due in 5 days, needs one pattern per casting and each casting weighs 7 lbs. Furthermore, each casting has one core which can only be produced at one core per box and which weighs 1 lb. The job has 10 possible reorders coming at 2 week intervals and requires one core position and one molding position to produce the necessary cores and castings respectively.

FINANCE

The financial manager is responsible for making certain the company has its funds invested in the best manner. Cash flows require special attention; the financial manager must make certain that the firm has the necessary capital it needs in the form of cash and must allocate available cash to the best use.

SOURCES OF FUNDS

Outside financing is available from several sources at varying rates of interest.

Bank Loan

Bank loans are considered interim financing only and thus must be paid off each quarter. Interest rates vary dependent upon the firm's financial condition. For example, interest rates vary from a low of 7 percent to a high of 20 percent based on the firm's asset to future debt ratio as shown in the table below. Future debt is defined as total amount of all debts including the bank loan to be made.

Table 1

Asset to Future Debt Ratio	Interest Charge Percent
20:1	7
10:1	8
5:1	10
3:1	12
2:1	15
1:1	20

Notes

A large insurance company is willing to hold notes for the firm at a cost of 12 percent per year. These loans may be acquired at any time, but must be paid off in 24 months or less. The insurance company has also stipulated that it will not loan money to any firm whose debt to equity ratio is 0.5:1 or more after the loan. Notes are for 24 months and must be paid

in eight equal installments beginning the quarter after the loan is made. They can, of course, be paid off more rapidly.

Bonds

Bonds may be issued that pay eight percent with interest paid quarterly. The student is given the appropriate form for selling bonds. This form must be filed with the administrator two periods before the actual issuance. Bonds are callable at any time at face value.

Investments

Surplus funds may be used by the financial manager to purchase interest-earning securities.

Short-Term Securities

Short-term securities are an asset almost as liquid as cash. They earn interest at an annual rate of 4 percent. If the firm accidentally runs short of cash, any short-term securities it owns may be sold before a bank loan is made.

Long-Term Securities

Long-term securities may be bought which earn interest at the rate of 6 percent. These securities are not quite as liquid as short-term securities and therefore cannot be sold in time to avoid a bank loan.

MARKETING

After establishing corporate objectives and strategies, participants are required to make promotional decisions about their monthly expenditures for Direct Mail Advertising, Trade Magazine Advertising, TV Advertising, and Sales Promotion. They must also decide on the percentage commission they are willing to pay their sales representatives.

A list of jobs is then generated for which prices must be quoted. For example, spending five hundred dollars in each category and a sales percentage of one percent may result in five jobs to bid on while one million dollars in each and a 20% sales commission may result in 20 jobs on which to bid. Note that this is for illustration only. A history of late shipments will override all marketing activities and result in a significant reduction in the number of requests for quotation.

BIDDING ON JOBS

The amount of business (jobs) firms receive will depend on how successful the companies are in quoting on available jobs. In order to operate profitably, each firm must sell at a price higher than its costs. However, if the price quoted is deemed too high, there will be no chance to produce that particular job.

Historical data is provided that allow companies a chance to determine with reasonable accuracy their production costs and overhead. Scrap iron is currently selling at $100 per ton and labor costs are on the basis of $3.20 per hour plus an incentive factor.

FINANCIAL STATEMENTS

This simulation does not produce financial statements for the participants. Instead, they are given information which permits them to create financial statements. It also gives them flexibility in their handling of accounts payable and other liabilities. Receipts and payments of cash are not ‘automatic.”

PRODUCTION DECISIONS

Job bidding and production have been geared to a four- week cycle. Companies will be able to bid on a new job list every fourth week; i.e., weeks 1, 5, 9, 13, 17, etc. Specific jobs, however, may be rescheduled on a weekly basis to different production stations as particular stations become vacant or backlogged. Additionally, as time in the simulation progresses, certain jobs previously completed will come up as reorders. There will be an opportunity at that time to accept the reorder and schedule the job into current production or reject the reorder as undesirable.

After bids have been accepted and jobs received, it will be necessary to establish a production schedule and assign jobs to molding and core stations. The foundry has eight mold stations where castings are produced and six core stations where cores are produced. If cores are required, no casting can be made until the necessary cores have been produced. Also, there is a 1/4 hour lag time between core production and usage at a molding station. There is a 1/2 hour lag time between jobs to allow for set-up. The intent is to assign jobs received to mold (casting) and core stations to achieve the smoothest production possible. The goal should be continuous operation throughout each four-week bidding period.

Subsequent to each week’s operations, the computer prints out an accounting report detailing production activities for the week. This report will print the completed jobs by number, the time it took to complete each job. total job time required, a promptness index to show how early or late the job was (in days), when it was completed and the total number of cores and castings produced. In addition, information is print-ed on the mean core box production rate per hour and mean mold production rate per hour at each center as an aid to determining operator efficiency.

The computer will also print out a status report for jobs still in progress. This status report will include cores currently available, cores produced to date, and castings produced to date, as well as the mean core box rate/hour and mean mold production rate/hour.

Finally, data is printed on employee hours of experience, the number of days absent the previous week, direct and indirect labor costs, overhead costs and raw material costs.

RAW MATERIALS

When the foundry operations begin, sufficient molding sand, core sand and scrap will be provided to meet production needs for the first two-week period. After this period, enough data should be available to enable the participants to predict the respective usage rates of each.

Prior to the beginning of production each week, the

student will have an opportunity to order molding sand, core sand and scrap. When an order is placed, it will arrive on Wednesday of the following week. Thus, if the order is sent in week 6, it will arrive on Wednesday of week 7. Without sand or scrap, the foundry cannot operate.

EVALUATION

Each company has a board of directors consisting of faculty members from different functional areas to which it must report quarterly. Each group also must prepare an annual report to the stockholders which the directors also review. Evaluations are based not only on total profits and sales, but also on the amount and quality of planning and analysis during the simulation.

FIGURE 1
GENERAL FLOWCHART FOR FOUNDRY