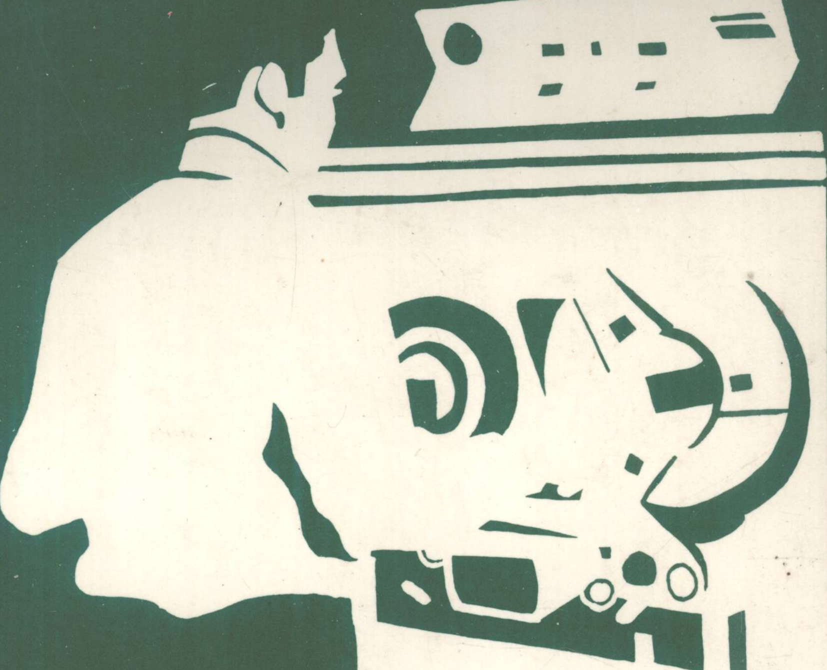
PROSIM

A Production Management Simulation



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A Production Management Simulation

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International
HARPER & ROW, PUBLISHERS
New York Hagerstown San Francisco London

PROSIM: A Production Management Simulation

 For information address Harper & Row, Publishers, Inc., 10 East 53rd Street, New York, N.Y. 10022.

Library of Congress Catalog Card Number: 77-76410
ISBN 0-352-07309-0

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Preface

In recent years, a number of new instructional methods have been designed in the area of education for business. One of these is business simulation (often called business gaming). A business simulation is a dynamic, sequential, decision making problem, structured around a model of a business operation, in which participants make a number of interrelated decisions in managing the operation.

Our experience has been that business simulations have generally stimulated considerable student interest and involvement. Our philosophy is, however, that simply having students play a game because it is a stimulating experience is inadequate. Rather, simulations are most valuable if they can serve as a vehicle for the application of the specific concepts, analytical tools, and problem-solving techniques taught in the courses in which they are used. For this reason, this text includes not only the PROSIM simulation itself, but also extensive materials showing how many of the basic concepts and analytical tools commonly taught in production management courses can be applied by the student in managing his PROSIM firm. Among those covered in this text are production scheduling techniques, marginal analysis, *EOQ*, order point and order cycle systems, etc.

In developing PROSIM, we have attempted to meet two other objectives. First, the simulation has been designed so that it can be used at various levels. PROSIM has been utilized at The Pennsylvania State University in the beginning management course and in introductory and advanced production management courses. Second, we have designed PROSIM so that the computer program can be easily used by instructors having little or no knowledge of computer programming or technology. Program decks have been specifically developed for two different IBM systems—the 700/7000 and 360 series. The instructor will be provided, free of charge from the publisher, with whichever of these decks his system utilizes. Further, both decks are written in FORTRAN and may be utilized—with possibly a few modifications made by the instructor's computer center—on various computer systems other than the two mentioned above. Detailed instructions for computer use of the simulation are given in the PROSIM Instructor's Manual.

Our acknowledgments to those who have helped us in developing PROSIM are numerous. We owe special gratitude to Dr. Max D. Richards of The Pennsylvania State University, who helped conceptualize and develop the PROSIM model in its earliest form; to Dr. Robert L. Stafford of The Pennsylvania State University, who both helped program the computer model and aided us in its "debug-

ging"; and to Dr. Robert D. Smith of Kent State University, for his review of and suggestions on the PROSIM text.

For their enthusiastic support and assistance in making PROSIM possible, we also wish to thank the Dean of our College, Ossian R. MacKenzie, our Department Head, Dr. Rocco Carzo, Jr., and our secretaries who patiently typed numerous drafts of the manuscript. Last, but not least, we wish to thank our wives, Shirley and Ruth, for their patience and understanding during the course of this project.

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University Park, Pennsylvania
April, 1969

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chapter 1[1]

Introduction

An exciting new educational technique designed to provide business students with greater insight and skills in dealing with managerial problems is business simulation, or business gaming, as it is often called. A business simulation is a sequential decision-making problem structured around a model of a business operation in which participants assume the role of managing a simulated firm. One purpose of this text is to prepare the reader for assuming such a managerial role in PROSIM—a computerized production management simulation.

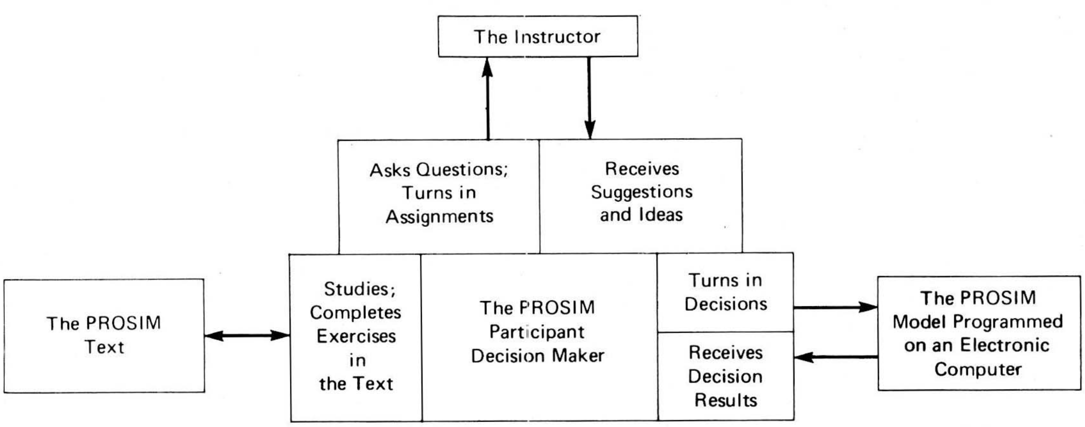
THE PROSIM LEARNING EXPERIENCE

PROSIM was developed to provide the student with a *planned learning experience* in dealing with numerous problems involved in production management. Aiding him in gaining such an experience, as is graphically shown in Figure 1-1, are:

1. His instructor, who will be available for guidance when necessary.
2. This text, which centers attention on numerous concepts, ideas and ana-

Figure 1-1

THE PROSIM LEARNING EXPERIENCE



[1]Numerous sections of this chapter have been patterned after those in Chapter 1 of Paul S. Greenlaw and Fred W. Kniffin, *MARKSIM, A Marketing Decision Simulation* (Scranton, Pa.: The International Textbook Company, 1964) and Chapter 1 of Paul S. Greenlaw and M. William Frey, *FINANSIM, A Financial Management Simulation* (Scranton, Pa.: The International Textbook Company, 1967), with the permission of the publisher.

lytical tools relative to production management, and their application to the simulation.

3. The PROSIM model which is programmed on an electronic computer. This computer program provides a dynamic simulated production decision-making environment, for which operating data are fed back to participants periodically.

More specifically, the procedure followed in assuming the role of production manager in the simulation is as follows:

1. Participants familiarize themselves with the simulated environment in which they are to manage by studying the materials presented in this text and possibly also by discussing these materials in class.
2. They are next given an opportunity to analyze available data on their past operations and to make a set of decisions for the first period in which they will manage their firms.
3. When firm decisions are due for this period, they are handed in to the instructor or someone designated by him as a simulation administrator.
4. Then each firm's operating results for the period are calculated and printed out by the computer system, and this information is returned to its management.
5. This cycle of decision making, calculation, and feedback of results is repeated for a number of periods of play.

In addition, the instructor may require various problem assignments relative to the simulation to be handed in from time to time, and/or meet with the PROSIM managers on one or more occasions to review their operations. More specific information about the times at which decisions are to be handed in, the types of assignments required, and so on, will be indicated by the instructor.

PROSIM: OBJECTIVES AND FOCUS

The design of PROSIM as a planned learning experience oriented towards production management was based on three notions:

1. The central activity engaged in by production managers is that of making decisions such as controlling inventories and assigning workers to machines.
2. Basic to making such decisions effectively is an understanding of certain fundamental concepts, ideas and analytical tools of production management, such as incremental analysis, production scheduling, and economic lot size inventory models.
3. An understanding of these concepts, ideas, and tools can be gained more effectively by the student if he is both:
   a) First exposed to them in the classroom and/or by outside reading, and *then*
   b) Given an opportunity to *apply them* to a specific production decision problem situation.

Thus, the fundamental objective of PROSIM is to *facilitate the learning and mastery of certain basic concepts and techniques of production management by pro-*

viding an opportunity for their application by the student in making decisions in a simulated production-management-oriented environment. In accordance with this objective, decision problems in other functional areas of the business firm, e.g., marketing and finance, have been included in PROSIM only to the extent that they bear relevance to production management.

FUNDAMENTAL CHARACTERISTICS OF THE PROSIM PROBLEM

The simulated business environment of PROSIM, like that of most business simulations, is an abstract one. The decision variables included in it are generalized ones, and the simulation environment is not intended to replicate that of any specific real world firm or industry. Further, the relationships between decisions made and results obtained in the simulation simply reflect general business and economic principles—e.g., the probability of machine breakdowns will decrease as expenditures for plant maintenance increases up to a point, all other factors remaining the same—rather than empirical findings developed by any real company.

However, PROSIM has been designed so that the decision problems which it poses to the student possess many of the same *fundamental characteristics* as those faced by real world production managers. The PROSIM manager, like his real world counterpart, is concerned with making *a number of interdependent decisions* in a *dynamic environment,* in which *uncertainty exists* and *in which no direct analytical solution to his overall problem is known.* Following are some of the values which may be acquired by the student from assuming the role of PROSIM manager under such conditions.

Dealing with a Number of Interrelated Decision Variables

Few, if any, decisions in PROSIM can be made effectively in any period without simultaneously evaluating their impact in relation to all others being considered for the period. For instance, in scheduling his (three) products on his machines in any period, the manager should consider the proficiency of his workers, the probable number of machine breakdowns which will occur depending upon his plant maintenance decisions, the effect of his quality control decisions on the number of substandard pieces (rejects) likely to be turned out, and so on.

Dynamic Decision Making over Time

Each period's decision situation in PROSIM is influenced by what has transpired earlier in the simulation. For this reason, the PROSIM manager must learn to live with his previous successes and failures. Furthermore, he must devote considerable attention to advanced planning. For example, he must look ahead in making his procurement decisions, since regular raw materials orders are not filled until three periods after they are placed.

Decision Making under Conditions of Uncertainty

The behavior of certain variables in PROSIM is not known with certainty by the simulation manager, e.g., the exact number of machine breakdowns which will occur in any period or, if any, which machines will break down. Furthermore, although he is given future demand estimates for his firm's products, actual demand may vary from these forecasts by as much as $\pm 5\%$. Thus, PROSIM does *not* present a decision problem in which all key data are given to the student. Rather, it is necessary for him to learn to *predict*, through experience and by utilizing various production management concepts and techniques, the occurrence of numerous key events in the simulated environment.

No Direct Analytical Overall Problem Solution

The application of a number of quantitative analytical tools can be helpful in arriving at decisions in PROSIM. However, the simulation problem *in its totality* is so complex that *no direct analytical solution to it is known.* That is, no single set of equations or other mathematical procedures is available, which, if followed, will always enable the PROSIM manager to arrive at an optimum or "best" answer to the overall management of his firm. Rather, he must learn to decide which of the numerous concepts and analytical tools available to him can be usefully applied to various facets of the PROSIM problem situation. Thus, the simulation provides the student with experience not only in making decisions *per se*, but also in determining the conditions under which the utilization of different *approaches* to decision making is appropriate.

PROSIM LEARNING: SOME CONCLUDING COMMENTS

As indicated previously, the PROSIM environment is an abstract one, not intended to replicate any specific real world situation. For this reason, the student should not base his decisions in the simulation on assumptions drawn from his knowledge of any specific firm with which he may be familiar. For example, he should not reason: "Because several weeks of training are usually necessary before new tire builders become proficient in their jobs, such will also be the case with workers being trained in PROSIM." Rather, he should attempt to *learn* more each period about how the variables in PROSIM behave by a thorough analysis of the data provided in the simulation itself and, in doing so, to master the concepts and techniques which PROSIM is designed to teach.

Nor, conversely, should the student assume, upon completion of his PROSIM managerial experience, that he can take any of the specific decision strategies which have proven successful for him in the simulation and apply them to real world business situations. For example, because an additional $50 spent for plant maintenance may reduce the PROSIM firm's total costs more than does an additional $50 spent for quality control under certain conditions, the participant certainly should not conclude that "plant maintenance efforts always generally have a greater impact than those geared to quality control in the real world." On the other hand, many of the *concepts, techniques,* and *ways of dealing* with PROSIM decisions do have direct applicability to real world decision problems. For example, *EOQ* analysis, which we will discuss in Chapter 6, is utilized today by many business firms.

With the focus and objectives of PROSIM in mind, let us now turn our attention to a description of how the student is to assume his role as a production manager in the simulated PROSIM environment.

chapter **2**

Participant Instructions

As we indicated in Chapter 1, the PROSIM manager, operating in a simulated environment, both makes decisions and receives feedback information generated by an electronic computer each period. In this chapter, we will (1) describe this environment, (2) indicate how PROSIM decisions are to be entered on a decision form, and (3) explain the meaning of each information item which will be returned to participants from the computer each period. The rules, procedures, variables, and relationships discussed in these three sections are *basic to the play of PROSIM*, and should be studied carefully until the reader has a *thorough understanding* of them. It is also suggested that the reader take the quiz provided at the end of the chapter to test his knowledge of these materials.

THE PROSIM ENVIRONMENT

Each PROSIM firm manufactures and sells three different unidentified products. For each period of play, which represents one day, PROSIM managers make a number of decisions: expenditures for quality control and for plant maintenance, the placing of regular and/or expedited raw materials orders, the assignment of either of the three products to each of four machines on each of two production lines, the hiring and training of workers, the assignment of workers to machines, and the number of hours of work to be scheduled for each employee. In the following sections, we will describe in detail the nature of these decisions.

The Products and Production Lines

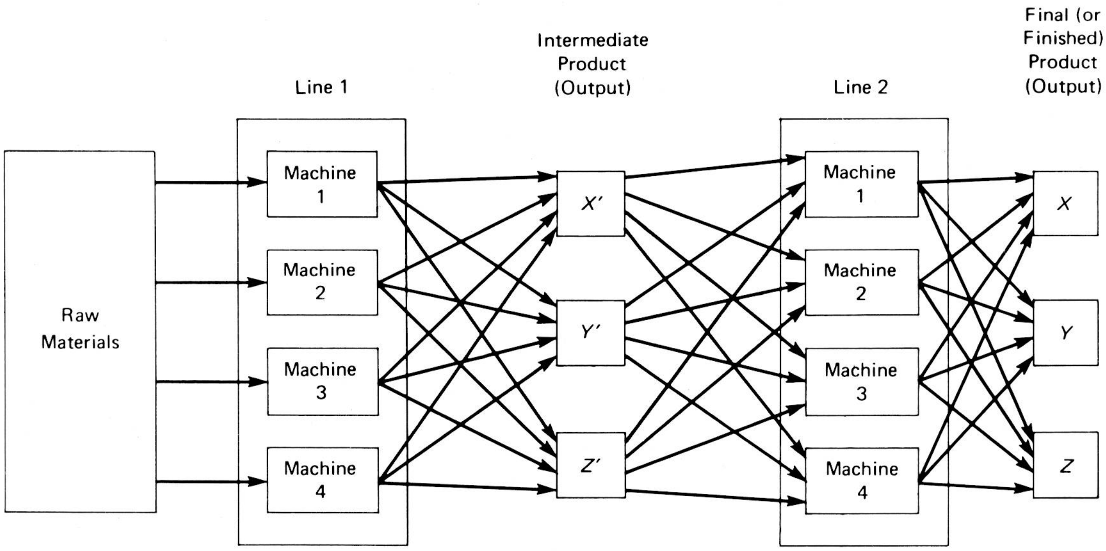
The PROSIM manufacturing operation is comprised of two production lines—Line 1 and Line 2—each of which consists of four identical machines. The firm's three products, which are referred to as X, Y, and Z, each require processing on each of these two lines:

1. Raw materials are first fabricated into rough, unfinished products on Line 1. These unfinished fabricated products will be referred to as X', Y', and Z'.
2. After X', Y', and Z' have been fabricated on Line 1, they are then converted into final (or finished) products (X, Y, and Z respectively) on Line 2.

This manufacturing process is illustrated graphically in Figure 2-1. Each period (day), the PROSIM manager must decide which product, if any, is to be scheduled on each machine on each of the two production lines. X', Y', and Z' may be scheduled on any or all of the machines on Line 1, and the same is true of X, Y,

Figure 2-1

THE PROSIM MANUFACTURING PROCESS



and Z on Line 2. Only one product per day, however, may be scheduled on any given machine. The manager *cannot*, for example, schedule Product X on Machine 1 of Line 2 for part of a day, and Product Y on the same machine for the remainder of the day.

If the PROSIM manager should schedule a different product on any machine in either line in one period than that scheduled on the machine in the last previous period in which the machine was being operated, time will be required to set up the machine to meet the specifications of the newly assigned product. Set-up times required for the firm's products are as follows: (1) for both X' and X, 1 hour; (2) for both Y' and Y, 2 hours; and (3) for both Z' and Z, 3 hours. No production, of course, can be turned out during the hours in which a machine is being set up. For each hour of set-up time required in any period, the firm incurs set-up costs of \$5. Thus, if a firm's product scheduling decisions were as illustrated in Figure 2-2, for example, its set-up costs in Period 4 would be \$60.

Plant Maintenance and Machine Breakdowns

Each period, any or all of the firm's eight machines may break down due to one or more of their components failing. Only one breakdown may occur on any machine in any given period. Two hours of repair time will be required (and scheduled automatically by the computer) for each machine that breaks down, regardless of the product scheduled upon it for the period. No production, of course, will be turned out on any machine during the 2 hours when it is down for repair. In addition, the firm will be charged \$100 in repair costs for each necessary repair.

The probability of machine breakdowns is inversely related to the firm's plant maintenance efforts each period. The PROSIM manager may spend any amount for plant maintenance he desires (up to \$9,999), and these expenditures have an immediate effect upon the probability of breakdowns occurring. The breakdown

Figure 2-2

ILLUSTRATION OF SET-UP TIMES AND COSTS

		Product Scheduled Period 2	Product Scheduled Period 3	Product Scheduled Period 4	Hours Set-Up Time Required Period 4	Set-Up Costs @ $5/Hour Period 4
Line 1	Machine 1	*X′*	*X′*	*X′*	0	$ 0
	Machine 2	*X′*	*X′*	*Y′*	2	10.00
	Machine 3	*Y′*	*X′*	*X′*	0	0
	Machine 4	*Y′*	*X′*	*Z′*	3	15.00
Line 2	Machine 1	*Y*	*Y*	*X*	1	5.00
	Machine 2	*Y*	*Y*	*Z*	3	15.00
	Machine 3	*Z*	None	*Z*	0*	0
	Machine 4	*X*	None	*Z*	3	15.00
				Total	12	$60.00

*No set-up time is required since Machine 3 was set up for Product *Z* in the last previous period in which the machine was operated, i.e., in Period 2.

probability, however, is also influenced by previous plant maintenance expenditures, so that in evaluating his maintenance decision in any period, the manager should also consider past expenditures.[1]

Quality Control and Rejects

Each period, numerous units of *X*, *Y*, and *Z* turned out on Line 2 may be rejects, i.e., they fail to meet quality specifications. No rejects are ever turned out in the manufacture of *X′*, *Y′*, and *Z′* on Line 1.

The *percentage of total* units of *X*, *Y*, and *Z* which will be rejects in any period will be determined by, and *inversely* related to, the firm's expenditures for quality control, *both past and present*. Each period, the PROSIM manager may spend any amount he desires (up to $9,999) for quality control, and all such expenditures take effect immediately in the period in which they are made.[2]

The Work Force

Hiring, firing, and layoffs. The PROSIM manager has available for work assignment a "pool" of twenty-eight workers (or operators), of whom eight (Operators 1–8) have already been hired by the firm and assigned to machines in Period 1 of the simulation.[3] The other twenty (Operators 9–28) have not yet been

[1] A breakdown will never occur on a machine on any given day *regardless* of the firm's plant maintenance expenditures if no worker is assigned to the machine, or if a worker is scheduled for zero hours of work on the machine that day.

[2] It should also be pointed out that the percentage rejects in any given period will be approximately the same on all machines in Line 2, regardless of whether *X*, *Y*, or *Z* is produced. For example, if the reject rate were 10% in Period 2, and 400 units of *X* were turned out on Machine 1 of Line 2, and 320 units of *Y* on Machine 2, approximately 40 units of *X* and 32 units of *Y* would be rejects. We use the word "approximately" here, since the percentage rejects may differ very slightly from one machine to another due to the rounding characteristics of the computer.

[3] As will be indicated later, all PROSIM managers begin the simulation by making decisions for Period 2.

hired, but remain available for employment at any time. To hire any of these potential employees, the PROSIM manager need only to assign them to work on any machine in any period. For each new worker so assigned and hired, the firm will automatically be charged a hiring cost of $50. To illustrate, if Workers 1, 2, 3, 4, 5, 9, 17, and 21 are assigned to work in Period 2 of the simulation (with Workers 9, 17, and 21 replacing Workers 6, 7, and 8 who were assigned to work in Period 1) a hiring cost of $50 would be incurred for each of the three new employees.

If a PROSIM worker who has been hired is not assigned to work on any given day, he is considered to be laid off, and the firm's union contract stipulates that he must be paid $8 in layoff pay for that day. If a worker is not assigned to work for any three *consecutive* days, he will automatically be *fired* in the third such idle period, and the firm will be charged a firing cost of $25 at that time. A worker will not receive any layoff pay, however, in the period in which he is fired. For example, if Worker 2, who was hired in Period 1, is assigned to work each period through Period 3, but then is not assigned to any machine in Periods 4, 5, and 6, the firm will be charged: (1) layoff costs of $8 in each of Periods 4 and 5 and (2) a firing cost of $25 in Period 6. Although laid off workers can be brought back to work on the following day, once any worker has been fired, he can never be rehired by the PROSIM firm.

NOTE: Both layoff pay and firing costs will be automatically charged to the firm by the computer and included as "layoff and firing costs" on its computer printout for the Period (see Figure 2-5).

Worker assignment. Any worker, except, of course, one who has previously been fired, may be assigned to any machine on either production line in any period. A worker, however, must spend the full day on the same machine—he may *not* be assigned to one machine for part of the day and to another for the remainder of the day. In addition, any worker may be assigned to work any number of *full hours only* up to a maximum of *twelve* in any period. Labor rates which must be paid to each worker while on the job are as follows:

1. For each hour up to and including 8 hours a day, each worker is paid on a straight-time basis of $2 per hour, except that
2. The firm's union contract specifies that a worker must always be paid for a minimum of 4 hours' work regardless of the number of hours for which he is scheduled. For 1, 2, 3 or 4 hours in any period, he must be paid for 4 hours' work—4 × $2, or $8. If a worker is scheduled for 0 hours, he is considered as being laid off and receives $8 in layoff pay as indicated earlier.
3. For each hour above 8 hours, each worker is paid on a time-and-a-half overtime basis of $3/hour.

   Note: In all cases, workers must be paid for all hours *scheduled*, not simply for hours worked, i.e., workers must be paid for those hours during which they are scheduled to work, but idle due to a machine breakdown, set-up, or lack of product on which to work (as will be discussed later).

Several other observations are in order concerning worker assignment. First, if the manager inadvertently assigns a nonexistent worker to a machine, i.e., a worker whose number is greater than 28, or a previously fired worker, no worker will be considered to have been scheduled to that machine. Second, if the manager should assign the *same* worker to two or more machines on a given day:

1. He will be considered scheduled on the *first* machine so assigned (in the order Line 1, Machines 1, 2, 3, and 4, and then Line 2, Machines 1, 2, 3, and 4).
2. No worker will be considered scheduled on the second, third, etc., machines to which the worker has been assigned.

For example, if Worker 1 is inadvertently scheduled to work on Machines 1 and 2 in Line 1 as well as on Machine 3 in Line 2 in a particular period, he will be assigned to Machine 1 in Line 1, and no worker will be considered assigned to either Machine 2 in Line 1 or Machine 3 in Line 2.

Third, if it is necessary to set up a machine in any period, the worker assigned to that machine must be scheduled to work for at least: (1) 1 hour if the product scheduled is either X' or X, (2) 2 hours if either Y' or Y is scheduled, and (3) 3 hours if the product scheduled is either Z' or Z. If he is not, the set up will not be permitted, and the same product will automatically be scheduled on the machine as in the previous period, regardless of which product the manager assigns to the machine. For example, if Product X is turned out on Machine 2 in Line 2 in Period 8, and only 1 hour of worker time is scheduled on this machine in Period 9, Product X will automatically be assigned to the machine in Period 9, even if the manager schedules either Product Y or Z.

Fourth, the PROSIM firm will incur an equipment usage cost of $10 for each hour that a worker is scheduled on any machine each period. In each case, this cost will be assigned to the product scheduled on the machine.

Worker productivity. A standard hourly production rate has been established for each product on each production line, i.e., a rate of production which the "average" worker is expected to turn out in 1 hour. The standard hourly rates for the PROSIM products are as follows:[4]

1. For both X' on Line 1 and X on Line 2, 50 units/hour
2. For both Y' on Line 1 and Y on Line 2, 40 units/hour
3. For both Z' on Line 1 and Z on Line 2, 30 units/hour

The actual productivity of any worker, however, may vary from these standard rates depending upon his proficiency. A new, inexperienced worker, for example, may produce at below 50% of the standard rate on his first day of work, whereas a highly proficient, experienced man might work at as high as 120% of the standard rate.

The proficiency of each worker is a function of three variables:

1. His "potential," i.e., his native ability,
2. His number of days of previous work experience, and
3. The number of days of training which he has been given.

Data concerning each of these three variables for each of the twenty-eight workers available to the PROSIM firm are given in Figure 2-3. Two observations

[4]We will point out in Chapter 4 how many days of training and work experience are required for the average operator to reach the standard hourly rates of production.