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# PRODUCTIVITY IMPROVEMENT ANALYSIS USING SIMULATION

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## ABSTRACT

In recent years, a growing number of American industries have faced increased competition from foreign manufacturers. As a result, many corporations are investing more of their resources in productivity and process modernization studies. This paper describes how the Remington Arms Corporation is using a simulation model as part of the productivity improvement/process modernization program at its Ilion, New York plant. The objectives of this simulation modeling effort are reviewed; the development of the model and the data requirements are summarized; and aspects of the implementation are discussed. Examples of its initial application in the analysis of short-term process improvements are presented.

## 1. BACKGROUND

The Remington Arms Corporation, a wholly-owned subsidiary of E. I. du Pont de Nemours & Co., has been in the business of producing sporting firearms and ammunition since the Company was founded in 1816. The Ilion, New York plant is Remington's firearms production center, producing a wide variety of rifles, shotguns, target pistols, and trap and skeet guns.

Productivity improvement is a major concern of Remington, as it is of most American industries. In fact, the decline in U.S. productivity growth has been cited as "the most persistent of the economic problems plaguing American industry" (Dallas, 1979). Although Remington currently holds a leadership position in the firearms business, it recognizes the crucial need to continually strive for more cost-effective operation.

Recently, Remington formed a long-range process improvement group at its Ilion plant. The primary goal of this group is to improve the productivity of the manufacturing operations both through improvements to the existing technology and through the development and application of new technology. The simulation model discussed here is being developed to assist the process improvement group in studying both of these areas.

## 2. OBJECTIVES

The overall objective of the simulation study is to provide a tool which can be used both in studying the current operations to pinpoint those areas of the shop with the greatest potential for improvement, and in determining the potential benefit of proposed changes to the manufacturing operation. The value of using simulation in meeting this objective, as opposed to other types of analysis methods, is that it can be used to simultaneously analyze all parts of the production process. Thus, the effects of a specific change in one part of the system can be predicted for the *total system*. As Buxey, Slack and Wild (1973) state, "... the most efficient line (production system) will not necessarily result from adopting the best available procedure for the design of each component part, as all parts interact and the operating environment changes accordingly. Thus an overall design philosophy is required that embraces all technological and all behavioral aspects of flow line operation." Simulation makes this type of comprehensive analysis possible for the complex and interacting manufacturing system at Remington.

In order to satisfy the overall objective, three specific "functional" objectives must be met. The *first* of these objectives is to develop an accurate model of the existing process. Although this objective can easily be overlooked in this type of study, it is one of the more important. In fact, benefits are often realized as a direct result of this objective even before the model itself is actually completed. The model-building process requires very explicit descriptions of each operation and all of the material flow systems. Extensive amounts of data are also required. As a result, personnel from several different functions including industrial engineering, manufacturing engineering, and production are forced to examine the manufacturing process very closely. In the process of gathering the operational and flow data, previously unknown problem areas can be uncovered.

The model of the existing process also serves as a model validation tool. In modeling a complex operation, it is difficult to initially include all of the interactions which take place. Any omissions are likely to go undetected if changes to the system are modeled directly, since all of the results will be attributed to the system modifications. In reality, however, the results may be affected by a failure to include all of the important aspects of the existing system. Thus, calibrating the model of the existing process with the actual data from the production floor is crucial in the development of a valid model. Additionally, the calibrated model can later be used as a "base case" in the evaluation of alternatives.

The *second* objective of the simulation study is to analyze "procedural" changes to the system, and other changes which do not require significant capital investment. This could involve the study of such areas as production scheduling, production smoothing, work force utilization, and work-in-process control. In addition to the direct benefits which can be realized as a result of studying these areas, this analysis could possibly help to avoid the expense of new equipment, which would be of much less value after the implementation of procedural changes.

OBJECTIVES OF SIMULATION MODEL

1. MODEL EXISTING PROCESS
2. ANALYZE PROCEDURAL CHANGES
3. DETERMINE IMPACT OF MAJOR PROCESS IMPROVEMENTS

The *third* and final objective is to determine the impact of major process improvements which require the introduction of new technology. Some examples are:

- The introduction of automated materials handling systems;
- The use of robots in the complete mechanization of selected woodworking and/or metalworking operations;
- The mechanization of the final assembly operation; and
- The replacement of existing equipment with improved or new equipment having faster cycle times, less changeover requirements, and/or additional processing capabilities.

## 3. AREA MODELED

The production of firearms involves three major processes: woodworking, metalworking and assembly. Although we plan to eventually model the entire manufacturing operation, we decided to initially concentrate on one fairly independent part of the production process. This strategy generally makes the modeling task more manageable, and allows useful results to be obtained more quickly. Also, the modeled part of the shop can be studied while model development for the other parts is being completed.

The wood shop and the metal shop run fairly independently of each other, except that the requirements of the assembly operation make it necessary to coordinate the scheduling between the two. Therefore, either the wood shop or the metal shop could be modeled in isolation, and useful results obtained. In fact, we determined that if it became necessary to control the size of the model, the wood shop and the metal shop could each be modeled separately and used to generate a time-history input to a separate model of the assembly operation.

The wood shop was chosen as the target of the initial modeling efforts because it seemed to have the greatest potential for improvement. The remainder of this paper will concentrate on the woodworking area, where at the time of this writing, modeling is complete and initial results have been obtained.

## 4. DESCRIPTION OF CURRENT PROCESS

The problems in the current wood shop are varied. The flow of material through the wood shop is fairly complex, mainly because of the widely-varied product line produced by Remington. This results in a significant amount of time being devoted to machine changeover. (Changeover times in the wood shop range from 30 minutes to 24 hours.) A large amount of scrap is generated here, both because of natural wood flaws and because of the precise cutting operations that are done. And, a walk through the wood shop immediately reveals an abundance of work-in-process.

The woodworking operations at Ilion are located throughout the four stories of three buildings.

The layout is the result of numerous expansions of the original shop. This in itself makes control difficult, since material is always being moved and the "flow" of material is not at all obvious.

The wood used in making firearms is either birch or walnut. Walnut long stocks, short stocks, and fore-ends are manufactured from a "wood blank". These are all illustrated in Figure 1. Birch stocks and fore-ends are manufactured from a different type of blank, but go over most of the same operations as the walnut.

over, the replacement of worn cutters, and other similar tasks in areas where an operator runs more than one machine.

Material handling duties are shared by the operators and by forklift truckers. Truckers are used depending on their availability and on the distance between operations. Operators also receive assistance with machine maintenance. (Although repair personnel were not explicitly modeled, their availability was taken into account in the machine repair time probability distributions.)

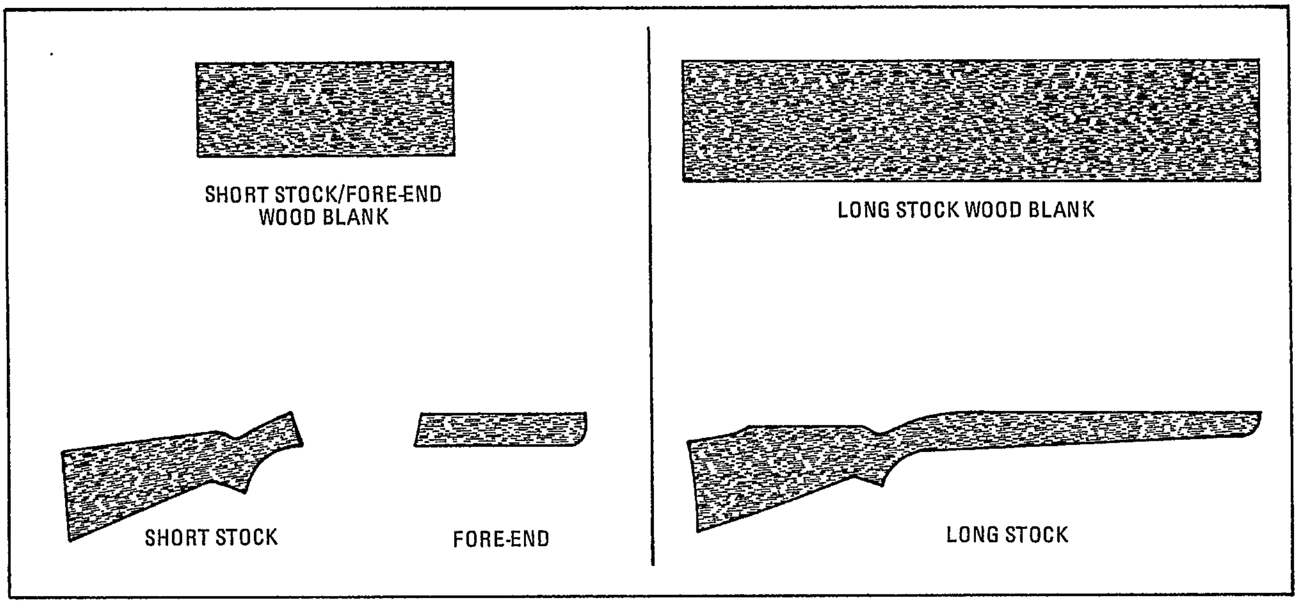


**FIGURE 1**

Wood blanks are transformed into the forms shown by putting them through a number of "shaping" operations, depending on the type of wood, the type of stock, and the gun model being produced. There are 29 machines in the shop which are used for these operations. A schematic flow diagram of the machines in the wood shop is presented in Figure 2 (see next page), along with an indication of the routings of some higher volume gun models. The wood is also put through a "finishing" process (including sanding, staining and sealing), before reaching the final assembly step. The finishing process has not been modeled in detail and is not discussed further here.

The current operator assignments are also indicated in Figure 2. All of the machines shown require at least one operator. Some machines will automatically cycle a number of stocks through several steps, and therefore, only require an operator for loading/starting and unloading/stopping the machine. In this case, an operator is usually responsible for running more than one machine. In contrast to this, some machines only aid an operator in making what is essentially a hand cut.

"Machine setters" are also assigned to several of the areas, as shown in Figure 2. Generally, machine setters are responsible for machine change

## 5. MODEL DESIGN

In the initial stages of model design, we decided not to attempt to have the model do any optimization, considering that optimization modules could easily be added later if desired. We felt that the wide range of objectives discussed would best be met by designing the model to be controlled by input data and prespecified contingency rules. All analysis would, therefore, be on an experimental "case study" basis.

Another major consideration was that the model be designed so it could be easily used by people in the process improvement group, who are very familiar with the operation of the plant, but not necessarily knowledgeable in simulation. We felt that allowing the process improvement group to run case studies was the most efficient and effective way of obtaining useful results.

Based on these conclusions, the primary consideration in the design of the model was that it be "data driven". Case studies could then be run simply by making the appropriate data changes via a CRT terminal and then running the model using these data. The goal was to design the model so that at least the second objective (the analysis of procedural changes) could be met by running case studies

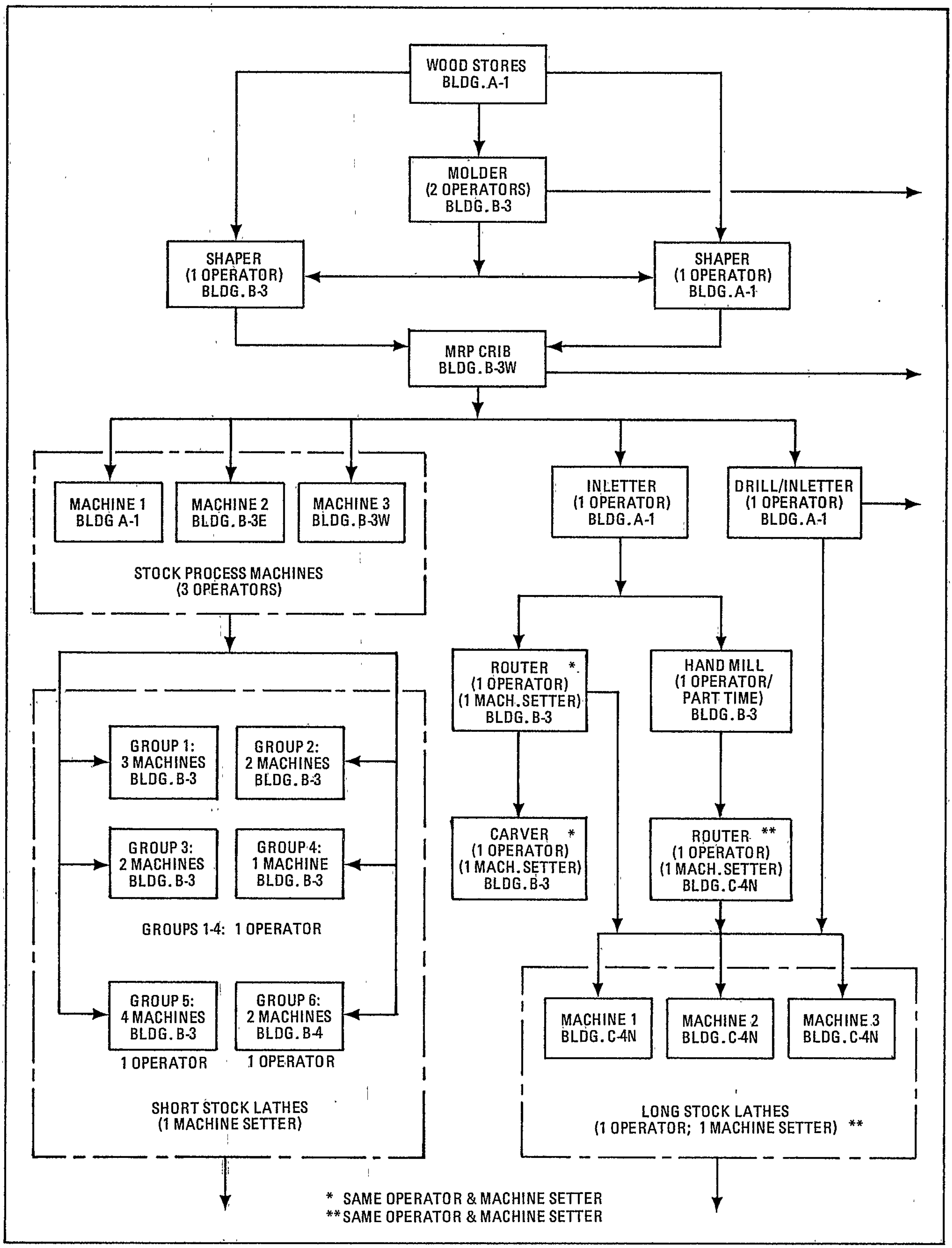


FIGURE 2 – REMINGTON ARMS WOOD SHOP – SHAPING OPERATIONS

which would be completely specified by changing the input data.

It would also be advantageous if many of the case studies run to analyze major process improvements could be handled in this way. However, the fact that some of these changes would require additional modeling could not be overlooked. The design of the model had to be such that the addition of these new parts could be made with a minimum of extra programming effort.

The modeling language used was SIMSCRIPT II.5. The major advantage of SIMSCRIPT II.5 in meeting the model design goals is that its data input facilities are very flexible, allowing free-form and keyword-based input to be used. Thus the model input can be specified in terms most familiar to the users. This language also has extensive report writing features, so that the results of the model can be easily displayed in user-specified formats.

## 6. MODEL STRUCTURE

The process interaction capabilities of SIMSCRIPT II.5 (Russell, 1979) were used almost exclusively in the implementation of the model. Process modules were used to model the individual machines and/or the operators (depending on how closely the operator interacts with the machine); the machine setters; and the material handlers. Lunches, operator breaks and the scheduling of shifts were also controlled using process modules.

## 7. INPUT DATA

Probably the most valuable feature of the model is its data driven design. The input to the model also serves to illustrate the basic model structure. The data is divided into five major sections.

INPUT DATA SECTIONS

1. GENERAL DATA
2. TIME STANDARDS DATA
3. OPERATIONS DATA
4. PRODUCT DATA
5. SCHEDULING DATA

### 7.1 General Data

This first section of data contains basic run control information such as the calendar date on which the simulation begins and the total length of time to be simulated. In addition, a detailed trace of the activity at specified operations and/or of specific functions (i.e., machine changeovers) may be requested for any interval of simulated time. This capability has been useful in both studying particular problem areas and in explaining the operation of the simulation to users.

### 7.2 Time Standards Data

The data for all of the time standards used in the wood shop are input here. "Standard-dependent" data includes:

- Beginning of shift start-up allowance.
- Machine load/cycle/unload times.
- End-of-shift cleanup time.
- Allowances for random interruptions to operations.

The time standard that is in effect on a given machine at a particular time depends on what is being produced, and is determined from the data for the specific gun model (Section 7.4 of the input data).

### 7.3 Operations Data

The operations data is divided into a number of subsections, one for each machine or group of similar machines. Any data that is tied to a particular operation but which is not part of a time standard is input here. This includes:

- Operator and machine setter assignments.
- Weekly scheduling of shifts.
- Materials handling information.
- Machine maintenance information.
- Machine changeover matrices.

Special operating rules may also be enforced for particular gun models specified here. For example, an operator may have the option (under specific conditions) to split campaigns of data-specified types of gun stocks, and run an operation for the partial batch on an alternate machine.

### 7.4 Product Data

Information on the routing of each product (gun model) through the shop is provided here. The operations in the flow sequence are specified with an indication of a particular machine (or a particular group of machines, if an operation can be run on more than one machine). The time standard that will be in effect while processing the gun model on each of the machines is also indicated.

Note that the routing of any of the gun models through the shop can easily be changed here. Thus, to study the effect of adding a new piece of equipment (to replace one or more existing pieces) the routing of the gun model need only be changed to process it on the new equipment.

7.5 Scheduling Data

Data for the release of campaigns of wood blanks from the "wood stores" (see Figure 2) is input here. The stocks are then "pushed through" the shop based on this schedule, the flow of operations specified in 7.4, and any additional rules at the individual operations (see 7.3).

## 8. OUTPUT REPORTS

Several different types of output reports are generated by the model, and most of this output may be selectively turned on or off using input data. Some examples of the reports available include:

- Detailed activity traces;
- Weekly production reports for each operation; and
- Summary statistics on operator and machine activity.

Generally, the reports are designed to give the user a summary of the activity that took place during a specified period of simulated time, at whatever level of detail is desired.

## 9. RESULTS

At the time of this writing, the model of the existing wood shop has been completed, and the results calibrated with actual production data for a six-month period of time. After some initial fine-tuning, the model predicted the actual performance of the shop fairly closely. As expected, there were slight differences between modeled and actual performance due to the random nature of some events. Other minor differences in the day-to-day operations in the shop resulted from human interactions, such as the way operators banked work-in-process to spread the idle periods. In general, however, the model accurately depicts the current wood shop operations.

Case studies are now being run to analyze the effects of procedural changes in the shop, using the data from the model of the existing shop to measure the improvement value of the proposed changes. Three examples of these case studies follow:

- *Production Scheduling is being studied* by looking at the effects of changing the sequence of products run. This technique has successfully identified schedules which significantly reduce machine changeovers while continuing to meet assembly requirements.
- A number of *bottleneck machines as well as machines with excess capacity have been identified*. The model is currently being used for production smoothing based on these findings. This is primarily being done by changing operator assignments and the scheduling of shifts. Results to date have shown increased throughput with a corresponding decrease in work-in-process.
- Most recently, *cases have been run which are aimed at increasing machine operator productivity* through improved utilization of machine setters and material handlers.

## 10. FUTURE WORK

The simulation model described in this paper is being successfully used to analyze procedural changes aimed at increasing efficiency and raising throughput in the wood shop, and these studies will be continued. The use of the model to analyze proposed major process changes should begin soon.

As the use of the wood shop model continues, additional modeling work for the metalworking and assembly areas is planned. The ultimate goal of this work is to eventually develop a complete simulation model of the plant which will be a useful analysis tool for a number of years into the future.

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