AN ABSTRACT OF THE THESIS OF

Robert J. Swan for the Master of Science in Industrial Engineering

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Title INVESTMENT DECISIONS BY THE USE OF PRESENT AND SIMULATED MATHEMATICAL MODELS

Abstract approved (Major Professor)

The study of investment decisions by the use of mathematical models verifies how models aid in accumulating and presenting information to management in the evaluation of a complete sub system. Most important, in discussing model information, management is motivated to make improvement changes in both future and present operations. Models motivated the operating personnel to suggest over 75 percent of the proposed changes.

Construction of models uncovers more comprehensive data than the information usually collected in the conventional analysis approach. The model points out relationships between storage requirements, avoidable delays and unavoidable delays. In addition, the elements which control key cycle times become more clearly identified. For example, in developing man machine charts, the role of machine times, material handling within and between
operations and human sense times are clearly demonstrated. Most important, simulated models can be used to effectively appraise the overall efficiency of a sub system. For example, a twenty percent allowance for personal and unavoidable delays was assumed. The sample data accumulated in the study shows that this allowance may lie in the thirty five to forty percent range.

The mathematical models were applied to a window and door frame factory, theoretically workable and ultimate systems were developed. The following results were obtained:

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The three main reasons for the difference in estimated savings between the model and the conventional analysis is felt to be the allowance factor of unavoidable delays and personal times, inaccuracies in the representative sample, and hidden transportation costs.

The conventional approach is used to analyze the remaining two departments within the factory. This is done so a comparison of the two approaches can be made. The value of the management
model approach is clearly demonstrated by the identification of the future study areas shown below.

The study points out seven future areas for study. They are:

1. Apply model under a different set of restrictions. For example, different dimensions of raw material entering the plant and variations in material recovery.
2. Test sampling validity by substituting values of all dimensions in formulas.
3. Expansion of the mathematical models to illustrate a product from the time the raw material enters the factory until the time the completed product leaves for shipment.
4. Investigation of expected recovery loss between single and multiple ripping.
5. Investigation of recovery for all operations.
6. Investigation of allowance factors for unavoidable delays and personal times at each operation.
7. Investigation of unidentified transportation costs.
INVESTMENT DECISIONS BY THE USE OF PRESENT AND SIMULATED MATHEMATICAL MODELS

by

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INVESTMENT DECISIONS BY THE USE OF PRESENT AND SIMULATED MATHEMATICAL MODELS

INTRODUCTION

The study of making investment decisions by the use of mathematical models is appropriate under several circumstances. Mathematical models give a means of evaluating a layout or system in terms of its overall functions. Once a model is developed for a system it can be adapted to varying conditions. By changing variables within the model the effects can be observed upon the entire system. Thus it would be relatively easy to compare a new machine's performance or process change by inserting the related variables into the model and examining the effects produced.

In this study models were used to evaluate the cutting department in a window sash and frame factory. The basic analysis employed a relatively new concept in itself. This is the ideal system concept.

The ideal system would involve the best method of producing a product without being limited by equipment or methods. A selection of the most feasible system can be determined after a vision of the ideal system has been obtained. The philosophy of
thinking, in terms of developing a workable system as close as is practical to the ideal system, is a relatively new concept. The usual approach to study the present work system and to ask what is wrong with it. This develops resistance and resentment to change as people tend to prefer and defend present procedures. On the other hand, when a person is asked to suggest changes for an entirely new or an ideal system, he is usually anxious to offer his suggestions.

Following the ideal system concept, two complete systems of the factory's cutting department have been designed. After the analysis of the cutting department was completed, mathematical models of the present and proposed systems were developed. Data for the construction of the models was obtained from observed times, calculated machine times, and simulated times by the use of SET. The related variables were then inserted into the model and an evaluation obtained.

The evaluation was based upon the cycle-times and direct labor cost required to produce an average board. By selecting the most representative board, the complete system appraisal is made
by an operation analysis of a sample of the entire system. Thus a complete system analysis is possible by a partial system study. Results of this analysis are shown in Table IX.

Also employed in this study were a series of conventional analysis of operations in the sash and frame departments. Within the sash and frame departments, individual operations were selected and analyzed. After the analysis of the present operations, new equipment that would combine operations, or produce at a faster rate was considered. The analysis also improved the work-place arrangement to reduce the delays occurring during the operation cycle. Since operation analysis requires considerable manpower and expense, the conventional approach was made as a by-product of the subsystem study.

A comparison of methods of making an analysis is made. One of the common problems with the conventional analysis is the tendency to improve an operation that may be eliminated completely if an entire system analysis was performed.

The results from the ideal system concept, used in the cutting department, and the conventional analysis of individual
operations, within the sash and frame departments, are shown in summary form in the final section of this thesis.
SECTION I

IDEAL SYSTEM CONCEPT
FOR IMPROVEMENTS

The ideal system concept would involve no work or cost to produce the product. This philosophy is used for the original design of work not yet done, the betterment of work progressing satisfactorily, and the improvement of work with problems.

The ideal concept may sound theoretical, but it is extremely practical to help an organization and its people achieve continual product increases. This concept forces one to find a way in which a suggestion will work, rather than envisioning why the suggestion will not work. This is the positive way of using experience. The ideal system gives everyone in an organization a continuing and forward moving objective.

Doctor Nadler states that there are three levels in the ideal concept. They are theoretical ideal, ultimate ideal, and technologically workable ideal system (12, p. 44).
It will never be possible to reach maximum productivity at no cost. The theoretical ideal system was defined to open the widest possible horizons, and to place no limitations on thought processes. This is a limit, and like all such limits, is intended to be increasingly approached without ever being absolutely reached. The theoretical ideal system is a definitional level, not an operational level. That is, no attempt would be made to develop or design a theoretical ideal system, whereas much effort is used in developing ultimate and technologically workable systems.

The ultimate ideal system is represented by a definite design. This system is almost always automatic and requires additional research and development before the design can become usable. This is the system which gives direction for the forward movement of an organization, and gives those studying the work the opportunity to present challenges to all other fields. When an idea can be detailed with a fair degree of eventual operating certainty, it is not an ultimate ideal system. If the idea has foreseeable future implementation capabilities, then further thought must be utilized to
develop true ultimate ideal systems.

The **technologically workable ideal system** design could be installed if there was no question of capital and financial costs, volume required, or hazard in the design. The technologically workable solution should have a minimum departure from the ideal system.
Figure 1

Schematic Representation of the Ideal Concept

The horizontal distance between the legs of the triangle is cost, or any other criteria such as time, hazards, etc.
DATA COLLECTION

Collecting data is basically the process of making measurements. Particular caution was used in gaining accurate information. A variety of methods was employed in gathering the data.

Interviews with various supervisory and operation personnel were conducted on an informal basis. These interviews provided an excellent overall picture of the company. They showed the relationships that exist between the various departments and the processes conducted within these departments. In all the informal discussions, information was discussed and suggestions on improvements were freely made by the operation personnel. Interviews or discussions were conducted with the following people:

General Manager          Barney Irwin
Factory Superintendent   Wilbur Rosier
Chief Accountant         Lee Simpson
Sales Representative     Vicent Pickens
Foreman of Cutting Department  Adam King
Foreman of Sash Department  Iru Rosenthu
Foreman of Frame Department  Ed Burkart
Foreman of Maintenance     Ted Allen

Weyerhauser Timber Company, Jeld Wen Company, and Metler Brothers plants were visited in Klamath Falls, Oregon. Each
of these plants employed different methods of manufacturing their products. These visits offered many valuable ideas.

Motion pictures were taken to record the methods presently used within the factory. Approximately 600 feet of film was taken of the present method (6) and another 50 feet of film was taken while on a plant visit (19). Various still pictures were taken to record work place arrangements and various pieces of equipment.

Each operation was observed for a short period of time and stop watch time values for the operation were recorded.

Production records and accounting records were employed to obtain depreciation costs, production per day, and wage rates for the employees.

Technical magazines were researched to determine methods employed in similar factories throughout the nation.

Various letters were written to leading manufacturers of woodworking equipment to determine the latest equipment available. Personnel contact was made with six equipment manufacturers in the Portland, Oregon area for cost estimates and equipment ideas (Appendix).
When data is gathered from a number of sources, such as in this case, it becomes difficult to insure the reliability of all data. In the case of interviews, the stated data is always subject to the personal views of the person interviewed. However, the people participating in the informal discussions were sincere and endeavored to present representative data. Production records, accounting records and wage rates can be assumed accurate. Information supplied by equipment manufacturers as to capacities of their equipment should be assumed to be maximum limits.

The amount of observed time data that was obtained was limited by the time available. The advantage of the mathematical model technique is exhibited in this thesis. By identification of a representative sample, limited data can be obtained in a short time. When this data is used in mathematical models, executives can use quantitative criteria to aid them in decision making. At a later date more extensive observations should be conducted to check the accuracy of present conclusions.
EVALUATION OF PRESENT AND PROPOSED SYSTEMS BY THE USE OF MATHEMATICAL MODELS

Webster describes a model as "a miniature representation of a thing."

A model is a representation of a real life situation. Since a model is an explicit representation of reality it can be less complicated than life itself, but it must be complete enough to approximate those aspects of reality which are being investigated. Estimates of various situations can be simulated by applying varying conditions and then obtaining the results.

Models are constructed describing basic systems and how they work and react. The model shows the relationship each function or activity has upon the entire system and what effect the individual functions have upon one another.

Models have been developed for the present and proposed systems under study in the cutting department. The models were constructed to represent the majority of the product flow. The re-ripping operation was not shown. This amounts to ten percent of the total volume.
Each system under consideration will have following the description of the system, a mathematical formula representing the system.

The unit of production that the model will illustrate is a representative board as it enters the cutting department. Basic assumptions were made describing the board size and individual operation characteristics. These assumptions are shown in conjunction with each model.

Data for the construction of the model of the present system was obtained from observed times, micromotion data and (SET) simplified estimated time values. Time values for the two proposed systems were simulated by the use of the SET technique. (18, p. 15).

When developing the proposed systems and their respective models, specific restrictions were placed on the performance required from the overall system. They were:

1. The system must handle a volume of approximately 40 M board feet of sash cut stock and approximately the same volume of frame cut stock per day.

2. The system must obtain the highest material utilization from the raw material received. This means that some material
must be remanufactured.

3. The system must insure satisfactory quality in the cut stock that is manufactured.

4. The system must accept raw material in random width ranging from four to 30 inches and random lengths ranging from six to 20 feet. The finished cut stock must be sorted to length and quality.

5. The system must be flexible enough to handle the size and length of cut stock that is produced in large volume and still be able to meet the special order requirements for cut stock.

6. The proposed system must be evaluated on the assumption of a product life of ten years.

7. The system must fit into the present floor area.
DESCRIPTION OF PRESENT SYSTEM
IN THE CUTTING DEPARTMENT

The present system takes rough kiln dried lumber and manufactures it into stock cut to the desired length, thickness, width, and grade.

The system employs five basic operations:

1. **Planing** two surfaces.

2. **Ripping** to the desired width.

3. **Trimming** to the desired lengths.

4. **Sorting** the finished product to length and desired quality.

5. **Remanufacturing** approximately ten percent of the production volume.

The present system employs:

- 2 men surfacing
- 7 men ripping
- 10 men cutting
- 14 men sorting and stacking
- 8 men remanufacturing

41 TOTAL
The system is operated on a two shift basis with production approximately 40 thousand board feet per shift.

The planing, ripping, and remanufacturing is done on a continuous basis with regard only to maximum utilization of the raw material. The trimming and sorting operations are affected by maximum utilization plus order requirements as to length and quality needed from the sash and frame departments.

Lumber is delivered to the department in two ways. Approximately 75 percent of the volume enters the department in the form of rough lumber and approximately 25 percent enters in the form of planed and ripped stock.

The planing operation starts with the delivery of rough lumber in unit lots of 2500 board feet to a transfer chain leading into the planer. The planer operator controls this transfer. He advances the transfer forward only when he has completed the lumber unit positioned at the planer. The planer operator feeds directly from the unit load of lumber into the planer. The feeding is accomplished by the use of a feed roller which allows the operator to balance the boards from the unit to the planer. The boards range from five to
117 pounds. This presents a definite problem to the planer operator when he is required to obtain boards from the bottom of the pile. As the lumber moves through the planer the top and bottom surfaces of the board are planed. There is considerable delay from boards stalling in the planer and the exchanging of raw material units.

The boards are received from the planer by the planer off­ bearer who by the use of a balancing roll stacks the surfaced boards into piles while the stock awaits the ripping operation.

The ripping operation employs three ripsaws with an input pile of lumber at each saw. Two of these piles are so positioned that the planer offbearer can stack boards where the ripsaw operators are taking boards from the pile for ripping. One ripsaw requires the pile to be shifted. This results in a delay of two ripsaws. The ripping operation is one of selecting the various combinations of widths which best conform to the policy of obtaining maximum utilization of the board. Once the selection is determined, the board is physically fed into the ripsaw. The board is then recycled through the ripsaw until the desired rips are completed. The number of cycles will vary due to the random width of the boards and the width variations that are ripped from the boards.
The cycle of reripping involves obtaining a board from the ripping pile, deciding what ripping is required, setting the saw, feeding the board into the saw, receiving the board from the saw and returning the section of the board requiring more ripping to the saw operator. The board is then recycled through the same process. The number of times the board is returned by the offbearer to the saw operator varies from two to six times with the average number being approximately four times. The offbearer moves the boards not requiring additional ripping to the trim saw infeed tables.

The trimming operation involves visual inspection of each board and selection of the proper lengths to cut from the board. The trim saw operator does the physical cutting with a circular saw. In some cases saws are manually controlled. In other cases semi-automatic controls are used. The waste material drops in the waste conveyor while the good stock drops on a belt transfer.

In the case of the cut stock for the sash department the material is sorted to length by the use of a drop sorter. After the stock has been sorted in the drop sorter it is graded manually for
remanufacturing or movement to pallets for shipment to the sash department.

Stock that is cut for frame orders is conveyed directly to a grader at each trim saw. The grader sorts the stock for quality, length, and remanufacturing. Men then carry the sorted stacks to pallets.

Remanufacturing is the process of reripping the cut stock to obtain usable pieces from an otherwise unsatisfactory board. The reripping is done on three heavy duty table saws and two multiple rip saws. In some instances stock requires replanning, but this operation is performed only ten percent of the time. The remanufactured stock is placed on pallets and removed to departments that utilize the particular size of stock that was salvaged.

The material is moved to the sash department by hand truck which is a two man operation. The material movement within the department is accomplished by four wheel cart and hand trucks. The movement to the frame department is by lift truck.

Material that enters the factory preripped represents approximately 25 percent of the total volume. The preripped
stock is brought into the factory in unit lots of 2500 board feet. The units go to two semi-automatic saws. Here they are handled in the same fashion as previously described in the trimming, sorting, and remanufacturing processes. Approximately 90 percent of the material processed in this fashion is frame stock. The sorting is handled by the grader and is not conveyed over the drop sorter.
Figure 2. Layout of present system for cutting department.
FIGURE 3

Mathematical Models and Man Machine Charts for Present System

Each operation has a formula which shows the cycle time and direct labor costs for producing an assumed representative board. A 20 percent allowance factor is included for personal delays and unavoidable delays.

**Planing Operation** (representative unit: Sash 6/4" x 10-3/4" x 18')

**Frame** 4/4" x 11-1/4" x 18'

**Man-machine Chart**

- Feeder
  - A
  - D
- Planer
  - B
  - E
- Offbearer
  - C
  - F
- 0
- 20
- 40

A. Get Bd. #1 and position for feeding
B. Plane two surfaces
C. Move bd. to ripsaw
D. Get bd. 2
E. Plane Bd. 2
F. Move Bd. 2 to ripsaw

**Model**

\[
(sash \& frame) = \left( \frac{\text{length of bd}}{\text{planer speed}} + \frac{\text{time to change units \& setups}}{\text{No. of bds / unit}} \right) \left[ \text{allowance factor} \right] \\
\text{cycle time} = \left( \frac{18 \text{ ft}}{108 \text{ lm}} + \frac{240 \text{ sec}}{100 \text{ bd}} \right) [1.2] = 14.9 \text{ secs} \\
\text{direct labor cost} = (\text{cycle time}) \times (\text{total wage rate/sec}) \\
= (14.9 \text{ sec}) (\$0.0014) = \$0.0209/\text{board}
\]
Figure 3 (continued)

Ripping Operation (representative unit: Input

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<tr>
<th>Sash</th>
<th>6/4&quot; x 10-3/4&quot; x 18'</th>
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<tbody>
<tr>
<td>Frame</td>
<td>4/4&quot; x 11-1/4&quot; x 18'</td>
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Output

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<tr>
<th>Sash</th>
<th>6/4&quot; x 2-1/2&quot; x 18' - 4 pieces</th>
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<tbody>
<tr>
<td>Frame</td>
<td>4/4&quot; x 3-1/2&quot; x 18' - 3 pieces</td>
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Man-Machine Chart (Sash Present System)

Feeder

Saw

Offbearer

Belt Return

Wasteman

A. Get board, inspect and position
B. Select first cut (mental decision time)
C. Rip first cut (usually a shim)
D. Offbearer moves board to belt return
E. Belt returns board to feeder for additional ripping
F. Feeder receives board and positions in saw
G. Rip board
H. Offbearer moves board requiring additional ripping to belt return
I. Offbearer takes ripped board to trimsaw
J. Belt returns board to feeder for additional ripping

Ripping (Frame Present System)

Feeder

Saw

Offbearer

Belt Return

Wasteman

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<td>A</td>
<td>B</td>
<td>C</td>
<td>F</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3 (continued)

Present system

\[
= \left\{ \begin{array}{l}
\text{get bd.} + \text{select} + \text{length of bd.} + \text{offbearer} + \text{length of bd + 5ft} + \\
\text{position} + \text{cut} + \text{machine speed} + \text{return bd, belt speed} + \\
\text{inspect} + \text{length of bd.} + \text{to saw oper.} + \\
\text{position} + \text{length of bd.} + \text{No. of rips} + \text{factor} + \\
\text{for sawing} + \text{machine speed} + \text{allowance} + \\
\end{array} \right. \\
\text{cycle time (sash)} = \left\{ \begin{array}{l}
8 \text{ sec} + 1 \text{ sec} + \frac{18\text{ ft}}{360 \text{ lfm}} + \left[ 1 \text{ sec} + \frac{18 + 5\text{ ft}}{460 \text{ lfm}} + \frac{18\text{ ft}}{360 \text{ lfm}} \right]^4 \right\}
\end{array} \right. \\
= \left\{ \begin{array}{l}
8 \text{ sec} + 1 \text{ sec} + \frac{18\text{ ft}}{216 \text{ lfm}} + \left[ 1 \text{ sec} + \frac{18 + 5\text{ ft}}{460 \text{ lfm}} + \frac{18\text{ ft}}{216 \text{ lfm}} \right]^3 \right\}
\end{array} \right. \\
\text{cycle time (frame)} = 52.8 \text{ sec/bd.} \\
\text{direct labor cost} = \left[ \frac{\text{Total cycle time}}{3 \text{ sec.}} \right] \left[ \frac{\text{total wage rate/hr.}}{3} \right] + \left[ \frac{\text{time for ripping}}{3} \right] \left[ \frac{\text{wage of wasteman/}}{3} \right] \\
= \left( \frac{52.8 \text{ sec}}{3} \right) \left( \frac{$0.00136}{\text{sec}} \right) + \left( \frac{52.8 \text{ sec}}{3} \right) \left( \frac{$0.00064}{\text{sec}} \right) = \$0.083/\text{board}
Figure 3 (continued)

Trimming Operation (representative unit: Input

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sash</td>
<td>6/4&quot; x 2-1/2&quot; x 18&quot; -- 4 pieces</td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>4/4&quot; x 3-1/2&quot; x 18&quot; -- 3 pieces</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sash</td>
<td>6/4&quot; x 2-1/2&quot; x 2' -- 28 pieces</td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>4/4&quot; x 3-1/2&quot; x 2' -- 21 pieces</td>
<td></td>
</tr>
</tbody>
</table>

Present = \[\text{move bd.} + \text{length of bd} \div \text{cutting rate} \times \text{No. of bd/std bd} + \text{allowance factor}\]

- Cycle time (sash) = \left(\frac{3 \text{ sec} + 18\text{ ft}}{38 \text{ lfm}}\right) \times 4 \times 1.2 = \frac{150.5 \text{ sec}}{\text{bd}}
- Cycle time (frame) = \left(\frac{3 \text{ sec} + 18\text{ ft}}{50 \text{ lfm}}\right) \times 3 \times 1.2 = \frac{88.8 \text{ sec}}{\text{bd}}

Direct labor cost = \left(\text{cycle time} \times \text{labor cost/second}\right)

- Direct labor cost (sash) = \left(\frac{150.5 \text{ sec}}{\text{sec}}\right) \times \$0.00068 = \$0.101/\text{bd}
- Direct labor cost (frame) = \left(\frac{88.8 \text{ sec}}{\text{sec}}\right) \times \$0.00072 = \$0.064/\text{bd}
Figure 3. (continued)

Sorting (representative unit

<table>
<thead>
<tr>
<th>Sash</th>
<th>Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/4&quot; x 2-1/2&quot; x 2' -- 28 pieces</td>
<td>4/4&quot; x 3-1/2&quot; x 2' -- 21 pieces</td>
</tr>
</tbody>
</table>

Present = \( \text{sorter operator's time/std bd.} + \left[ \text{grasp + inspect + move bd. + position move \ to pile & release back} \right] \text{No. of bd/ std bd} \) +

\[ \text{grasp + move + position + move to pile to pile on pallet sorter} \][No. of bd/ std bd] allowance

\[ \text{factor} \][No. of bd/s pile]

cycle time = \[
\begin{align*}
\text{(sash)} & = 22 \text{ sec} + \left[ 0.1 + 0.6 + 0.7 + 0.2 + 0.6 \frac{\text{sec}}{\text{bd}} \right] 28\text{bd.} + \left[ 0.3 + 4.5 + 0.5 + 4.5 \frac{\text{sec}}{\text{pile}} \right] \\
\text{(frame)} & = 0 + \left[ 0.1 + 0.6 + 0.7 + 0.2 + 0.6 \frac{\text{sec}}{\text{bd}} + 0.7 \frac{\text{sec}}{\text{delay}} \right] 21\text{bd.} + \left[ 0.3 + 4.5 + 0.5 + 4.5 \frac{\text{sec}}{\text{pile}} \right]
\end{align*}
\]

\[ \frac{28\text{bd}}{10 \text{ bd/pile}} \] 1.2 \text{ bd} = 140 \frac{\text{sec}}{\text{bd}}

\[ \frac{21\text{bd}}{10 \text{ bd/pile}} \] 1.2 \text{ bd} = 98.0 \frac{\text{sec}}{\text{bd}}

direct labor cost = (cycle time) (Labor/sec)

sash = (140 \frac{\text{sec}}{\text{bd}}) (0.000613/\text{sec}) = $0.0856/\text{bd}$

frame = (98.0 \frac{\text{sec}}{\text{bd}}) (0.000613/\text{sec}) = $0.06/\text{bd}$
### TABLE I

Summary of cycle times and direct labor costs calculated from mathematical formulas for present system in cutting department.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Sash cycle (seconds)</th>
<th>Sash direct labor cost</th>
<th>Frame cycle (seconds)</th>
<th>Frame direct labor cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planing</td>
<td>14.9</td>
<td>$0.0209</td>
<td>14.9</td>
<td>$0.0209</td>
</tr>
<tr>
<td>Ripping</td>
<td>52.8</td>
<td>$0.0830</td>
<td>52.8</td>
<td>$0.0830</td>
</tr>
<tr>
<td>Rip Sorting</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Trimming</td>
<td>150.5</td>
<td>$0.1010</td>
<td>88.8</td>
<td>$0.0640</td>
</tr>
<tr>
<td>Sorting</td>
<td>140.0</td>
<td>$0.0856</td>
<td>98.0</td>
<td>$0.0600</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td>$0.2905</td>
<td></td>
<td>$0.2279</td>
</tr>
<tr>
<td><strong>Total Time</strong></td>
<td>358.2 sec.</td>
<td></td>
<td>254.5 sec.</td>
<td></td>
</tr>
</tbody>
</table>
TECHNOLOGICALLY WORKABLE SYSTEM FOR THE CUTTING DEPARTMENT

With an investment of $72,448, an annual savings of $135,000 can be realized. This is accomplished by rearranging the present system and investing in some new equipment. The present labor force will be reduced from 39 to 27 men per shift. The production capacity will remain constant. The two man planing operation will be moved from the cutting department to another location.

The proposed system employs two straight line ripsaws that can be converted to gang ripsaws in a matter of seconds (figure 4). Each ripsaw will be equipped with a tilt hoist to aid the feeding operation. Also accompanying each saw is a push button saw set and automatic stock return for material requiring several cutting cycles.

As the ripped boards leave the ripsaws they are ejected onto a sorting conveyor. From this conveyor, the boards are sorted into unit loads according to their width and quality. The waste shims from the ripsaws continue down the conveyor to the waste hog.

When a unit of sorted stock is completed it is moved by gravity rolls to a transfer cart. There are three transfer carts.
SAVE TWO WAYS with this VERSATILE RIPSAW

SAVE LUMBER With Tri-State Model 816

Here's a heavy-duty multiple ripsaw that really "doubles in hours," and saves you lumber and money. You can use it as a heavy gang ripper or as a two-blade selective ripsaw. Either way, it's rugged, fast, accurate.

Note these Model 816 features.

- Built for rugged, accurate ripping at fast speeds with thin kerf, small diameter blades.
- 1½" long saw other provides sufficient saw spacing for most gang ripping requirements.
- Two drive arrangements available — direct coupled for 2,500 r.p.m. speed, high-speed timing belt drive for spindle speeds up to 8,000 r.p.m.
- Eight powered feed rolls ensure positive feeding at any desired speed.
- Two upper idler rolls easily adjustable for straight-line feeding or level "as or trim" - axis. Powerful machined cross-head feed roll assembly for short stock ripping optional.
- Extended shelf on lower inner feed roll provides built-in support blanks for booster rolls or conveyors.
- Provides easy glue joint accuracy on surfaced hardwoods or softwoods.
- Convenient pushbutton controls — squeezed anti-kickback fingers for maximum safety — easy, quick rip fence adjustment.

SAVE MONEY With One-Man Ripping Department

The Model 816 two-blade selective ripsaw is ideal for a ripping and cutoff operation. When it is used in a conveyorized layout with Industrial's booster rolls and automatic tailboy conveyors, one operator can do the work of four men and two straight-line rips. And in a matter of minutes the machine converts to a conventional gang ripsaw. On this basis it's easy to figure how quickly this equipment will pay for itself.

Figure 4. One Man Ripping Station: Shown is a single ripsaw that can be converted into a gang ripsaw. Connected with the ripsaw is an automatic tailboy that returns stock requiring additional ripping. The automatic stock return eliminates the ripsaw offbear.
The carts accept unit loads from the sorting conveyor, and feed them to the trimsaws. The unit load is moved from the transfer cart to gravity rolls leading to the trimsaws. The transfer cart has electric powered wheels and rolls.

There are three trimsaw subsystems. Each subsystem is composed of a scissor hoist and two semi-automatic trimsaws. When the unit load of boards is received from the transfer cart, it is elevated by a scissor hoist to the desired operator's height. The trimsaw operator takes the boards from the elevated unit to his trimsaw rolls, and makes the desired trims. The scissor hoist continues to rise as the boards are removed from the unit load. Each trim saw is accompanied by a cutting hopper that directs boards over four feet in length to the upper level of a two level sorting tray (Figure 5). The shorter boards are conveyed to the lower sorting belt. Waste is cut in lengths up to two feet long and conveyed to a waste hog.

The sorting tray is composed of two levels of sorting belts. The upper level moves the boards over four feet in length to the right end of the tray and holds them until they can be stacked on a
Figure 5. **Trim Saw Hopper.** Shown is a combination of chutes and belt conveyors for the direction of the trimming operation. The waste is directed down an air operated waste chute to a waste conveyor. The boards over 4 feet in length are directed to the upper level of the sorting tray while the boards under four feet drop straight down to a conveyor that conveys them to the lower sorting belt. The shorter boards then move down the sorting belt where they are sorted as to length and quality. The man in the right corner does the sorting. The man in the upper portion of the picture is the trimsaw operator.
Figure 6. A Two Level Sorting Tray. Shown is one end of a two level sorting tray. At the end of the tray there is a holding area for the board from the upper level. Two men are shown moving stacks of cut stock from a conveyor belt to shipping pallets.
pallet. The boards under four feet in length move along the lower sorting belt. As they move along the sorting belt, men sort them to length and quality. When a stack of sorted material is accumulated, it is placed on a belt conveyor which moves it to the stacking area (Figure 6).

The material for reripping is fed directly from the sorting belt into chutes that feed two table ripsaws.

The system employs the two semi-automatic saws, presently being used to handle raw material that has been preripped before entering the factory.

Figure 7. Savings and payoff period for workable system.

\[
\text{Savings} = \frac{23.825/\text{hr} \times 8\text{hr/shift} \times 2 \text{ shifts/day} \times 118\% \times 300\text{days/yr}}{135,000/\text{year}} = \frac{72,448 \times 12 \text{ months}}{135,000} = 6.42 \text{ months}
\]
<table>
<thead>
<tr>
<th>Operator's Description</th>
<th>Present labor force per shift</th>
<th>Proposed labor force per shift</th>
<th>Savings in labor per hour</th>
<th>Number of the improvement associated to labor savings (Table III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripsaw operator</td>
<td>3</td>
<td>2</td>
<td>2.195</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Ripsaw offbearer</td>
<td>3</td>
<td>0</td>
<td>5.865</td>
<td>4, 5</td>
</tr>
<tr>
<td>Stock sorter</td>
<td>0</td>
<td>2</td>
<td>(3.74)</td>
<td></td>
</tr>
<tr>
<td>Waste Cleanup man</td>
<td>1</td>
<td>0</td>
<td>1.95</td>
<td>6, 16</td>
</tr>
<tr>
<td>Trimsaw operator</td>
<td>10</td>
<td>8</td>
<td>4.16</td>
<td>8, 9, 10</td>
</tr>
<tr>
<td>Sorter operator</td>
<td>1</td>
<td>0</td>
<td>1.935</td>
<td>11, 12, 15</td>
</tr>
<tr>
<td>Sorter and stackers</td>
<td>13</td>
<td>10</td>
<td>5.61</td>
<td>11, 12, 13, 14, 15</td>
</tr>
<tr>
<td>Rerip operator</td>
<td>8</td>
<td>5</td>
<td>5.85</td>
<td>17</td>
</tr>
</tbody>
</table>

| Total manpower            | 39                             | 27                             |                           |                                                              |
| Total labor savings       | $27,565                        |                                |                           |                                                              |
| minus additional labor    | 3.74                           |                                |                           |                                                              |
| Net labor savings         | $23,825                        |                                |                           |                                                              |

* Labor cost not required in the present system.
### TABLE III

Summary of Cost of the Conversion of the Present System to the Technological workable System.

<table>
<thead>
<tr>
<th>Ripping Operation</th>
<th>Cost per Unit</th>
<th>Cost for System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Straight line ripsaw that can be converted into gang ripsaw.</td>
<td>$ 5,000</td>
<td>$ 10,000</td>
</tr>
<tr>
<td>2. Tilt Hoist and unit approach</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>3. Push Button Saw set</td>
<td>2,000</td>
<td>4,000</td>
</tr>
<tr>
<td>4. Automatic return for stock requiring additional ripping</td>
<td>1,500</td>
<td>3,000</td>
</tr>
<tr>
<td>5. 44 foot sorting transfer</td>
<td>4,400</td>
<td>4,400</td>
</tr>
<tr>
<td>6. Relocate present hog to new location and install waste belt.</td>
<td>1,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

**Unit Transfer**

<table>
<thead>
<tr>
<th>Unit Transfer</th>
<th>Cost per Unit</th>
<th>Cost for System</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Unit load transfer to move the sorted ripped units to the trimming operation.</td>
<td>10,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>

**Trimming And Sorting**

<table>
<thead>
<tr>
<th>Trimming And Sorting</th>
<th>Cost per Unit</th>
<th>Cost for System</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Scissor lift for each two trim saws.</td>
<td>3,000</td>
<td>9,000</td>
</tr>
<tr>
<td>9. Replace 6 manuel trimsaws with 4 semi-automatic saws</td>
<td>2,187</td>
<td>8,748</td>
</tr>
</tbody>
</table>
### TABLE III (continued)

<table>
<thead>
<tr>
<th>Ripping Operation</th>
<th>Cost per Unit</th>
<th>Cost for System</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Trimsaw hopper to handle waste and separate long boards (over 4 feet) from short boards.</td>
<td>1,000</td>
<td>6,000</td>
</tr>
<tr>
<td>11. 50 foot lower sorting belt</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>12. Upper sorting belt</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>13. Relocate belt conveyor presently moving stock to drop sorter, to be used to move piles of sorted stock to stacking area.</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>14. Roller conveyor for sorted stock</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>15. Construction material and labor</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>16. Hog to handle trim and rerip waste.</td>
<td>3,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

**Rerip**

| 17. Relocate ripsaws and construct feeding chutes to each saw.                   | 500           | 500             |

**TOTAL COST**

$72,448
Figure 8. Layout of workable system for cutting department.
FIGURE 9

Mathematical Models and Man-Machine Chart for Workable System

Each operation has a formula which shows the cycle time and direct labor costs for producing an assumed representative board. A 20 percent allowance factor is included for personal delays and unavoidable delays.

**Ripping Operation** (representative unit: Input 6/4" x 10-3/4" x 18' )
- **Input**: Sash 6/4" x 10-3/4" x 18'
- **Output**: Sash 6/4" x 2-1/2" x 18' -- 4 pieces
  - **Frame**: 4/4" x 11-1/4" x 18'
  - **Frame**: 4/4" x 3-1/2" x 18' -- 3 pieces

**Feeder**
- A. Get board from tilt hoist and inspect both sides of board.
- B. Select cuts.
- C. Machine rips board.
- D. Automatic return - returns boards needing additional ripping and rejects other on drag conveyor.
- E. Feeder receives board from return positions for next cut.

**2-saw Ripsaw**
- **Auto-return**
  - 0
  - 10
  - 20
  - Seconds

Diagram:
- A
- B
- C
- D
- E

---

38
Figure 9 (continued)

Workable system
\[
= \left( \text{get bd. + select + position cut + machine speed return bd. & inspect} \right) \left( \text{length of bd + automatic + receive + allowance position} \right) \frac{\text{No. of recycle rips}}{\text{allowance factor}}
\]

Cycle time
\[
= \left( 2.4 \text{sec} + 1 \text{sec} + \frac{18 \text{ft}}{400 \text{ lfm}} + 4 \text{sec} + 1 \text{sec} \right) \times 2 \text{ rips} \times (1.2) = 22.6 \text{ sec/bd}
\]

Direct labor cost
\[
= \text{(cycle time)} \times \text{(labor/sec)}
\]

Sash & Frame
\[
= \frac{(22.6 \text{ sec/bd}) \times (0.00072/\text{sec})}{\text{representative unit: Sash 6/4" x 2-1/2" x 18' -- 4 pieces) Frame 4/4" x 3-1/2" x 18' -- 3 pieces}} = \frac{0.0162}{\text{bd}}
\]

Ripsorting Operation
\[
= \left( \text{inspect + grasp + move bd.} \right) \times \frac{\text{No. bds}}{\text{std bd.}} + \frac{\text{time to transfer load}}{\text{No. of bds/unit}} \times \text{allowance factor}
\]

Cycle time (sash)
\[
= \left( 0.6 + 0.3 + 2.2 \text{ sec} \right) \times 4 + \frac{180 \text{ sec}}{100 \text{ bd}} \times 1.2 = 16.8 \text{ sec/bd}
\]

Cycle time (frame)
\[
= \left( 0.6 + 0.3 + 2.2 \text{ sec} \right) \times 3 + \frac{180 \text{ sec}}{100 \text{ bd}} \times 1.2 = 13.3 \text{ sec/bd}
\]

Direct labor cost
\[
= \text{(cycle time)} \times \text{(labor/sec)}
\]

Sash
\[
= \frac{(16.8 \text{ sec/bd}) \times (0.00064/\text{sec})}{\text{std bd.}} = \frac{0.0109}{\text{bd}}
\]

Frame
\[
= \frac{(13.3 \text{ sec/bd}) \times (0.00064/\text{sec})}{\text{std bd.}} = \frac{0.0085}{\text{bd}}
\]
Figure 9 (continued)

**Trimming Operation** (representative unit: Sash 6/4" x 2-1/2" x 18' -- 4 pieces)  
Frame 4/4" x 3-1/2 x 18' -- 3 pieces

Workable allowance  
\[ \text{move bd. from storage to feed rolls} + \frac{\text{length of bd}}{\text{cutting rate}} \times \frac{\text{No. of bd/ std bd.}}{\text{factor}} \]

\[
\begin{align*}
\text{cycle times (sash)} & = \left(\frac{3\text{sec} + \frac{18\text{ft}}{55\text{ lfm}}}{4}\right) 1.2 = 10.9\text{sec/bd} \\
\text{cycle times (frame)} & = \left(\frac{3\text{sec} + \frac{18\text{ft}}{55\text{ lfm}}}{3}\right) 1.2 = 81.6\text{sec/bd}
\end{align*}
\]

Direct labor costs  
\[
\text{direct labor costs (cycle time) (labor/sec)} = \text{cycle time} \times \text{labor/sec}
\]

Direct labor costs (sash)  
\[ (10.9\text{sec/bd}) \times ($0.00072/\text{sec}) = $0.0785/\text{bd} \]

Direct labor costs (frame)  
\[ (81.6\text{sec/bd}) \times ($0.00072/\text{sec}) = $0.0588/\text{bd} \]
Table 1.1: Workable cycle time and labor cost

<table>
<thead>
<tr>
<th>Operation</th>
<th>Sash (6/4&quot; x 2-1/2&quot; x 2') - 28 pieces</th>
<th>Frame (4/4&quot; x 3-1/2&quot; x 2') - 21 pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workable cycle time</td>
<td>1.4 = 106 sec/bd</td>
<td>1.2 = 84 sec/bd</td>
</tr>
<tr>
<td>Labor cost</td>
<td>$0.065/bd</td>
<td>$0.0515/bd</td>
</tr>
</tbody>
</table>

Note: The labor cost is calculated using the formula:

\[ \text{Labor cost per bd} = \frac{\text{Labor cost per sec}}{\text{Cycle time per sec}} \]
TABLE IV

Summary of cycle times and direct labor costs calculated from mathematical formulas for workable system in the cutting department.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Sash</th>
<th></th>
<th>Frame</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cycle time (seconds)</td>
<td>direct labor cost</td>
<td>cycle time (seconds)</td>
<td>Direct labor cost</td>
</tr>
<tr>
<td>Planing</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Ripping</td>
<td>22.6</td>
<td>$0.0162</td>
<td>22.6</td>
<td>$0.0162</td>
</tr>
<tr>
<td>Rip Sorting</td>
<td>16.8</td>
<td>$0.0109</td>
<td>13.3</td>
<td>$0.0085</td>
</tr>
<tr>
<td>Trimming</td>
<td>109.0</td>
<td>$0.0785</td>
<td>81.6</td>
<td>$0.0588</td>
</tr>
<tr>
<td>Sorting</td>
<td>106.0</td>
<td>$0.0650</td>
<td>84.0</td>
<td>$0.0515</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
<td>$0.1706</td>
<td></td>
<td>$0.1350</td>
</tr>
<tr>
<td>Total Time</td>
<td>254.4 sec.</td>
<td></td>
<td>201.5 sec.</td>
<td></td>
</tr>
</tbody>
</table>
ULTIMATE IDEAL SYSTEM FOR THE
THE CUTTING DEPARTMENT

The ultimate ideal system design is a system that requires further research and development before the system can become usable. This system has a definite design that employs automation as much as possible. It also gives a goal that all personnel can be thinking about for future improvements.

The ultimate system, for the cutting department, is centered in a push-button actuated multiple ripsaw with its six ripsaw blades automatically regulated by the ripsaw operator. Integrated with the ripsaw, is a tilt hoist that raises the lumber unit to a convenient feeding height. Above the ripsaw feed table are shadow lights that move independently with each blade (9, p. 45) (Figure 10, 11). After being ripped, the boards are transferred automatically on a drag conveyor, where the boards are sorted to width and quality. Defects that cannot be adequately scanned in the automatic trimsaws are sorted during the sorting operation.

Unit loads of sorted boards are transferred to the automatic trimsaw's feed table. The feeding operation is accomplished by
Figure 10. A Cutting Department Employing A Multiple Ripsaw. Shown is the cutting operation at the Malta Mfg. Co. The heart of the system is a multiply ripsaw equipped with electropneumatic saw controls, tilt lumber hoist, and a system of shadow lights. The shadow lights move with the saw blades of the ripsaw. The system cuts approximately 40 M board feet per shift (8, p. 45).
Figure 11. A Multiple Ripsaw Operation at the Hines Lumber Company, Hines, Oregon. The new saw is employed to selectively rip pine shop lumber to desired widths, making it unnecessary to return the unripped boards to the operator repeatedly.
one operator, with the assistance of a scissor lift. The boards that are directed to the automatic saws are scanned for defects. Programmed instructions eliminate the defects and cut the good pieces to the desired lengths. The boards are then deposited on a sorting belt where they are sorted to length and directed to pallets for shipment.

Unit loads of sorted boards, containing defects that cannot be scanned, are directed to two semi-automatic saws that are accompanied by a scissor lift and cutting hopper. The trimmed boards drop on the same sorting belt that services the automatic saws.

The material that must be reripped is selected directly from the sorting belt and placed into a hopper leading to a reripping operation. The reripping operation is accomplished by two saws and a crew of five men.

All waste from the system is automatically conveyed to waste hogs.
Areas Requiring Further Research

Presently there are conflicting feelings about the multiple ripsaw. Raymond E. Johnson of Malta Mfg. Co. states that he receives 80 percent yield from his raw material, which is four percent above the industrial average (9, p. 44).

The Weyerhauser Timber Company cut stock plant in Klamath Falls, Oregon, installed a multiply ripsaw and later replaced it with single ripsaws because they were receiving less recovery from their raw material.

The main point of the controversy seems to be that the ripsaw operator is unable to make adequate decisions when he is required to rip the board all at once, while he can obtain better recovery when he has to make only one decision at a time when using a single ripsaw. This presents the question that perhaps extensive training of a multiple ripsaw operator could be the answer.

Further research is needed to determine the expected recovery loss in comparison with single line ripsaws. Some drop in recovery could be experienced, and the system could still be economically feasible. Rough estimates determine that changes in yield
of 0.5 percent could be allowed and the multiple ripsaw still remain feasible. The savings in capital investment and reduced labor cost would compensate for the reduced recovery.

Some of the advantages of the multiple ripsaw are:

1. It is capable of producing a much larger volume of rip material than a single ripsaw.
2. It reduces the overall manpower requirements, as one multiple ripsaw operator can accomplish as much as four single ripsaw operators.
3. It eliminates the need for an automatic return behind the ripsaw.
4. It provides more production per square foot of floor space.
5. It requires a lower capital investment for one multiple ripsaw system than for a series of three or four single ripsaw systems.

Automatic electronic trim saws system was developed by the Western Pine Association in Portland, Oregon. The machine consists of six component parts. They are:
1. Infeed belt that feeds the boards from the drag transfer to the electronic scanner.

2. The scanner, which is basically two photoelectric cells, is focused on each of the board's two planed surfaces. The edges of the boards are not scanned. The board moves by conveyor belt, at speeds up to 300 linear feet per minute, through the dual scanner. Any change in light reflecting intensity of the board as it moves along is sent in the form of an electrical impulse to the computer control box.

3. A roller device records the board's length in relation to its defects, and feeds the information to the control box.

4. The control box is the heart of the system. It takes the information from the scanner and roller and combines them to form an image of the board. This image tells how long the defect is and the length of the good section in between the defects. With this information the control box compares the programmed usable lengths, supplied by the operator, with the length between defects. The
control box then directs the longest usable length cut from the board.

5. A paint sprayer places a black mark on the edge of the defective section. The black mark is the length of the section to be cut from the board and is dependent upon the instructions received from the control box.

6. The final components of the system are Irvington automatic cutoff saws equipped with a special crowding wheel and air stops. When the board approaches the cut off saw, the black mark sprayed on the edge of the board activates an air clamp that holds the board while the cut is made.

Two test models have been constructed. The first test model had the control mechanism open so that dust was able to disrupt some of the control functions. The second test model has its controls enclosed. It can be considered free from the effects of dust and vibration. The second test model has been run over an extensive test period and is felt ready to be tried on a production basis.
The International Paper Company at Weed, California was considering installation of the unit on a production basis, but it has been delayed until a machine manufacturer can join in the undertaking. Two manufacturers are being considered to manufacture the system. They are Mandrel Industries of Houston, Texas, and Food Machinery Company of San Jose, California. Both companies have had a great deal of experience in the manufacturing of scanning devices. It is estimated that the system will be ready for production by 1965 or 1966.

Figure 12. Effects That Defects Have on the Automatic Electronic Saw System

The scanner can detect:

1. all knots
2. all dark colored defects
3. splits
4. dark pitch.

The scanner has a problem detecting:

1. light pitch
2. medium and light blue stain
3. some types of twisted grain.
The automatic saw can operate at speeds up to 300 feet per minute. The infeed belt and scanner operate up to speeds of 300 lineal feet per minute. Each automatic saw operates at 50 lineal feet per minute. The system can hence be operated at full capacity with six automatic saws.
TABLE V

Comparison of labor requirements for present, workable, and ultimate systems for the cutting department.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Present labor force per shift</th>
<th>Workable labor force per shift</th>
<th>Ultimate labor force per shift</th>
<th>Savings in labor per hour-present vs. ultimate (Table VI)</th>
<th>The number of the improvement associated to labor savings.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripsaw operator</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4.39</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>Ripsaw offbearer</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>5.865</td>
<td>5</td>
</tr>
<tr>
<td>Stock sorter</td>
<td>0</td>
<td>*2</td>
<td>*2</td>
<td>(3.74)*</td>
<td></td>
</tr>
<tr>
<td>Waste Cleanup man</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1.95</td>
<td>6, 21</td>
</tr>
<tr>
<td>Trimsaw operator</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>14.56</td>
<td>8, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Sorter operator</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1.935</td>
<td>13, 14, 15</td>
</tr>
<tr>
<td>Sorter and stackers</td>
<td>13</td>
<td>10</td>
<td>7</td>
<td>9.35</td>
<td>16, 17, 18, 19, 20</td>
</tr>
<tr>
<td>Rerip operator</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>5.85</td>
<td>18</td>
</tr>
<tr>
<td>Total labor/shift</td>
<td>39</td>
<td>27</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross labor savings</td>
<td></td>
<td></td>
<td></td>
<td>$43.90</td>
<td></td>
</tr>
<tr>
<td>Minus additional labor</td>
<td></td>
<td></td>
<td></td>
<td>3.74</td>
<td></td>
</tr>
<tr>
<td>Net labor savings</td>
<td></td>
<td></td>
<td></td>
<td>$39.16</td>
<td></td>
</tr>
</tbody>
</table>

* Labor cost not required in the present system.
### TABLE VI

Summary of Cost of the Conversion of the Present System to the Ultimate System

<table>
<thead>
<tr>
<th>Ripping Operation</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple ripsaw (2)*</td>
<td>$7,400</td>
</tr>
<tr>
<td>2. Tilt hoist (6)*</td>
<td>$4,000</td>
</tr>
<tr>
<td>3. Shadow light</td>
<td>500</td>
</tr>
<tr>
<td>4. Automatic saw control (5)*</td>
<td>$5,000</td>
</tr>
<tr>
<td>5. 38 ft. belt drag transfer</td>
<td>$3,800</td>
</tr>
<tr>
<td>6. Hog relocation and hog conveyor</td>
<td>$1,000</td>
</tr>
<tr>
<td></td>
<td>$21,700</td>
</tr>
</tbody>
</table>

**Unit Transfer**

7. Unit load transfer to move the sorted ripped units to the trimming operation $5,000

**Automatic Trimsaw**

8. 51 ft. belt feed                        $1,200
9. 4 belt feeds -- 65 ft. each             $2,600
10. Automatic saw control (1)*             $20,000
11. Dual scanner (1)*                      $20,000
12. Purchase of 2 semi-automatic saws (3)* $4,374
13. Adapt 4 semi-automatic saws (1)*       $2,400
14. Waste conveyor - 57 ft. (use part of present waste conveyor) $750

**TOTAL COST** $51,324

**Trimming and Sorting**

15. 2 trimmer hoppers                      $2,000
16. Lower sorting belt                     $2,000
17. 26 ft. top sorting belt               $500
18. Relocation of ripping station          $500
19. 40 ft. of roller conveyor (4)*         $400
20. Construction labor and material        $1,000
21. Hog to handle trim wastes              $3,000

**TOTAL COST** $9,400

*Association and companies contacted for cost estimates:
1. Western Pine Association, Portland, Oregon.
2. Star Machinery, Portland, Oregon.
TABLE VII

Cost of Converting From Technological Workable System to Ultimate System:

<table>
<thead>
<tr>
<th>Ripping Operation</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple ripsaw</td>
<td>$7,400</td>
</tr>
<tr>
<td>2. Shadow lights</td>
<td>500</td>
</tr>
<tr>
<td>3. Automatic saw set controls</td>
<td>5,000</td>
</tr>
</tbody>
</table>

**Automatic Trimsaw**

| 4. Automatic saw system (51324-4374) | 46,950  |

**Total Cost** ------------------------- $59,850
Figure 13. Potential savings and estimated payoff for Ultimate System

\[
\text{Savings} = 39.16/\text{hr} \times 16\text{hr/day} \times 118\% \times 300\text{ days/yr} = 222,000/\text{year}
\]

\[
\text{Payoff period} = \frac{\text{cost of change} \times 12\text{ month/yr}}{\text{potential savings}}
\]

\[
= \frac{$87,424 \times 12}{$222,000}
\]

\[
= 4.75\text{ months}
\]
Figure 14. Layout of Ultimate System.
Each operation has a formula which shows the cycle time and direct labor costs for producing as assumed representative boards. A 20 percent allowance factor is included for personal delays and unavoidable delays.

**Ripping Operation** (representative unit: Input

- Sash: 6/4" x 10-3/4" x 18"
- Frame: 4/4" x 11-1/4" x 18"

Output

- Sash: 6/4" x 2-1/2" x 18' -- 4 pieces
- Frame: 4/4" x 3-1/2" x 18' -- 3 pieces

**Ripping (Sash and Frame Ultimate)**

<table>
<thead>
<tr>
<th>Feeder</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saw</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

- A. Get board from tilt hoist
- B. Select cut
- C. Rip board
Figure 15 (continued)

Ultimate System = [get bd. + select cut] allowance
position factor

cycle time(sash & frame) = (4 sec + 2 sec) 1.2 = 9.36 sec/bd.

direct labor cost = (cycle time) (labor/sec)

(sash & frame) = (9.36 sec/bd) ($0.00072/sec) = $0.00521

Rip sorting Operation (representative unit: Sash 6/4" x 2-1/2" x 18' -- 4 piece)
Frame 4/4" x 3-1/2" x 18' -- 3 piece

Ripsorting = [(inspect + grasp + move bd.) No. bds/ std bd. + time to transfer load] allowance

workable & ultimate

(sash) = [(0.6 sec + 0.3 sec + 2.2 sec) 4 + 180 sec] (1.2) = 16.8 sec/bd

(frame) = [(0.6 sec + 0.3 sec + 2.2 sec) 3 + 180 sec] (1.2) = 13.3 sec/bd
Figure 15 (continued)

direct labor cost (sash) \[ \text{direct labor cost} = (16.8 \text{sec/bd}) (0.00064/\text{sec}) = \$0.0109/\text{bd} \]

direct labor cost \[ \text{direct labor cost} = (13.3 \text{ sec/bd}) (0.00064/\text{sec}) = \$0.0085/\text{bd}. \]

**Trimming Operation**

(Representative unit input: Sash 6/4" x 2-1/2" x 18' -- 4 pieces)

Frame 4/4" x 3-1/2" x 18' -- 3 pieces

Output:

Sash 6/4" x 2-1/2" x 12' -- 28 pieces

Frame 4/4" x 3-1/2" x 2' -- 21 pieces

Ultimate

\[
\text{Ultimate} = \left( \frac{\text{Length of bd}}{\text{cutting rate}} \right) \left( \frac{\text{No. of bd/standard}}{\text{bd}} \right) \left( \frac{\text{Ratio of automatic saws to total saws}}{\text{move bd + length of bd}} \right) \left( \frac{\text{No. of bd/standard}}{\text{bd}} \right) \left( \frac{\text{Ratio of semi to total saw}}{\text{total saw}} \right)
\]

(sash)

\[
\left( \frac{18\text{ ft}}{55 \text{ lfm}} \right) \left[ \frac{4}{3} \right] \left[ \frac{4/6}{4/6} \right] + \left( \frac{3\text{ sec} + 18\text{ ft}}{55 \text{ lfm}} \right) \left[ \frac{4}{3} \right] \left[ \frac{2/6}{2/6} \right] \times 1.2 = 53.6 \text{ sec/bd}
\]

(frame)

\[
\left( \frac{18\text{ ft}}{200 \text{ lfm}} \right) \left[ \frac{5}{3} \right] \left[ \frac{3/6}{3/6} \right] + \left( \frac{3\text{ sec} + 18\text{ ft}}{55 \text{ lfm}} \right) \left[ \frac{3}{2} \right] \left[ \frac{2/6}{2/6} \right] \times 1.2 = 40.4 \text{ sec/bd}
\]

direct labor cost (sash) \[ \text{direct labor cost} = (58.6 \text{ sec/bd}) (0.00072/\text{sec}) = \$0.0377/\text{bd} \]

direct labor cost \[ \text{direct labor cost} = (40.4 \text{ sec/bd}) (0.00072/\text{sec}) = \$0.0288/\text{bd}. \]
Figure 15 (continued)

**Sorting Operation**

(Representative unit: Sash: 6/4" x 2-1/2" x 2' -- 28 pieces)

4/4" x 3-1/2" x 2' -- 21 pieces

Ultimate = \[
\left(\frac{\text{grasp} + \text{inspect} + \text{move to} + \text{position} + \text{move} \& \text{release back}}{\text{bd pile}}\right) \frac{\text{No. of bd/}}{\text{std bd}} + \left(\frac{\text{grasp} + \text{turn} \& \text{+ turn} \text{pile position back}}{\text{std bd}}\right) \frac{\text{No. of bd/}}{\text{std bd}} + \left(\frac{\text{grasp} + \text{move to} + \text{position} + \text{move} \& \text{release back}}{\text{bd pile}}\right) \frac{\text{No. of bd/}}{\text{std bd}}
\]

allowance factor

Cycle time (sash) = \[
(0.1 + 0.6 + 0.7 + 0.2 + 0.7 \text{sec}) \frac{28}{\text{bd}} + (0.3 + 0.7 + 0.7 \text{sec}) \frac{28}{\text{bd pile}} + (0.3 + 3.0 + 0.5 + 3.0 \text{sec}) \frac{28}{\text{bd pile}} (1.2) = 106 \text{ sec/bd.}
\]

Cycle time (frame) = \[
(0.3 + 0.6 + 0.7 + 0.2 + 0.7 \text{sec}) \frac{21}{\text{bd}} + (0.3 + 0.7 + 0.7 \text{sec}) \frac{21}{\text{bd pile}} + (0.3 + 3.0 + 0.5 + 3.0 \text{sec}) \frac{21}{\text{bd pile}} (1.2) = 89.5 \text{ sec/bd}
\]

Direct labor cost (sash) = \(106 \text{ sec/bd} \times (\$0.000613/\text{sec}) + \$0.065/\text{bd}\)

Direct labor cost = \(79.1 \text{ sec/bd} \times (\$0.000613/\text{sec}) = \$0.0494/\text{bd}\)
Summary of cycle times and direct labor costs calculated from mathematical formulas for ultimate system in the cutting department.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Sash</th>
<th>Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cycle time</td>
<td>cycle time</td>
</tr>
<tr>
<td></td>
<td>seconds</td>
<td>seconds</td>
</tr>
<tr>
<td></td>
<td>direct</td>
<td>direct</td>
</tr>
<tr>
<td></td>
<td>labor cost</td>
<td>labor cost</td>
</tr>
<tr>
<td>Planing</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Ripping</td>
<td>9.36</td>
<td>9.36</td>
</tr>
<tr>
<td></td>
<td>$0.00521</td>
<td>$0.00521</td>
</tr>
<tr>
<td>Rip Sorting</td>
<td>16.8</td>
<td>13.30</td>
</tr>
<tr>
<td></td>
<td>$0.0109</td>
<td>$0.00850</td>
</tr>
<tr>
<td>Trimming</td>
<td>53.6</td>
<td>40.40</td>
</tr>
<tr>
<td></td>
<td>$0.0377</td>
<td>$0.02880</td>
</tr>
<tr>
<td>Sorting</td>
<td>106.0</td>
<td>79.10</td>
</tr>
<tr>
<td></td>
<td>$0.0650</td>
<td>$0.04940</td>
</tr>
<tr>
<td>Total Cost</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Total Time</td>
<td>185.76 sec.</td>
<td>142.16 sec.</td>
</tr>
</tbody>
</table>
SECTION II

CONVENTIONAL APPROACH

Analysis of the sash and frame departments was accomplished by analysis of specific operations within the departments. The operators were selected because they were considered potential improvement areas. The conventional method of analysis was used to investigate the operators. Each analysis includes a brief description of the present and proposed methods. Also included with each analysis is a table summarizing the production, labor, cost of change and potential savings of each change.

IMPROVEMENT OF WORKPLACE ARRANGEMENT AT THE TENONER MACHINES IN THE SASH DEPARTMENT

The present method employs a crew of three operators at each of the two tenoners in the sash department. The three man crew is composed of one feeder, one machine operator, and one off bearer. During operation, the feeder and the machine operator feed the boards for machining into the tenoner. The machine operator is also responsible for adjusting the tenoner, and the accuracy of the
work which the machine performs. The offbearer takes the machined boards from the tenoner and places them on carts. When one pallet load is completed, the machine operator and feeder moves another pallet to the tenoner from nearby in-process storage. While the new pallet load is being positioned the tenoner is idle. The operation of changing pallets requires an average of two and one-half minutes compared to an average machining time of five minutes per pallet.

The proposed method would involve a rearrangement of the tenoner crew and elimination of one of the feeding men. A purchase would be required of two scissor lifts, 30 feet of storage rolls, and a battery powered hand truck.

The proposed tenoner crew would be composed of two, instead of three, men. The machine operator would feed the boards into the machine by himself. He would be aided by a scissor lift that would maintain the feeding pallet load at a convenient height. One of the men previously feeding the tenoner would bring the pallets from the in-process storage area to the tenoner storage rolls. He would also be required to have carts available for the offbearer.
The operation of changing pallets would involve moving the completed pallet skid to one side, then moving the new pallet forward, recording the new pallet on the production record, and commencing to feed from the new pallet. The proposed pallet changing operation can be accomplished in approximately 30 seconds compared to the previous time of two and one-half minutes.

With the reduction of the feeding operation, from two men to one man, a slight reduction in production is encountered, even when the scissor lift is employed. The savings in pallet changing time results in a total production increase of 13.4 percent.
Figure 16

Cost Comparison for Improving Work Place Arrangement at Tenoner Machine in Sash Department

Analysis of labor force, analysis of the present and proposed production times

<table>
<thead>
<tr>
<th>Present</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to change pallets</td>
<td>2-1/2 min.</td>
</tr>
<tr>
<td>Time to machine average pallet load</td>
<td>5 min.</td>
</tr>
<tr>
<td>Total time</td>
<td>7-1/2 min.</td>
</tr>
<tr>
<td>Total percent increase</td>
<td></td>
</tr>
</tbody>
</table>

Cost of the Proposed Change

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Powered Hand Truck</td>
<td>$1,500</td>
</tr>
<tr>
<td>Two section of storage rolls, 15 feet each</td>
<td>300</td>
</tr>
<tr>
<td>Two scissor lifts</td>
<td>1,300</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$3,100</td>
</tr>
</tbody>
</table>

Calculation of Proposed Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly cost of one machine feeder</td>
<td>$5,600</td>
</tr>
<tr>
<td>Savings from production increase 13.4%</td>
<td>3,900</td>
</tr>
<tr>
<td>(Total labor costs $29,200)</td>
<td>$9,500</td>
</tr>
</tbody>
</table>

Calculation of Payoff Period

\[
\text{Payoff period} = \frac{\$3100 \times 12 \text{ months}}{\$9500} = 3.92 \text{ months}
\]
Analysis of Men and Equipment Requirements for the proposed and present methods

<table>
<thead>
<tr>
<th>Present Method</th>
<th>Proposed Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
</tr>
<tr>
<td>2--feeder operators</td>
<td>2--machine operators</td>
</tr>
<tr>
<td>2--machine operators</td>
<td>2--offbearers</td>
</tr>
<tr>
<td>2--offbearers</td>
<td>1--hand truck operator</td>
</tr>
<tr>
<td><strong>EQUIPMENT</strong></td>
<td></td>
</tr>
<tr>
<td>2--manual hand trucks</td>
<td>1--battery powered hand truck</td>
</tr>
<tr>
<td></td>
<td>2--scissor lifts</td>
</tr>
<tr>
<td></td>
<td>30' of storage rolls</td>
</tr>
</tbody>
</table>
INSTALLATION OF A ONE-MAN TENONER-MORTISER MACHINE

The present method of placing the end pattern and mortised slot in the bottom stile requires the use of two machines with unloading and loading operations at each machine.

The first operation is performed on a double end tenoner. The stiles are unloaded from a pallet, and fed into the tenoner. The tenoner machines the end pattern, and trims the stile to the desired length. The stiles are unloaded by an offbearer, and placed on carts for movement to the mortiser.

The mortiser is a one man operation. The operator takes one stile at a time, feeds it into the machine, and then places the completed piece on another cart.

The proposed method would employ a Challoner #780 Tenoner-Mortiser Combination Machine. (figure 17). The stiles are brought to the machine on a pallet. Then with one operator, the stock is passed through the machine, where it is automatically trimmed, tenoned, coped, and the mortise slot cut. Convenient hoppers at the front of the machine enable the operator to stack the pieces handily; the stock is then returned to him for unloading on out-feed bars below the hoppers.
Figure 17. Mortise-Tenoner Combination. It is the customary practice, when manufacturing bottom stiles, to trim, tenon and cope the stock on a double-end tenoner, and then perform the mortising on a separate multiple mortiser, with usually two men on the tenoner and one on the mortiser. The principle of the 780 is the combining of these operations in one machine, with only one operator.
Figure 18

Cost Comparison for the Installation of a One-man Tenoner Mortiser

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Production/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortiser</td>
<td>1-1/2 machines/shift-- 24/min</td>
<td>4,800 pc</td>
</tr>
<tr>
<td>Tenoner</td>
<td>90/min</td>
<td>17,280 pc</td>
</tr>
<tr>
<td>Mortiser-Tenoner Combination</td>
<td>21/min</td>
<td>4,000 pc</td>
</tr>
</tbody>
</table>

Labor Costs per Piece

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortiser</td>
<td>$2.00/hr x 8 hr. x 118% x 1.5 mach. = 0.59¢/pc</td>
</tr>
<tr>
<td></td>
<td>4800 pc/day</td>
</tr>
<tr>
<td>Tenoner</td>
<td>($1.97 + 2.41 + 1.97) 8hr x 118% = 0.348¢/pc</td>
</tr>
<tr>
<td></td>
<td>17280 pc/day</td>
</tr>
<tr>
<td>Combination</td>
<td>$2.41/hr x 8hr x 118% = 0.57¢/pc</td>
</tr>
<tr>
<td></td>
<td>4000pc/day</td>
</tr>
</tbody>
</table>

Savings

Savings/pc = (0.59 + 0.348) - 0.57¢/pc = 0.368¢/pc

Annual savings = 1,440,000 pc/yr x 0.368¢/pc = $5300

Cost of Change

Cost of #780 Tenoner Mortiser Machine with saw, tenon cope and three chain mortising units. $28,250

Installation 750

Total Cost $29,000

Payoff Period

Payoff period = $29,000 = 5.41 years
$/5,300
IMPROVEMENT OF THE SASH ASSEMBLY OPERATION

The assembly operation requires the clamping, squaring and pinning of window sash.

In the present method, the assembly operation is performed by a team of two operators. The operators simultaneously place the required parts of the window sash into a power clamp. The clamp, when activated, squares the sash. The operators then hit each joint with a rubber hammer to insure a correct fit. Each corner of the sash is then pinned with a staple gun. The clamp is released, and the completed sash removed. The cycle is then repeated. The present operation requires 17 seconds per sash.

In the proposed method, an automatic clamping machine, designed by Handy Manufacturing Company, could be purchased. This machine is capable of clamping, squaring, and pinning window sash automatically. With loosely pre-assembled sash, and two operators, it is possible to clamp, square, and automatically pin at a rate of 16 or 17 sash per minute. The control of the production speed is governed by the speed at which the operators can place and remove the sash. When the sash parts are placed directly into the clamp,
two men can assemble a sash in 10 seconds.

The machine can be equipped with hoppers to speed the feeding of the parts into the clamp.

**Figure 19**

Cost Comparison of the Sash Assembly Operation

<table>
<thead>
<tr>
<th>Labor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present labor costs = production time/sash x hourly labor costs</td>
</tr>
<tr>
<td>= 17 sec/sash x 1/3600 sec/hr. x (2.11 + 2.025) 118%</td>
</tr>
<tr>
<td>= $0.023/sash</td>
</tr>
<tr>
<td>Proposed labor costs = 10 sec/sash x 1/3600 x (2.11 + 2.025) 118%</td>
</tr>
<tr>
<td>= $0.008/sash</td>
</tr>
</tbody>
</table>

**Savings per year**

Savings/year = (present cost - proposed cost) x annual production

= ($0.023 - 0.008) x 500,000 units/yr.

= $7500/year

**Cost of Clamp**

Cost = $8,000 Estimate--letter dated March 25, 1963, Handy Manufacturing Company

**Payoff Period for Investment**

Payoff period = $8,000 x 12 months/yr = 12.8 months

$7,500
INSTALLATION OF DADO-SILL TENONER IN THE FRAME DEPARTMENT

In the present process, the sill end pattern is machined on a sill saw. The sills are placed in the saw one at a time, and one end is machined. The sill is then rotated, and the remaining end machined.

Also in the frame process, the window and door frames are dadoed on a dado machine. The parts are placed in the machine three at a time, but only one piece is machined at a time. There is a separate dado saw for window frames and door frames.

In the proposed methods, a new tenoner, with an attachment which will perform both the sill end design and dado work, should be purchased. The attachment would eliminate the sill saw completely, and one dado saw. The other dado saw should be maintained for long boards. This dado saw could be used to supplement production if needed in special cases.
Figure 20

Cost Comparison of a Dado Sill Tenoner in Frame Department

<table>
<thead>
<tr>
<th>Production times</th>
<th>Normal</th>
<th>Allowance factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sill saw</td>
<td>(0.0715 pc/sec)</td>
<td>(1/1.25 \times 3600) sec/hr = 288 pc/hr</td>
</tr>
<tr>
<td>Window Dado</td>
<td>(0.172 pc/sec)</td>
<td>(1/1.25 \times 3600) sec/hr = 495 pc/hr</td>
</tr>
<tr>
<td>Door Dado</td>
<td>(0.172 pc/sec)</td>
<td>(1/1.25 \times 3600) sec/hr = 495 pc/hr</td>
</tr>
<tr>
<td>Sill and attachment</td>
<td>(0.735 pc/sec)</td>
<td>(1/1.25 \times 3600) sec/hr = 2120 pc/hr</td>
</tr>
</tbody>
</table>

Total Production presently from the sill, window dado, and door dado:

\[(288\text{pc/hr} \times 16\text{hr/day}) + (495\text{pc/hr} \times 16\text{hr/day}) + (495\text{pc/hr} \times 2\text{hr/day}) = 13,490\text{ pc/day} \]

Number of hours the tenoner attachment will have to work to produce the present production:

\[
\text{No. of hr.} = \frac{13490\text{pc/day}}{2120\text{pc/hr}} = 6.35\text{ hrs.}
\]

Present labor cost per day

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sill saw</td>
<td>16hr x 118% x $2.12/hr</td>
<td>$40.00</td>
</tr>
<tr>
<td>Window dado</td>
<td>16hr x 118% x $2.07/hr</td>
<td>$39.00</td>
</tr>
<tr>
<td>Door dado</td>
<td>2hr x 118% x $2.07/hr</td>
<td>$4.88</td>
</tr>
</tbody>
</table>

\[\text{Proposed labor cost} \]

\[
6.35\text{hr} \times 118\% \times ($2.33 = 1.95) = $32.00
\]

\[\text{Savings per day} \]

\[
\$51.88/\text{day} \times 300\text{days/year} = $15,500
\]
Figure 20 (continued)

Cost of a New Tenoner With a Dado Sill Attachment

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>New machine complete with attachments</td>
<td>$30,000</td>
</tr>
<tr>
<td>Installation</td>
<td>$1,000</td>
</tr>
<tr>
<td>Total cost</td>
<td>$31,000</td>
</tr>
</tbody>
</table>


Payoff Period

\[
\text{Payoff period} = \frac{\$31,000 \times 12 \text{ months/year}}{\$15,500} = 24.8 \text{ months}
\]
ANALYSIS OF THE TREATING DEPARTMENT

The present system employs one man with a hand truck and two loading the bundles into the treating tank. The man with the hand truck brings the pallets from nearby storage, and positions them in front of the treating tank. He also takes the treated pallet loads back to storage. Once the pallet is positioned in front of the treating tank, two men load the bundles into the tank. A chain conveyor travels at such a speed that the bundles are in the treating solution for three minutes, and then lifted out and drained on the return travel. The bundles are then unloaded from the tank onto pallets.

There are three possible alternatives. One method employs a two pallet dip tank, another method uses an attachment on a lift truck that will dip one pallet at a time. The third method is called the Dri-Vac process. In the Dri-Vac process, the treatment is applied by the use of a vacuum.

The proposed dip tank system employs a dip tank that dips two complete pallet loads of bundled or unbundled parts at one time. The system has storage rolls leading to the dip tank, and rolls for the
treated pallet loads to drain (figure 22). One man with a power operated hand truck can operate the entire treating process. Lift trucks from the sash and frame departments bring the pallet loads to the treating area, either placing them on the rolls leading to the treating tank, or nearby. The operator pushes two pallets from the rollers leading to the tank onto the treating elevator in the tank. The elevator then lowers the pallets and soaks them for 3 minutes. An automatic timing switch will activate the elevating mechanism. The treated pallets can then be moved forward on rollers where they can drain. After the treated pallets have been moved from the elevator, two more pallets can be moved forward for treating. While the pallets are being treated, the treating man with his hand truck can position two new pallets for treating, and remove the treated pallets from the output rolls. Very often lift trucks bringing pallets to be treated can place them directly on the input rolls, pick up the treated pallets, and take them back to their departments.

The treating quality is similar to the quality obtained from the present system. Some companies in the Northwest are using the pallet dip tank process and find it satisfactory. It does not give
as good a quality as the Dri-Vac process. The system will not meet the forecasted desired treatment quality, so the pallet dip tank will be only a temporary solution to the treating requirement.

A lift truck dip tank would work similar to the pallet dip tank previously described. A lift truck, with an attachment that will grasp the pallet unit from the top, grasps the pallet from storage, and moves it to the treating tank. The pallet is lowered into the treating solution and soaked for three minutes. The load is then raised and held above the tank until the load is drained. The unit is then moved back to storage.

The Dri-Vac process is a method of applying preservative to wood through the use of controlled vacuum. The vacuum method is not new, but it is only within recent years that it has been used to apply clean water repellent preservatives to wood. The Dri-Vac process gives deeper penetration and higher retention of preservative than other methods. The plant consists essentially of an airtight tank chamber capable of maintaining a controlled vacuum, and several preservative storage tanks. The application process involves a multi-step cycle in which a charge of wood enters the
chamber, is subjected to vacuum, lowered into solution, raised from solution after vacuum is released, subjected to vacuum again, and finally withdrawn from the chamber fully treated. The entire operation is automatic, but can be regulated to the specific requirements of the wood being treated. When the final vacuum is released, the solution remaining on the surface is drawn deeply into the wood, thus making the wood dry to the touch and ready for use.
Figure 21

Cost Comparison for Treating Window and Frame Parts by Dip Tank, Lift Truck, or Dri-Vac Process

<table>
<thead>
<tr>
<th>Labor cost for present and Proposed methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present = 6 men at $5500/year = $33,000</td>
</tr>
<tr>
<td>Proposed = 1 man at $5500/year = $5,500</td>
</tr>
<tr>
<td>Labor savings = $28,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of Each Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two pallet dip tank</td>
</tr>
<tr>
<td>60 feet of rolls</td>
</tr>
<tr>
<td>Tank, 10'x12'x6'</td>
</tr>
<tr>
<td>Electrical lifting and lowering device with timing switch</td>
</tr>
<tr>
<td>Labor and installation of new tank</td>
</tr>
<tr>
<td>Removal of old tank</td>
</tr>
<tr>
<td>Total cost = $3,000</td>
</tr>
<tr>
<td>Lift truck dip tank</td>
</tr>
<tr>
<td>Used lift truck</td>
</tr>
<tr>
<td>Attachment for lift truck</td>
</tr>
<tr>
<td>Tank</td>
</tr>
<tr>
<td>Total cost = $3,800</td>
</tr>
<tr>
<td>Dri-Vac process</td>
</tr>
<tr>
<td>Total cost with installation = $100,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Payoff periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two pallet tank = $3,000 x 12 months = 1.29 months</td>
</tr>
<tr>
<td>Lift truck tank = $3,800 x 12 months = 1.63 months</td>
</tr>
<tr>
<td>Dri-Vac process = $100,000 x 12 months = 42.8 months</td>
</tr>
</tbody>
</table>


Figure 22. Layout of two pallet dip tank.
SUMMARY

The study of investment decisions by the use of mathematical models had a threefold purpose in its usefulness.

1. Models demonstrated the need for more comprehensive data collection, and the analysis and development of manufacturing system images.

2. After a concept of the present, workable, and ultimate systems was conceived, mathematical models were used to evaluate and summarize each system.

3. The study provided an opportunity to analyze individual operations in the sash and frame departments, and apply industrial engineering techniques to them.

The study verified how mathematical models aid in presenting information to management when an evaluation of a system is required. A model provides a valuable presentation of information that may have been obscured in previous analyses. A model will also point out relationships between storage requirements, delays, machine capacities, and transportation requirements. Particular care was used in obtaining the most accurate data available. Motion pictures of the present system were
analyzed by the use of the micromotion and synthetic timing tech­
niques. Production records were analyzed, and observed times were acquired.

Using the ideal system concept, two complete systems were designed for the cutting department; the workable system being feasible now, and the ultimate system requiring additional development and training. The ideal system emphasizes system analysis, rather than individual operation analysis. The ideal concept requires the development of at least two systems. This provides the operating personnel with a goal for development of future processes. This encourages a company to continue striving for better methods, rather than being satisfied with the present system.

After developing the two systems in the cutting department, mathematical models were constructed of each system. A model was also constructed of the present system. The models provided an evaluation and comparison of each system. A unit which the model was to represent was decided to be an average size board as it entered the cutting department. Assumptions were made as to initial size of the board and subsequent sizes at each operation. A definite advantage in using a model is its flexibility. If one assumption
proves inaccurate, the model may be readily changed and the answer obtained. The models were used to calculate the direct labor cost and the cycle-times required to manufacture a representative board.

Each system in the cutting department was evaluated to determine the effects production has upon proposed savings. The results of this evaluation is shown in figure 23. It is shown that the ultimate system must maintain a production above 50 to 56 thousand board feet per day in order to break even on the proposed investment. It is also shown that the workable system must produce between 66 to 68 thousand board feet per day in order to break even. The workable system has a maximum production per 16 hour day of 105 to 111 thousand board feet depending on the mixture of sash and frame stock. The ultimate system has a maximum production of 108 to 120 thousand board feet per 16 hour day. A comparison of the results from the mathematical models for the present, workable, and ultimate systems is shown in table IX.

Analysis of the sash and frame department was accomplished by what could be called the conventional approach. Operations showing one or more of the following factors were examined:
Figure 23. Effects production has upon savings and break even point for workable and ultimate systems.
### TABLE IX

Summary of cycle times and direct labor costs calculated from mathematical formulas for present, workable, and ultimate system for the cutting department.

Results are shown in direct labor cost and man-seconds per representative board as defined on the following page. A 20% allowance factor has been included in the formula for personal time and delays.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Present System</th>
<th>Workable System</th>
<th>Ultimate System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sash</td>
<td>frame</td>
<td>sash</td>
</tr>
<tr>
<td>Planing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 0.0209</td>
<td>$ 0.0209</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>14.9</td>
<td>19.9</td>
<td>----</td>
</tr>
<tr>
<td>Ripping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 0.083</td>
<td>$ 0.0830</td>
<td>$ 0.0162</td>
</tr>
<tr>
<td></td>
<td>52.8</td>
<td>52.8</td>
<td>22.6</td>
</tr>
<tr>
<td>Rip Sorting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>----</td>
<td>$ 0.0109</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>----</td>
<td>16.8</td>
</tr>
<tr>
<td>Trimming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 0.1010</td>
<td>$ 0.0640</td>
<td>$ 0.0785</td>
</tr>
<tr>
<td></td>
<td>150.5</td>
<td>88.8</td>
<td>109.0</td>
</tr>
<tr>
<td>Sorting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 0.0856</td>
<td>$ 0.0600</td>
<td>$ 0.065</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>98.0</td>
<td>106.0</td>
</tr>
<tr>
<td>Total cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 0.2905</td>
<td>$ 0.2279</td>
<td>$ 0.1706</td>
</tr>
<tr>
<td>Total time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>358.2</td>
<td>254.5</td>
<td>254.4</td>
</tr>
</tbody>
</table>

Total cost minus cost of planing ($ 0.2696) ($ 0.2070)
1. Inequalities in work distribution among operators.
2. Large amounts of balance delay and idle time.
3. Excessive delays in the process.
4. Excessive floor space for in-process storage.
5. Unnecessary handling and transportation.

After individual operations were selected, new methods and equipment that would improve or eliminate the operation were investigated. Each method and/or piece of equipment was investigated to determine how it would affect cost. The results were prepared in tabular form with each improvement.

Shown in table X is a brief summary of the findings developed for the cutting, sash, and frame departments when using the conventional evaluation approach. Noted in table X are the evaluation results of the workable and ultimate cutting department systems by the use of mathematical models. The reason the models understate the savings may be largely due to personal time delays amounting to more than 20 percent of the cycle time, transportation to sash and frame departments, re-ripping, and the model may not be representative.
<table>
<thead>
<tr>
<th>Department</th>
<th>Savings</th>
<th>Cost</th>
<th>Payoff Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workable system</td>
<td>$135,000</td>
<td>$72,448</td>
<td>6.42 months</td>
</tr>
<tr>
<td>Ultimate system</td>
<td>$222,000</td>
<td>$87,424</td>
<td>4.75 months</td>
</tr>
<tr>
<td>Sash</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workplace rearrangement at sash tenoners</td>
<td>$9,500</td>
<td>$3,100</td>
<td>3.92 months</td>
</tr>
<tr>
<td>One man tenoner-mortiser machine</td>
<td>$5,300</td>
<td>$29,000</td>
<td>5.41 years</td>
</tr>
<tr>
<td>Sash assembly operation</td>
<td>$7,500</td>
<td>$8,000</td>
<td>12.8 months</td>
</tr>
<tr>
<td>Frame</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dado-sill machine</td>
<td>$15,500</td>
<td>$31,000</td>
<td>24.8 months</td>
</tr>
<tr>
<td>Treating operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two pallet dip tank</td>
<td>$28,000</td>
<td>$3,000</td>
<td>1.29 months</td>
</tr>
<tr>
<td>Lift truck dip attachment</td>
<td>$28,000</td>
<td>$3,800</td>
<td>1.63 months</td>
</tr>
<tr>
<td>Dri-vac process</td>
<td>$28,000</td>
<td>$100,000</td>
<td>42.8 months</td>
</tr>
</tbody>
</table>

* Evaluation results using mathematical models, plus saving from re-ripping operation.
RECOMMENDATIONS FOR FURTHER STUDY

There are several areas where further study may prove beneficial. They are:

1. Apply model under a different set of restrictions. For example, different dimensions of raw material entering the plant and variations in material recovery.
2. Test sampling validity by substituting values of all dimensions in formulas.
3. Expansion of the mathematical models to illustrate a product from the time the raw material enters the factory until the time the completed product leaves for shipment.
4. Investigation of the expected recovery loss between single and multiple ripping.
5. Investigation of recovery for all operations.
6. Investigation of allowance factors for unavoidable delays and personal times at each operation.
7. Investigation of unidentified transportation costs.
DEFINITIONS

Board Feet--A measurement used in the lumber industry. One board foot is equal in volume to a board one inch thick, twelve inches wide and twelve inches long.

Cycle--A cycle is a term that designates any portion of an operation that recurs regularly in the same order.

Element--An element is that subdivision of a cycle that can be described as a basic activity.

Man-Machine Chart--A graphic activity chart that shows type and duration of the activities of the men and the machines that are used in performing the designated operation.

Micromotion Study--Micromotion study is a technique for recording and timing an operation through the use of motion pictures taken at known speeds. It is a valuable aid in both the determination of the operation times and in the analysis of the methods used.

MTM--Methods-Time-Measurement is defined as a procedure which analyzes any manual operation or method into the basic motions required to perform it and assigns to each motion
a predetermined time standard which is determined by the nature of the motion and the condition under which it is made.

Operation--Operation is the designation of the activities that are performed at single machines or areas that have a definite, constructive effect on the conversion from the raw material to the finished product.

Rails--A rail is a cross or horizontal piece of the frame work of a sash or screen.

Sash--A sash is a single assembly of stiles and rails into a frame for holding glass, with or without dividing bars, to fill a given opening.

Standard time--Standard time is the time it will take a qualified "normal" person working at a normal pace to do a task throughout a workshift without excessive fatigue. The most common example of pace, as used in the definition, is the pace or effort required to walk on a level surface at the rate of three miles per hour.

Stiles--A stile is the upright or vertical outside piece of a sash or screen.
System Simulation--A way of performing experiments to determine the effect of changes in the laboratory, without the costly and disturbing job of experimenting with people and equipment.

Window--A window consists of two or more single sashes which fill a given opening. It may be either open or glazed.

Work System--A work system involves any level of the whole complex of physical and human activities required to process material or information to the desired state of product or service.
Standard Parts
Several widths of stiles, top rails, bottom rails and muntins are required. This is necessary in order to minimize the cutting of glass to fractional sizes in divided light windows and sash.
Specific layouts for all designs of windows and sash are given in the headings under each design. Deviations of any kind from these standard layouts necessarily result in windows or sash classified as "Special."

Sticking Profiles
Slight variations in profile of stickings are permitted among manufacturers under this Standard. Likewise, the bottom rails of all 1½" check rail windows may, at the option of the manufacturer, be furnished plain beveled as shown or plowed or shaped in conformity with the manufacturer's regular shop practice.

Figure 24. Window parts are shown in relation to the complete window. Noted are the sizes and machine patterns of each part.
BIBLIOGRAPHY


APPENDIX
Visits to Western Pine Manufacturing In Spokane, Washington

1. The first visit was made October 15th and 16th, 1962.
   a. The first objective was to outline the scope of the project.
   b. Special emphasis was placed on meeting with the operating personnel and obtaining their support.
   c. Considerable time was spent learning the manufacturing processes within the factory.
   d. Samples of various orders were examined to determine the various products manufactured.
   e. Motion picture films previously taken by Professor Engesser were shown to the operating personnel.

2. The second and third visits were made on November 2, 3, 4, and December 16, 17, 18. These visits were used to gather data about operations within the factory.

3. A fourth visit was made on March 11 and 12, 1963. This visit was used to present the primary results that had been developed, and verify some of the data previously gathered.
Visits To Northwest plants producing similar products.

On January 11, 1963 three plants were visited in Klamath Falls, Oregon.

- Weyerhauser Timber Company
- Jeld Wen Inc.
- Metler Brothers

Machinery Companies that were contacted.

Letters to equipment manufacturers were written to obtain information about capacities and costs of the newest equipment available.

- Greelee Bros. & Co., Rockford, Illinois
- Mereen Johnson Machine Co., Minneapolis, Minnesota
- Challoner Machinery Division, Oshkosh, Wisconsin
- J. A. Fay & Egan Co., Cincinnati, Ohio
- Protection Products Mfg. Co., Kalamazoo, Michigan
- Handy Manufacturing Company, Chicago, Illinois
- Stetson-Ross, Seattle, Washington

Personnel contact was made with the following machinery companies and association.

- Moore Dry Kiln Co., Portland, Oregon
- Oregon Handling Equipment, Portland, Oregon
- Irvington Machine Works, Tigard, Oregon
- Star Machinery Company, Portland, Oregon
- Sel-Set Machinery Corporation, Salem, Oregon
- Western Pine Association, Portland, Oregon