TRSys: a hardwood lumber grading Training and Remanufacturing System

P. Klinkhachorn
R. Kothari
R. Annavajjhala
C.W. McMillin

Abstract

The Training and Remanufacturing System (TRSys) is a new training tool for teaching both hardwood lumber grading and remanufacturing of lower grade boards into smaller boards of higher total value. TRSys is based on the HaLT2, ReGS, and enhanced HaRem computer programs. The most important feature of this new program is its ability to evaluate remanufacturing beyond simple edging and trimming. Provided the result is an increase in value, up to four boards can be remanufactured from one large board. The TRSys program, like the HaLT2 and HaRem programs, is limited to processing rectangular boards.

The Training and Remanufacturing System (TRSys) is a comprehensive program for personal computers that provides training in the grading of lumber[1] and the remanufacturing of lower grade lumber to boards with a higher overall value. TRSys contains a grading trainer module and a remanufacturing module. The grading trainer is based on HaLT2[2] and includes some of the features of ReGS.[3] The program determines the grade of the board and questions the user about key steps in the grading process. The operation of the TRSys grading trainer parallels HaLT2 and ReGS and will not be described here.

The TRSys remanufacturing module is an enhanced version of that used by HaRem.[4] The HaRem procedure calls for edging and/or trimming a board to a higher grade if the resulting smaller board has a higher value. Boards produced with HaRem must, of necessity, be of a higher grade. TRSys uses a new, value-driven, division-based remanufacturing system that can call for remanufacturing a single large board into as many as four smaller boards. One or more may be of the same or lower grade than the original board. The constraint is that the total value of all new boards must exceed that of the original board. Included in this value are the costs of remanufacturing.

TRSys requires an IBM PC (or compatible) with at least 640K of RAM and EGA graphics (or better). DOS 3.3 (or later) is required. The performance of the program can be enhanced with an AT-class (or better) machine, a hard disk, and a math coprocessor, although they are not essential to program operation. A mouse is required for most of the program operation.

Remanufacturing

Remanufacturing, as performed by the HaRem program, can be shown to produce nonoptimal results in many cases. The example in Figure 1 shows both

[1] National Hardwood Lumber Association. 1990. Rules for the measurement and inspection of hardwood and cypress. Memphis, Tenn.

[2] Klinkhachorn, P., C.J. Gatchell, C.W. McMillin, and R. Kothari. 1992. HaLT2: an enhanced lumber grading trainer. Forest Prod. J. 42(10):41-46.

[3] Gatchell, C.J., P. Klinkhachorn, and R. Kothari. 1992. ReGS — a realistic grading system. Forest Prod. J. 42(10):37-40.

[4] Schwehm, C.J., P. Klinkhachorn, C.W. McMillin, and H.A. Huber. 1990. HaRem: hardwood lumber remanufacturing program for maximizing value based on size, grade and current market prices. Forest Prod. J. 40(7/8):27-30.

Figure — A sample board (figure not to scale).

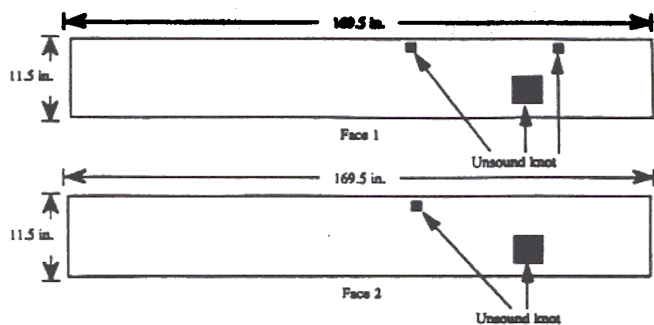Figure 3. — Board from Figure 1 as remanufactured by TRSys.

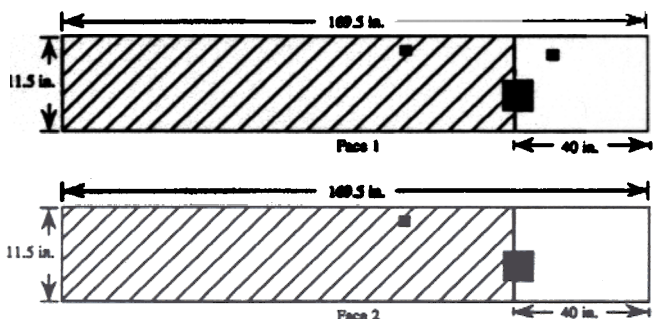

Figure 2. — Board from Figure 1 as remanufactured by HaRem. The resulting board is striped. (Figure not to scale).
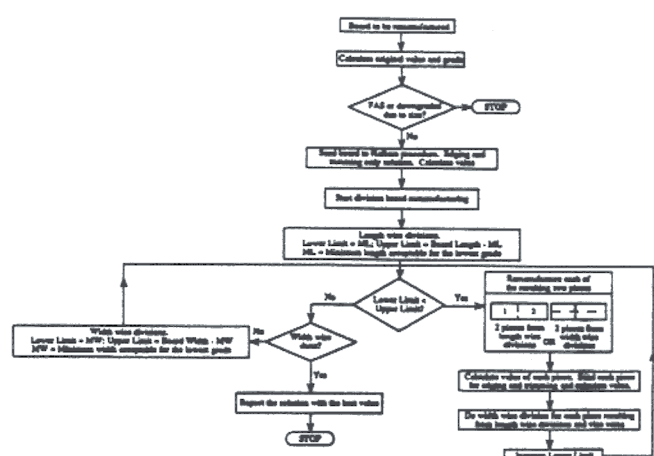
Figure 4. — The TRSys flowchart. The HaRem procedure is described in Forest Prod. J. 40(7/8):27-30.

faces of a board. The board grades as 13 board feet (BF) of No. 1 Common. Assuming current market prices of $900/thousand board feet (MBF), $800/MBF, $500/MBF, $350/MBF, and $250/MBF for grades FAS, Selects, No. 1 Common, No. 2 Common, and No. 3 Common, respectively, the board, as is, has a market value of $6.50. The solution obtained from HaRem is shown in Figure 2. A total of 40 inches has been crosscut from the right end of the board. This board now grades as 10 BF of FAS. Based on the market prices assumed previously, the board has a current market value of $9. The increase of $2.50 is substantial even after the cost of remanufacturing the board is taken into account.

However, an even higher value may result by dividing the board into two or more smaller boards. Consider the board divided into three separate boards, as shown in Figure 3. These three pieces now grade as 5 BF of FAS, 2 BF of No. 1 Common, and 6 BF of Selects. Again, based on our assumed market prices for the various grades, these three smaller boards have a value of $4.50, $1, and $4.80, respectively; resulting in a total market value of $10.30. This value is substantially higher than either the original value ($6.50) or the value of the board as remanufactured by HaRem ($9). Although simplified, this example illustrates that ripping and/or crosscutting alone do not guarantee the highest possible remanufactured value for a given board.
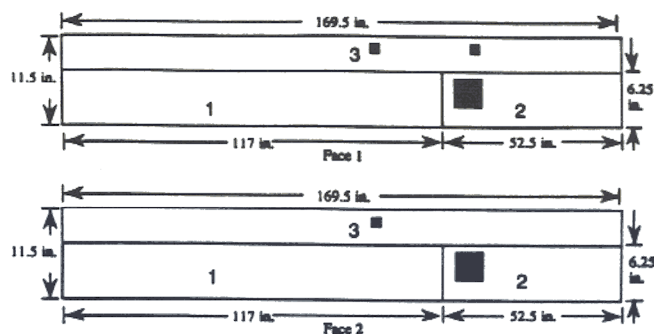
Division-based remanufacturing

Ripping and crosscutting are effective remanufacturing strategies in cases where grade-reducing defects such as wane are present along the edges of the board. In many cases, however, grade-reducing defects are present toward the center (away from the edges) of the board. In these cases, ripping and crosscutting are ineffective as remanufacturing strategies and division-based remanufacturing must be attempted.

The TRSys division-based remanufacturing procedure is outlined in the flowchart shown in Figure 4. The program starts by determining the highest possible grade of the board and the associated value. If the board grades as FAS, no additional remanufacturing is performed because the value of the board cannot be increased. If the board does not grade FAS because of its width or length, any further division of the board would yield only boards of lower grades and processing is also stopped. In all other cases, an attempt is made to obtain a remanufacturing solution that produces lumber with a total higher value.

After determining the best edging and/or trimming solution based on the HaRem algorithm, TRSys attempts to remanufacture the board using two additional methods — width first and then

length (WL) and length first and then width (LW) remanufacturing (Fig. 5).

The WL remanufacturing strategy is attempted first. The board is examined to see whether two narrower, full-length boards would have more value and, if so, what the widths are for the maximum value. Then, each of these new and narrower boards is examined to see whether a single crosscut can produce two shorter boards of greater total value than the newly generated narrow board. The maximum WL solution is compared to the optimum ripping and crosscutting solution and the solution providing the highest value is retained.

The LW strategy is then tried starting with the original board. The board is examined to determine whether it can be crosscut into two shorter boards of greater total value. If so, each shorter piece is evaluated to determine whether it can be ripped once to two narrower boards of greater total value. Again, the optimum LW solution is compared with the highest value retained from the previous step. The solution providing the highest value is retained.

Program operation

The initial TRSys screen is shown in Figure 6. The first step is to select the board file to be processed (SAMPLE3.BRD in this example). This may be done by highlighting (clicking) with the mouse or by typing in the file name. If the file is on a different drive or in a different subdirectory, the "Quick entry" may be used by specifying the name and the location of the file (i.e., A:\TRSYS\ANDY.DAT).

Create menu

The create menu has three sub menus: create a board file, create a price file, or create a cost file. Selecting any of these options allows the user to create, append, or overwrite the corresponding file. Each of these options behaves in a manner consistent with the rest of the program. Selecting the create board file brings up a window similar to the one shown in Figure 6. The user may click on the file in the list, in which case the program will automatically append to the existing file, or type in a name to create a new file.
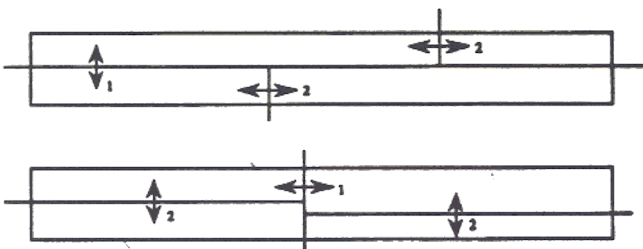

Figure 5. — The width first/length second (top) and length first/width second (bottom) remanufacturing strategies used during division-based remanufacturing. Numbers indicate the sequence in which the cuts are placed. The bidirectional arrows indicate that these cuts may be moved.

Defaults menu

The defaults menu controls the system's operation and provides a high degree of flexibility. In addition to bringing together all of the information in the create menu option, the default menu allows the following choices:

1. Rounding to next highest or lowest foot of surface measure for all boards found to be halfway between two consecutive surface measures.

2. Wane aggregation.

3. Specification of maximum allowable time to reach solutions.

4. Selection of sampling method: sequentially, randomly, by serial position, or by specific board number.

5. Grading without training or grading training without remanufacturing through use of the "Invoke Program" option.

6. Specification of the extent of remanufacturing: edging and trimming only or division-based remanufacturing (several levels possible).

Quit menu

The quit menu allows the user to return to the DOS prompt and do other things while a file is being processed or quit the program altogether.
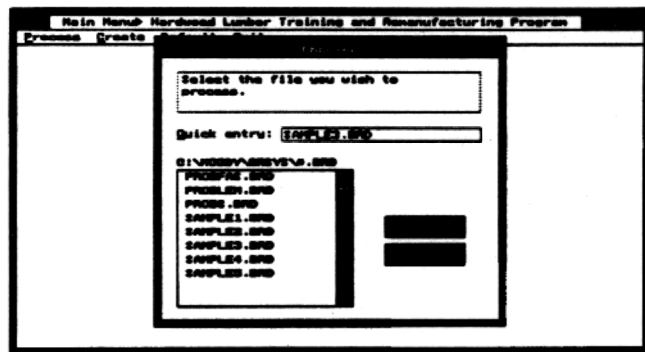

Figure 6. — TRSys shows all files pertinent to the current operations being performed.
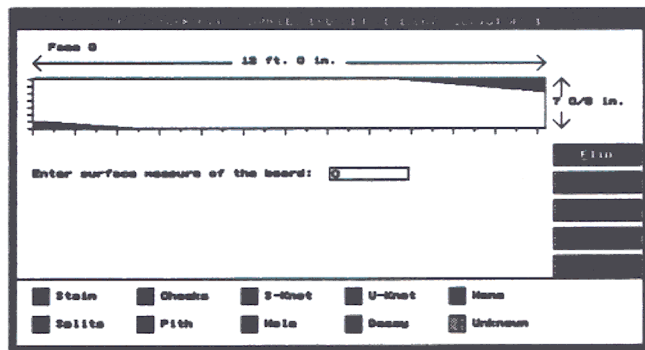

Figure 7. — TRSys prompts the user for answers. Shown is the prompt for surface measure. At any time, the user has the option of zooming in or flipping the board by clicking on the buttons at the right.
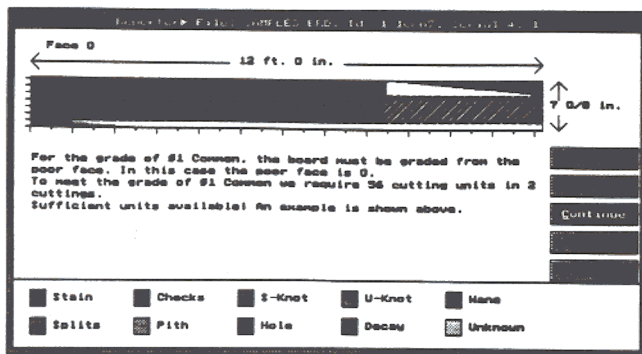
Figure 8. — TRSys allows the user to examine how the grade was computed. Shown are the cutting units required to meet the grade in question.

Figure 9. — Results of division-based remanufacturing as implemented by TRSys.

Process menu

Board processing begins by selecting a specific board within a board file as described previously. The program starts by showing a full screen view of the board and prompting the user for the surface measure as shown in Figure 7. The user may enter the surface measure or select any of the buttons shown in Figure 7 (i.e., zoom, flip the face of the board being shown, go to the next board, continue, or abort). If the answer given is incorrect, the program explains how the correct answer is calculated. The user is then prompted for the grade. Again, the program can show a detailed explanation of how it arrived at a particular grade (Fig. 8). Further explanations on the grade computation process are described elsewhere (2).

Once the grading portion is completed, the program tries to remanufacture the board. Although not every board is a good candidate for remanufacturing, this program will examine every board to determine if its value can be increased. A sample of the automated remanufacturing results is shown in Figure 9.

The program also allows an interactive mode of operation at this point, where the user may go in and divide the board manually into two or more smaller boards and see the total resulting value.

It should be noted that the exhaustive strategy employed during remanufacture of the board requires additional time for processing but results in an increased total value obtained from a set of boards. The next section details the total amount of time required and the resulting increase in value.

Remanufacturing performance expectations

The TRSys division-based remanufacturing method was evaluated using four algorithms. Algorithm A was edging and/or end trimming only. Algorithm B (division based) was for remanufacturing unedged and untrimmed boards. Algorithm C (divi-
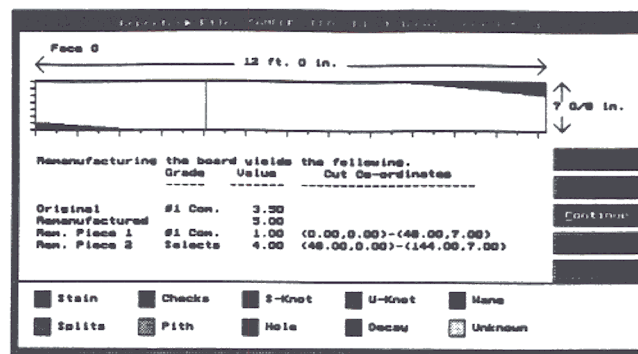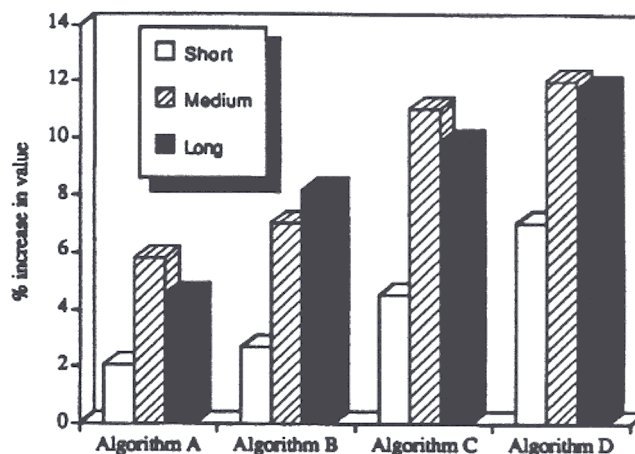

Figure 10. — Comparison of the increase in value obtained from the four algorithms.

sion based) was for remanufacturing using only incremental surface measure points. Algorithm D (division based) used an exhaustive search of edged and/or end-trimmed boards. These tests were carried out on a sample of 802 boards from a new red oak lumber databank.[5] Of these, 172 were long (length greater than 12 ft.); 488 boards were medium (length between 8 and 12 ft.); and 142 were short (length less than 8 ft.). Some edging and end trimming was done at the sawmill during lumber manufacture. Together, they totaled 4,613 BF of lumber.

The results of the four algorithm tests are shown in Figure 10. The results were not unexpected. The division-based remanufacturing algorithms (B,C, and D) produced higher overall values than simple edging and/or end trimming (Algorithm A). The combination of edging and/or end trimming using an exhaustive search (Algorithm D) gave the largest increase in value. However, Algorithm D also took six times as long on average to complete than Algorithm A (60 sec. vs. 10 sec. on an 80486-based PC). Also of interest was that the largest increases in dollar values were obtained from the medium and long boards.

[5] Gatchell, C.J., J.K. Wiendenbeck, and E.S. Walker. 1992. 1992 databank for red oak lumber. Res. Pap. NE-669. USDA Forest Serv., Northeastern Forest Expt. Sta., Radnor, Pa.
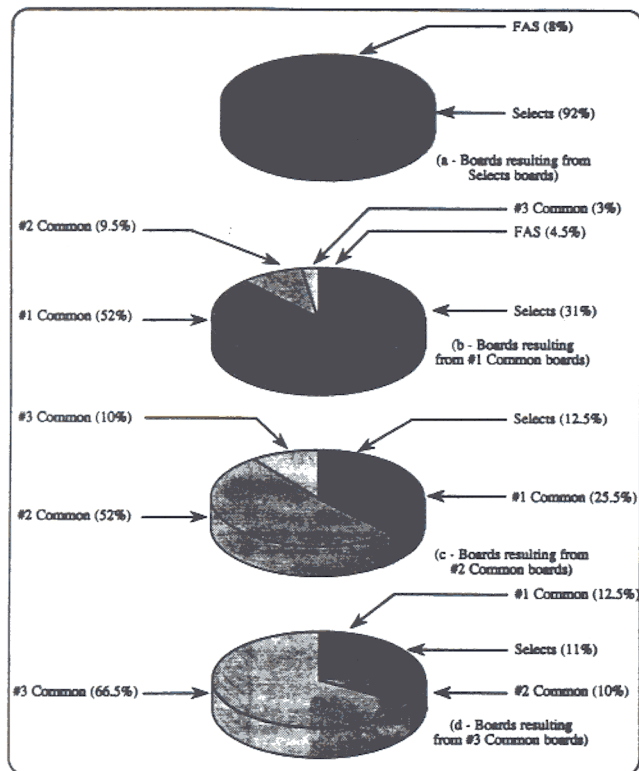
Figure 11. — Grades of valid boards resulting after remanufacturing.

Figure 11, illustrating the results obtained with Algorithm D, shows the grades of the boards that resulted from remanufacturing. Boards that could not be remanufactured were not included. No implication should be drawn that all who remanufacture will experience the changes shown. Grade distributions will depend on the average size of the input boards and how well the full range of quality is contained within each grade. For our sample, 35.5 percent of the No. 1 Common remanufactured boards were converted to smaller Selects (31%) and FAS (4.5%) boards with only 12.5 percent of the new boards grading less than No. 1 Common. A total of 38 percent of the new boards from remanufactured No. 2A Common lumber were No. 1 Common and Selects. Only 10 percent were No. 3A Common.

Summary of program features

TRSys features include:

1. Grading of a board into six grades (FAS, Selects, No. 1 Common, No. 2A Common, No. 3A Common, and Below Grade) without requiring prior knowledge of the grade of a board. Both faces are considered while grading a board. The user is then shown in a limited interactive procedure how the grade was computed.

2. Automated remanufacturing of a board to a higher dollar value by ripping, crosscutting, and division of a board into multiple boards. The combination of ripping/crosscutting and division-based remanufacturing results in the best possible increase in value but requires a longer time to process each board. For faster and more limited results, the user has the option of just ripping and crosscutting, in which case the program behaves like HaRem. At present, TRSys will divide a board into a maximum of four boards.

3. Manual remanufacturing allows the use of a mouse to draw individual boards on the screen allowing for interactive remanufacturing of the board.

4. A true mouse-driven standalone windowed, high resolution color graphics interface allows color encoding of nine types of defects (stain, checks, sound knots, unsound knots, wane, pith, splits, holes, and decay). The windowed interface allows zooming into a board to see greater detail. Also included are on-screen rulers to measure the defects and board dimensions.

5. Built-in editors for creating board, price, and remanufacturing cost files. The board file contains data describing a board, the price file includes the current market prices of the various grades of lumber, and the cost file includes the cost of remanufacturing a board defined in terms of a fixed overhead per board and an incremental cost based on the amount of remanufacturing required.

6. Boards are called up by the user in one of four ways: sequentially; in random order (so solution sequences are not memorized); by serial position in the file (1st, 10th, or 16th, etc.); and by board identification number or name.

7. Allows reconfiguration of common options on line. The user may decide to round up or truncate halfway surface measures. TRSys also allows reconfiguration of how wane should be aggregated and supports two procedures, edge- and median-based aggregation.

8. Species specific exceptions to the standard rules may be considered through modification of a file containing the rules.

Conclusions

Division-based remanufacturing combined with ripping and crosscutting as employed by TRSys results in an approximate increase of 10 percent over the original value of the boards. Current research is focused on further improving the speed of the grading program on which TRSys relies.