Economics of grading and sorting pallet parts

Technical Note

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Abstract

Before trying to develop an automated inspection system for pallet part grading we analyzed the economics of such a system. Our results suggest that higher quality pallets produced by grading and sorting pallet parts would be attractive to both manufacturers and their customers, who would have to pay increased prices for higher quality pallets. Reductions in cost-per-trip for the pallet purchaser should permit pallet manufacturers to recoup investments for pallet part sorting. The utility of higher quality pallets should be economically attractive to pallet purchasers even for pallets with much higher prices than those currently used.

Wood pallets comprise the largest single use of sawn hardwoods in this country. Unfortunately, millions of pallets are discarded annually due to 1) pallet damage; 2) one-way use; 3) delivery to a location where they are not re-used; and 4) improper pallet design for a specific use. One-way-use pallets constructed with little concern for durability quickly find their way to landfills. When not disposed of in this way, they are often ground or chipped into fiber for fuel, animal bedding, or other uses (e.g., mulch), or are disassembled and re-used.

High quality wood pallets would be more durable and more expensive, but they would promote longevity and re-use. High quality and value would make repair and re-use good financial decisions. Aside from availability, pallet durability and re-usability are the two attributes most important to pallet buyers.[1] Pallet manufacturers and their customers, however, must be convinced of the economic viability of investment in high quality pallets.

The National Wooden Pallet and Container Association (NWPCA), the USDA Forest Service, and Virginia Tech have developed a computerized procedure for designing pallets, the Pallet Design System (PDS).[2] PDS permits the analysis of different pallet designs based on lumber species and grade, part dimensions, pallet geometry, fastening system, materials handling environment, and pallet price. Just by increasing pallet part thickness and changing fasteners, it is possible to more than double a pallet's durability. A survey of pallet users has indicated their willingness to buy higher quality, more durable pallets. [1]

High quality pallets require high quality parts. Standards for various grades of pallet stringers and deckboards, set forth by the NWPCA, allow for the potential to separate pallet parts according to grade prior to construction. However, there are three major problems to pallet part grading: 1) training and maintaining pallet part graders can be expensive; 2) the characterization of some degrading defects (e.g., slope of grain and knot cross section) can be difficult; and 3) the rate at which parts move through a pallet plant may preclude accurate visual grading. To address these problems, we are investigating the use of an automated inspection system to grade and sort pallet parts.

An automated inspection system would consist of a scanning system capable of detecting defects in

[1]National Wooden Pallet and Container Association. 1993. Pallet User Survey. NWPCA, Arlington, Va.

[2]National Wooden Pallet and Container Association. 1993. Pallet Design System. NWPCA, Arlington, Va.

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TABLE 1. — *Abbreviated list of grading criteria employed for stringers from PEP Study Report.* [a]

Defect	Description	2&BTR	3	4
Sound knots[b]	Maximum portion of cross section affected	1/4 of cross section	1/3 of cross section	1/2 of cross section
Location of knots[b]	Over notch or in end 6 in. of the stringer	1/2-in. max. diameter	1/4 of cross section	1/3 of cross section
Unsound knots[b]/holes	Knot holes, unsound or loose knots, and holes	1/8 of cross section	1/6 of cross section	1/4 of cross section
Cross grain	Slope of general cross grain Max. dimension of local cross grain	1 in. in 10 in. 1/4 cross section	1 in. in 8 in. 1/3 cross section	1 in. in 6 in. 1/2 cross section
Splits, checks, and shake	Max. length singly or in combination Defects 3 in. or less are ignored	1/4 of length of part	1/2 of length of part	3/4 of length of part
Wane	Max. portion of cross section Portion of nail face width	1/16 of cross section 3/16 of face	1/8 of cross section 1/4 of face	3/16 of cross section 5/16 of face

[a]See footnote 3 below.
[b]Clusters of knots — knots over 1/2 inch in diameter spaced 3 inches or less apart are measured as one defect and treated as sound or unsound knots.

TABLE 2. — *Abbreviated list of grading criteria employed for deckboards from PEP Study Report.* [a]

Defect	Description	2&BTR	3	4
Sound knots[b]	Maximum dimension across width of the board	1/4 of board width	1/3 of board width	1/2 of board width
Location of knots[b]	Knots in the edges and end 3 in. of the boards	1/2-in. diameter	1/4 of board width	1/3 of board width
Unsound knots[b]/holes	Knot holes, unsound or loose knots, and holes	1/8 of board width	1/6 of board width	1/4 of board width
Cross grain	Slope of general cross grain Max. dimension of local cross grain	1 in. in 10 in. 1/4 board width	1 in. in 8 in. 1/3 board width	1 in. in 6 in. 1/2 board width
Splits, checks, and shake	Max. length singly or in combination Defects 3 in. or less are ignored	1/4 of board length	1/2 of board length	3/4 of board length
Wane	Max. portion of cross section affected at point of deepest penetration	1/16 of cross section	1/8 of cross section	3/16 of cross section

[a]See footnote 3 below.
[b]Clusters of knots — knots over 1/2 in. in diameter spaced 3 in. or less apart are measured as one defect and treated as sound or unsound knots.

pallet parts. Computer software would then grade scanned pieces based on detected defects and established grading rules like NWPCA specifications or the Pallet Exchange Program study guidelines.[3] Parts could then be automatically separated into bins by grade. An abbreviated listing of grading defects for stringers and deckboards appears in Tables 1 and 2.

Before expending resources in developing this technology, however, it is important to assess whether both pallet manufacturers and purchasers can benefit economically from grading and sorting pallet parts. For a manufacturer to invest in technology to construct longer lasting pallets, there must be 1) a payback to the manufacturer greater than the cost of the technology; and 2) an economic incentive to induce customers to use high quality pallets. The intent of this study was to determine if both parties can benefit from using higher quality pallets, and consequently, if pallet part inspection is economically attractive for the marketplace.

[3]Wallin, W.B. and R.E. Frost. 1973. Government Industry Task Force Report/National Pallet Exchange Program. Part 10. Hardwood, Softwood, Plywood Use Grades and Utilization Factors. USDA Forest Sci. Lab., Princeton, W.Va. 1,200 pp.

Methods

An economic analysis of any proposed technology usually requires estimates of associated benefits and costs. In this case, however, we do not yet know what the cost of automated pallet part inspection will be. Our approach, therefore, was to estimate potential benefits based on the premium a manufacturer could charge for a higher quality pallet. For the technology to be attractive, then, automated inspection costs must be less than the premium charged for higher quality.

To calculate this increased revenue we used the known delivered price of a specific pallet in the marketplace and its economic durability as predicted by PDS. The prices of higher quality pallets were calculated using the known price of this specific pallet and recently published cant prices. PDS then estimated

TABLE 3. — *Nine different pallet designs are compared with respect to strength, cost, economic durability, and utility-equivalent price.*

Case	Pallet design	Volume of lumber required to construct pallet, including waste and cull	RAS[a] maximum	RAD[a] maximum	Stacked[a] one high maximum	Delivered price	Trips[b] to first repair[c]	Price per trip[b] before first repair	Utility-equivalent pallet price compared to cost per trip[b] of base case pallet
		(BF)	-----------(lb.)-----------			($)		------($)------	
1	Modified GMA (4&BTR)	20.9	1,778	2,088	5,506	7.07	11 (23)	0.64	3.3
2	Base case (All Lumber)	25.1	2,315 (30.2)	3,129 (49.9)	9,497 (72.5)	8.12	27 (48)	0.30	8.12
3	Grade 4&BTR	27.3	2,492 (40.2)	3,289 (57.5)	9,987 (81.4)	8.66	33 (58)	0.26	9.92
4	Grade 3&BTR	31.8	2,624 (47.6)	3,405 (63.1)	10,350 (88.0)	9.78	43 (73)	0.23	12.93
5	Grade 2&BTR	52.2	2,848 (60.2)	3,620 (72.5)	11,033 (100.4)	14.89	76 (116)	0.20	22.86
6	Grade 4&BTR (interior parts) Grade 2&BTR (lead top and bottom deckboards and exterior stringers)	40.2	2,575 (44.8)	3,445 (65.0)	10,379 (88.5)	11.88	57 (91)	0.21	17.14
7	Grade 4&BTR (interior parts) Grade 3&BTR (lead top and bottom deckboards and exterior stringers)	29.6	2,523 (41.9)	3,345 (60.2)	10,125 (83.9)	9.24	41 (70)	0.23	12.33
8	All Lumber (interior parts) Grade 2&BTR (lead top and bottom deckboards and exterior stringers)	39.1	2,415 (35.1)	3,361 (61.0)	10,068 (82.9)	11.62	56 (89)	0.21	16.84
9	All Lumber (interior parts) Grade 3&BTR (lead top and bottom deckboards and exterior stringers)	28.6	2,366 (33.1)	3,262 (56.2)	9,817 (78.3)	8.98	35 (60)	0.26	10.53

[a]RAS = racked across stringers; RAD = racked across deckboards. Values in parenthese are the percent increase over modified GMA.
[b]Per-trip handling is assumed to be 4 to 6.
[c]Values in parentheses are the lifetime total.

the economic durability of those better pallet designs. By equating the economic durability of all pallet designs we obtained utility-equivalent prices that reflect what an indifferent purchaser would pay for a pallet of specified utility (in terms of cost per trip). Then, the difference between estimated delivered pallet price based on manufacturing costs and the equivalent price based on purchaser utility equals the potential benefit of pallet part inspection. These calculations are detailed in the following sections.

Pallet designs

Most hardwood pallets are constructed by using *all* the parts that can be sawn from cants or lumber arriving at a plant. The grade of material used in this type of pallet is referred to as the *All Lumber* grade. Some culling of unusable parts may occur prior to assembly, where obviously undesirable parts are easily identified and separated. In general, however, grading and sorting prior to assembly are not standard practices at most pallet facilities. Culled parts are normally chipped and sold or burned for fuel.

We used PDS to generate and analyze nine different pallet designs that incorporated various grades of pallet parts. One of these pallet designs was a modified Grocery Manufacturers Association (GMA) pallet.[4] In all other cases, variants of a full-specification GMA pallet were used. Our *base case* full- specification GMA pallet has the following specifications: 48 inches by 40 inches, flush, partial 4-way, double-face non-reversible, and multiple use. There are three stringers, 1.75 by 3.75 by 48 inches, seven top deckboards, and five bottom deckboards. Wood in the pallet consists of green material comprised of 35 percent species class 21 (eastern red and white oaks) and 65 percent species class 1 (dense hardwoods). Fasteners used in these designs are stiff-stock, helically threaded nails. By using different combinations of pallet part grades, we obtained the eight designs in Table 3 in addition to the modified GMA pallet.

In the first four design alternatives (Table 3), all pallet parts are a particular grade or better, either *All Lumber*, *4&BTR*, *3&BTR*, or *2&BTR*. In the final four

[4]Pallet Profile Weekly. Feb. 5, 1993.

alternative designs, part grades are selectively placed, e.g., high quality parts *(2&BTR* grade) in the critical, exterior, and edge locations and lower quality parts *(4&BTR)* for the interior pieces. Based on the specifications for these pallets, PDS calculated maximum load-carrying capacities and generated an economic durability analysis. The economic analysis estimates numbers of one-way trips and the cost per trip based on pallet price, pallet durability, and the materials-handling environment. We calculated pallet price as described below and selected an "average" materials-handling environment.

Estimating pallet prices

We based our calculation of prices for pallets of different designs on the published price of a modified GMA pallet in Virginia.[4] By using published figures for pallet price and cant cost and estimating the amount of cant material used in pallet construction, we were able to estimate the percentage of pallet price attributable to wood and the percentage attributable to processing and delivery. We then assumed that pallet processing and delivery costs would be constant for the different pallet designs in this study. There should be no additional assembly costs for selecting from a bin of *4&BTR* parts versus selecting from a bin of *2&BTR* parts. Therefore, pallet prices change only in relation to the cost of construction materials, i.e., different grade parts.

Our *base case* pallet differs from a modified GMA pallet in that it uses thicker deckboards and stringers, and it uses *All Lumber* rather than the *4&BTR* material of the modified GMA. Our estimate for the total amount of cant material needed to create an average modified GMA pallet is 20.88 board feet (BF) (14.2 BF in the completed pallet, 5.01 BF in processing waste, and 1.67 BF in cull). Processing waste was estimated using several assumptions: 1) 1/8-inch sawkerf; 2) all stringers are cut from cants that are some multiple of 4 feet in length; 3) half of the deckboards are cut from 10-foot cants (no end waste) and half are cut from cants that are multiples of 4 feet in length; and 4) no waste is generated by cull sections of cants. Based on $250/MBF for cants and a delivered price of $7.07 for the pallet, we can then estimate that 74 percent of a pallet's delivered price is due to the cost of cants used in its construction. Therefore, $1.84 remains as the cost of processing, delivery, and allowance for profit. Because our *base case* design contains 18.5 BF in the completed pallet and produces approximately 6.6 BF in processing waste with no cull, our *base case* pallet would have a delivered price of $8.12 ($6.28 for cant material and $1.84 for processing and delivery). Delivered prices for the other seven pallet designs were calculated using our *base case* pallet price and adjusting cost to cover the culling of some parts as required by the higher quality pallets.

Increased wood costs for higher quality pallets were calculated as the cost of pallet parts that must be culled in order to use only higher quality parts. It has been estimated that across all pallet parts, 8 percent are cull, 21 percent are No. 4 or cull, and 52 percent are No. 3, No. 4, or cull.[5] This means that only 92, 79, and 48 percent of pallet part volume is usable for grades *4&BTR*, *3&BTR*, and *2&BTR*, respectively. Therefore, the cost of the wood in a delivered pallet will increase by ((1 ÷ usable volume) – 1) x 100 percent or 8.7 percent for *4&BTR*, 26.6 percent for *3&BTR*, and 108 percent for *2&BTR*. For pallets in which part grades are selectively placed, the appropriate proportions of different grades were used to estimate total board feet of cant material used for their construction.

Results

The bottom line for pallet purchasers (and manufacturers) appears in the next-to-last column of Table 3. Even though price increases with quality, it does so more slowly than durability. Hence, the utility, or cost per trip, to the pallet user is reduced for higher quality pallets versus lower quality ones. From a solely economic perspective, the pallet user should be indifferent to buying a *2&BTR* pallet (case 5) versus an *All Lumber* pallet (case 2) when the cost per trip is the same for each. Consequently, a pallet manufacturer could potentially sell a *2&BTR* pallet for 54 percent more than our estimated delivered cost of $14.89, or $22.86, to make it equivalent in cost per trip with the *All Lumber* pallet. Even more striking is the economic comparison between *2&BTR* pallets and the modified GMA, where a pallet purchaser should be economically indifferent to paying $48.88 (3.3 times our esti-

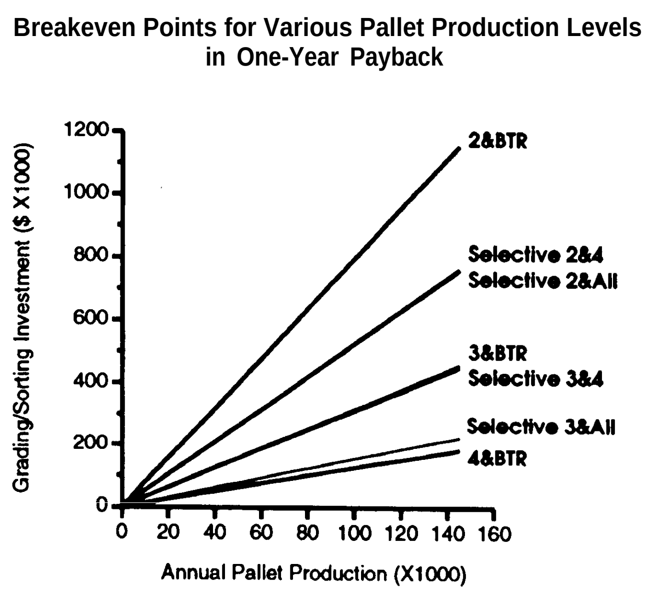

Figure 1. — Break-even curves for various pallet designs indicate maximum investment for pallet part inspection, where revenue increases are the difference between estimated pallet prices and utility-equivalent prices. The lines for *Selective 2 & 4* and *Selective 2 & All* are superimposed, and so are the lines for *3&BTR and Selective 3 & 4.*

[5]McLeod, J.A. III, M.S. White, P.A. Ifju, and P.A. Araman. 1991. Flexural properties of eastern hardwood pallet parts. Forest Prod. J. 41(7/8):56-63.

mated delivered price) for a *2&BTR* pallet for the same $0.64 per trip cost as the modified GMA pallet. In comparison with pallet design 2, the utility of the modified GMA pallet is actually less than its current delivered price ($3.31 vs. $7.07). Therefore, it is greatly overvalued compared to pallets costing only slightly more.

One can calculate the difference between estimated delivered price and utility-equivalent price (using the base case pallet) for each pallet design as the increased benefit of pallet part inspection. Theoretically, a manufacturer could afford to spend up to that difference for grading and sorting of parts. Thus, the break-even point for a pallet part inspection system would depend on the price differential and on annual pallet production. Break-even lines are shown in Figure 1. Annual production levels exceeding the break-even level for a particular pallet design would be profit for the manufacturer.

Although there are seven curves represented in Figure 1, there seem to be only four distinct cases. The greatest increase in manufacturing revenue can be obtained by producing pallets made of*2&BTR* parts,, with a price differential of $7.97 (the slope of the graphed line) over the cost of cant material, processing, and delivery. Selective placement using *2&BTR* parts and either *All Lumber* parts or *4&BTR* parts follows next. Then, selective placement using*3&BTR* parts with *4&BTR* parts or using entirely *3&BTR* parts results in almost identical increased revenues. At the lower level, there is little difference in revenue increase for either pallets consisting of *4&BTR* parts or selective placement using *3&BTR* parts with *All Lumber* parts. Consequently, there would be no need for a manufacturer to produce both selective placement using *2&BTR* with *4&BTR* parts and selective placement using *2&BTR* with *All Lumber* parts. Similar manufacturing caveats apply to the other two sets of overlapping curves.

A pallet manufacturer who grades and sorts parts and sells higher quality pallets will sell a variety of different designs and, therefore, will have a break-even curve that will be some weighted average of the curves in Figure 1. Suppose, for example, that a manufacturer produces 100,000 pallets annually, of which 50,000 are from sorted parts. Furthermore, let's assume that half of the higher quality pallets are *3&BTR* and half are Selective *3&All.* In this case, the grading/sorting operation only needs to distinguish parts of *3&BTR* from lower quality ones. The weighted average of the revenue increases for those two pallet designs equals $2.35 per pallet, which, for a production level of 50,000 pallets, means that a $117,500 expenditure on pallet part inspection could be paid back in 1 year.

Conclusions

Our actual delivered prices for higher quality pallets are probably overestimates because we have not specifically accounted for the value of cull material. Cull parts have value as chips and as lower grade parts for construction of lower quality pallets. The latter use has substantial value because these lower quality pallets are free of cant costs that have been absorbed by the higher quality pallets. These factors would reduce the net wood cost for higher quality pallets, thereby reducing their delivered prices and our cost per trip estimates. Therefore, the economics of Table 3 become more favorable for the higher quality pallets when these savings are considered.

Pallets prices of $20 to $50 may seem exorbitant considering the enormous outlay of capital involved. Despite their high price, however, higher quality pallets bring many side benefits to the purchaser. The *2&BTR* pallet maybe perceived as a better choice by purchasers based on improved pallet appearance, reduced product damage, reduced injury liability, easier and less costly repair when damage does occur, and reduced landfill disposal charges. Given that many typical pallets (e.g., the modified GMA) have a high cost-per-trip ($0.64 or more), even if manufacturers charge the full utility-equivalent pallet prices calculated here, it is still a better value to the consumer ($0.64 versus $0.30) to choose higher quality, higher priced pallets. Thus, although higher quality pallet prices may be daunting, in the present ways of buying and using pallets, the real cost of replacing or repairing, disposing, and using low quality pallets actually exceeds that of more expensive pallets.

Underlying this analysis is the implicit assumption that purchasers will choose to buy higher cost, higher quality pallets if they are produced by manufacturers. Pallet purchasers' desires for higher durability pallets, as previously noted, must translate into an actual decision to invest in them. Nevertheless, our analysis indicates that manufacturers could profitably invest in grading and sorting equipment and that pallet users could profitably pay higher prices for more durable pallets. Competitive market pressures will determine, in the end, how the economic advantages of pallet part inspection and more durable pallets will be divided between manufacturers and users of pallets.