Chapter 6

Determining Decision-Makers' Perceptions of Materials in the United States Railroad Infrastructure Market

The United States Railroad Infrastructure Market

The United States railroad system provides an opportunity for the wood products industry due to the many possibilities for the use of wood in railroad structures. Railroad officials spend 7 billion dollars per year for railroad track maintenance/crosstie replacement (Reynolds 1994). This large market has many opportunities for the wood products industry in the construction of railroad tracks, bridges, retaining walls, road crossings, sign systems and building construction. Railroad structures can be built of wood products, but the railroad infrastructure market is highly competitive and many structures are using alternative materials such as steel, reinforced concrete, prestressed concrete, aluminum and plastic. In order to compete in the US railroad market, wood products manufacturers need information about the decision-makers in charge of design, construction and maintenance of railroad structures. Manufacturers need to know why engineers and administrators choose materials implemented in today's railroad infrastructure. Once this information is documented, wood products manufacturers can develop strategies and may be able to compete more efficiently in the railroad infrastructure market.

The railroad market and its decision-makers were assessed using a mail questionnaire sent to 467 railroad officials. After the questionnaires were analyzed, personal interviews were conducted with railroad officials in four states (Georgia, Indiana, Maine and Montana). These interviews were used to clarify results found with the questionnaire and to further understand the US railroad infrastructure market. The methodology as outlined in chapter 2 was followed in this study.

Study Objectives

This study identified how materials for use in railroad structures were chosen and determined the decision-makers' perceptions of various materials in different infrastructure markets. The ultimate goal was to determine markets for wood in the infrastructure of the United States. Specific objectives used to meet the overall purpose were to:

1) Identify the factors important in the material choice decision in selecting infrastructure materials.

2) Determine the perceptions of wood in various infrastructure applications by different infrastructure decision makers.

3) Develop strategies for increased wood use in infrastructure markets.

The analysis of perceptional rating and material factor ratings of the railroad respondents met the first two objectives: which factors are important in the material choice decision; what are the perceptions of wood in various infrastructure applications by different level of decision makers. The factors analyzed were separated into six distinct factor groups:

1) cost group: *low initial cost, low maintenance cost* and *low life-cycle cost*;

2) durability group: *fatigue resistance*, *mechanical wear/abrasion resistance*, *fire resistance, corrosion resistance, weathering resistance* and *biological decay resistance*;

3) design group: *design standards available, material available, ease of construction, designer's experience with material*, and *construction equipment available*;

4) environmental group: *chemically safe, aesthetically pleasing, disposable/biodegradable, low environmental effects of material production, recyclable/reusable* and *percent recycled content of material*;

5) maintenance group: *standard structure design's available, field modification easy, ease of repair*, *experience in maintenance with material* and *inspection easy*;

6) innovativeness of material group: *innovative in performance*, *innovative in design, innovative in maintenance, innovative in durability* and *innovative in the environment*.

Each factor is an attribute when possessed by a material. For example, *corrosion resistance* could be a factor used by a railroad decision-maker when deciding on materials for sign system construction. The factor, *corrosion resistance*, also can be considered an attribute when possessed by a material such as plastic.

The mean importance of all factor ratings was determined using a 1-7 scale (1 = not important; 4 = average importance; 7 = above average importance). For instance, if the factor *corrosion resistance* was very important to a railroad decision-maker, that person would mark a 7 on the importance rating scale. The mean of all ratings by railroad decision-makers for this factor was determined.

The mean perceived ratings for all materials possessing attributes directly related to these factors was measured on a 1-7 scale. A rating of 1 indicated that a material did not possess the attribute at all and a 7 rating indicated that the material possessed the attribute to a high degree. For example, if the railroad decision-maker thought plastic highly possessed the attribute, *corrosion resistance*, then that individual may give a 7 rating for plastic possessing that attribute.

Analysis of Variance (ANOVA) was used to define relationships within the railroad group. Tukey's honestly significant difference (HSD) test was used to determine where differences were located among the railroad group's mean perceived factor and attribute ratings. A significance level of 0.05 was used throughout the study.

Results and Discussion:

Data entry errors were checked using variable ranges and mean ratings. Possible answers ranged from one to seven for the mean scores. When mean ratings or ranges were not found within these known ranges, the individual survey(s) in question was located and corrections were made.

Demographics:

Data analysis began with summary statistics from railroad respondents demographic data. A total of 166 railroad officials' returned the questionnaire for an adjusted response rate of 35.8%. More than one-half of the respondents worked primarily in maintenance (72.9%) (Table 23). Greater than one-half of the railroad officials' held a BS or MS degrees (56.9% combined) (Table 24). A little over one-third of respondents (35.8%) had formal course-work in wood design. Of those who did have formal course-work on wood design, the percentage of railroad respondents that said the course(s) was mandatory was 30.2% (Table 25). Railroad respondents in the age groups 40 to 49 years (39.0%) and 50 to 59 years (36.6%) represented the largest age categories (Table 26). The 25 or more years of work experience group contained the highest percentage of railroad respondents (33.5%) (Table 27). Less than one-half of railroad officials said they had guidelines for the use of wood products in railroad design, construction or maintenance (42.2%) (Table 28).

Railroad respondents said they had designed, constructed or maintained railroad crossties (91.0%), railroad bridges (79.0%) and sign systems (44.9%) (Table 29). Materials most used by railroad respondents in design, maintenance or construction were wood (97.6%), steel (74.9%) and reinforced concrete (56.3%) (Table 30). Railroad respondents were asked if they had used wood in the last three years in design, construction or maintenance of railroad structures. Almost all of railroad respondents (98.2%) said they had used wood in railroad structures in the past three years. Railroad respondents were asked if they had used engineered wood products for design, construction or maintenance in the past three years and if so, what type of engineered wood products they had used. Less than one-half of respondents (44.1%) had used engineered wood products in railroad structures (Table 31). Glue-laminated timber (15.6%) and plywood panels (14.4%) had the highest use in railroad structures in the past three years (Table 32). Railroad groups were asked if they had plans to use wood products in structure design, construction or maintenance in the next three years. The majority of railroad officials (96.3%) were planning to use wood in railroad structures in the next three years (Table 31).

Overall Factor Importance Ratings:

The railroad officials rated the following factors for overall importance in a material choice decision: *cost*, *durability*, *maintenance*, *ease of design*, *environmental impact* and *innovativeness of material*. Railroad officials had the highest mean factor importance ratings for *durability* (6.27), *maintenance* (6.12) and *cost* (5.89). Their mean importance ratings for these factors were significantly higher than their ratings for *environmental impact* (4.74), *ease of design* (4.44) and *innovativeness of materials* (3.56). Their mean importance ratings for *environmental impact* and *ease of design* were significantly higher than the lowest rated material *innovativeness of material* (Table 38).

Discussion of Overall Factors:

Railroad officials were responsible for safe and efficient operation of large, complicated structures and therefore had the highest importance for material *durability*, *maintenance* and *cost*. Interview participants said materials are expected to last at least 25 years (crossties) which caused officials to have the highest importance for *durability*. Railroad officials have to conduct a great deal of *maintenance* due to the size and risks involved with railroad structures. *Cost* of railroad structures was high because of their size therefore, officials have high importance for the material costs. These most important factors suggest that manufacturers should include plans to improve *durability*, *maintenance* and *cost* of materials in their marketing strategies.

Officials had above average importance for *environmental impact* to their responsibility for the environmental effects of structural materials. *Ease of design* was less important because officials generally had resources available to design a structure, including the American Railroad Engineers Association (AREA) the Railway Tie Association (RTA) and in-house structural design engineers. Innovative materials were perceived to be a risk because they were not proven in railroad structures. Therefore, *innovativeness of materials* was the least important material choice factor.

Overall Perceived Material Performance Ratings:

Railroad officials rated the following materials for perceived overall performance in structures: prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic. They had the highest mean perceived overall performance rating for steel (5.61), which was significantly higher than reinforced concrete (5.15), wood (5.01), aluminum (4.01) and plastic (3.06). Their mean perceived overall performance ratings for prestressed concrete (5.21), reinforced concrete and wood were significantly higher than aluminum and plastic. Railroad officials mean ratings for aluminum was significantly higher than the lowest rated material, plastic. Officials mean perceived overall material performance rating for wood was not significantly different than their mean perceived rating for prestressed concrete and reinforced concrete (Table 39).

Discussion of Overall Material Performance:

Railroad officials perceived wood to have an above average overall performance because of its performance as cross/bridge-tie material. Wood was not rated as high in overall performance as reinforced concrete and steel because wood has not performed as well as these materials in bridges. Due to wood having lower perceived overall material performance, manufacturers may want to improve the durability, maintenance and cost of structural wood products.

Perceptional Ratings of Cost Factors:

Railroad officials were asked to rate the importance of the following cost factors used when making a material choice decision: *low initial cost*, *low maintenance cost* and *low life-cycle* *cost*. Significant differences were found among the railroad officials mean importance ratings for the cost factors. They had the highest mean importance ratings for *low maintenance cost* (5.84) and *low life-cycle cost* (5.74), which had significantly higher mean importance ratings than *low initial cost* (5.17) (Table 41).

Discussion of Cost Factors:

Railroad officials had the highest importance for *low maintenance cost* due to the replacement and repair costs experienced with large railroad structures. They had high importance for *low life-cycle cost* because materials they used had to be low in initial, maintenance, and disposal costs for the railroads to operate efficiently. This indicates that manufacturers may want to include plans in their marketing strategy that would decrease initial, maintenance and disposal costs experience by railroad officials.

Perceptional Ratings of Cost Attributes:

Railroad officials were asked to rate the following materials for possession of cost attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the railroad officials' mean perceived ratings for each cost attribute ratings for all materials. Their mean perceived *low initial cost* rating for wood (5.41) was significantly higher then all other materials tested. They had the lowest mean perceived *low initial cost* rating for aluminum (3.40) and plastic (3.37). Railroad officials had the highest mean perceived *low maintenance cost* ratings for steel (5.35), reinforced concrete (5.23), prestressed concrete (5.20) and wood (5.05). These mean *low maintenance cost* ratings were significantly higher than aluminum (4.34) and plastic (4.01). Railroad officials had the highest mean *low life-cycle cost* rating for steel (5.40), wood (5.15), reinforced concrete (5.14) and prestressed concrete (4.99). These mean ratings were significantly higher than aluminum (4.30) and plastic (3.75). Railroad officials consistently rated wood not significantly different than other highest rated materials for each perceived *cost* attribute (Table 42).

Discussion of Cost Attributes:

Railroad officials perceived wood to have the lowest *initial cost* of all structural materials. This was supported by interview participants who said wood products were the lowest initial cost materials for crossties and many other railroad structures such as retaining walls and road crossings. They perceived wood to be among materials with the least *maintenance costs*. Interview participants said they only used wood in cross and bridge-ties because wood had the lowest maintenance and therefore lowest maintenance costs in these structural members. Officials perceived wood to be among materials with the lowest *life-cycle cost* because it has low initial, maintenance and disposal costs in railroads.

Based on these perceptions of wood products *cost* attributes by railroad officials, manufacturers who are competing in the railroad market may need to adjust their marketing strategy. It is suggested that manufacturers try to reduce the cost of large wood products used in railroad structures. Large wood products in this market indicates piles and bridge structure materials, but not crossties and bridge-ties. The price of wood crossties and bridge-ties should be kept competitive, but it is unlikely that any material will out-compete the wood tie in the foreseeable future. Railroads have expensive maintenance programs in place, and it might be important for manufacturers to develop methods to lower these *maintenance costs.* Manufacturers may want to reduce *maintenance costs* by developing of lower maintenance crossties and bridge structure designs. Finally, manufacturers and associations may want to further promote the reuse and sale of used wood crossties to keep wood disposal costs low for railroads. If each of these cost reduction ideas are incorporated, then it is likely that the *life-cycle cost* of wood will be reduced as a result. These cost reducing actions will improve a wood products manufacturer's competitive position in the railroad market.

Perceptional Ratings of Durability Factors:

Railroad officials were asked to rate the importance of the following durability factors when making a material choice decision: *fatigue resistance*, *mechanical wear/abrasion resistance*, *fire resistance*, *corrosion resistance*, *weathering resistance* and *biological decay resistance.* Significant differences were found among the railroad officials' mean *durability* factor importance ratings. They had the highest mean importance rating for *fatigue resistance* (6.11), *mechanical wear/abrasion resistance* (5.76), and *weathering resistance* (5.65). Their mean importance rating for *fatigue resistance* was significantly higher than their mean ratings for *biological decay resistance* (5.51), *corrosion resistance* (4.86) and *fire resistance* (4.61). Railroad officials' mean importance ratings for *mechanical wear/abrasion resistance*, *weathering resistance,* and *biological decay resistance* were significantly higher than their mean ratings for *corrosion resistance* and *fire resistance*. Railroad officials considered *corrosion resistance* and *fire resistance* lower in importance in material choice decisions than the other factors tested. Their mean importance ratings for these factors were above average which indicated that they were important in the material choice decision (Table 44).

Discussion of Durability Factors:

Railroad structures are under harsh conditions daily therefore, material *durability* factors were highly important to officials responsible for these structures. Wood products manufacturers will need to know which *durability* attributes were most important to railroad officials and why they were important so that they can improve their marketing strategy. Railroad cars passing over railroad structures could have over one-hundred ton axle weights, so it was most important that materials have *fatigue resistance* and *mechanical wear/abrasion resistance*. Being that railroad structures are subject to all weathering forces, it was important to railroad officials that structural materials be *weathering resistant*. Railroad officials considered *biological decay, corrosion* and *fire resistance* above average in importance, but not as important as *fatigue, mechanical wear/abrasion* and *weathering resistance*. *Biological decay resistance* was above average in importance because of decay organisms that damage railroad structures. *Corrosion resistance* was above average in importance due to the corrosive agents that would damage railroad structures. *Fire resistance* was important because the railroads use structural materials that were flammable. This indicates that manufacturers may want to consider *corrosion, weathering, mechanical wear/abrasion,* and *fatigue resistance* in their marketing strategy developments. Although they were the least important factors in a material choice decision, manufacturers may need to place large emphasis on *biological decay resistance* and *fire resistance* due to their possible effects on wood products.

Perceptional Ratings of Durability Attributes:

Railroad officials were asked to rate the following materials for perceived possession of durability factors: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the railroad officials' mean perceived ratings for materials with each *durability* attribute except *corrosion resistance*. Their mean perceived *corrosion resistance* ratings for all materials tested were statistically the same. This indicated that they perceived wood (5.01) to have similar *corrosion resistance* rating as each material tested, and that wood had above average *corrosion resistance* (Table 45).

Railroad officials had the highest mean perceived *fatigue resistance* rating for steel (5.83), which was significantly higher than all other materials tested. Their mean perceived *fatigue resistance* ratings for prestressed concrete (5.31), wood (5.29), and reinforced concrete (5.28) were significantly higher than aluminum (4.17) and plastic (3.88). Officials' perceived wood well above average in *fatigue resistance* and not significantly different from other high rated materials (Table 45).

Railroad officials had the highest mean perceived *mechanical wear/abrasion resistance* ratings for steel (5.86), which was significantly higher than all other materials tested. Railroad officials' mean perceived *mechanical wear/abrasion resistance* ratings for prestressed concrete (4.84), reinforced concrete (4.82) and wood (4.61) were significantly higher than their mean ratings for aluminum (3.84) and plastic (3.67). Their mean perceived *mechanical wear/abrasion resistance* rating for wood indicated that they perceived it to be above average and among the most *mechanical wear/abrasion resistant* materials (Table 45).

Railroad officials' had the highest mean *fire resistance* ratings for reinforced concrete (5.80), prestressed concrete (5.59) and steel (5.56). Their mean *fire resistance* ratings for these materials were significantly higher than the their mean ratings for aluminum (4.23) wood (3.23) and plastic (2.75). Also, their mean *fire resistance* rating for aluminum was significantly higher than wood and plastic. Officials perceived wood to be among the lowest *fire resistant* materials (Table 45).

Railroad officials had the highest mean perceived *weathering resistance* rating for prestressed concrete (5.51) and reinforced concrete (5.34) and steel (5.08). Their mean perceived *weathering resistance* ratings for these materials were significantly higher than aluminum (5.04), wood (4.56) and plastic (4.37). Wood was perceived to be above average in *weathering resistance*, but it was perceived to be among the materials with the least *weathering resistance* (Table 45).

Railroad officials had the highest mean perceived *biological decay resistance* ratings for steel (5.90), prestressed concrete (5.76), reinforced concrete (5.63) and aluminum (5.35). Their mean perceived *biological decay resistance* rating for steel was significantly higher than plastic

(4.94) and wood (4.09). Railroad officials' mean perceived *biological decay resistance* ratings for prestressed concrete, reinforced concrete, aluminum and plastic were significantly higher than wood. Wood was perceived by the railroad officials to have the least *biological decay resistance* of all the materials tested, but it still was slightly above average in its mean rating (Table 45).

Discussion of Durability Attributes:

Railroad officials perceived all materials to have the same *corrosion resistance* and be above average in possessing that attribute. This indicated that they perceived less corrosion resistant materials such as steel to be as corrosion resistant as wood, which was among the most corrosion resistant of materials. They perceived wood to be highly *fatigue resistance* due to its resilience in crossties and bridge-ties. Wood was very resistant to *mechanical wear/abrasion* as a railroad tie material therefore, was perceive to be above average in *mechanical wear/abrasion resistance* by officials. These perceptions indicate that manufacturers may want to develop their promotional campaigns to include *durability* aspects of wood. They may want to consider promoting wood as a highly *corrosion, mechanical wear/abrasion* and *fatigue resistant* material.

Manufacturers may need to improve wood products in order to remain competitive in the railroad market. Railroad officials perceived wood to be above average in *weathering resistance* but less *weathering resistant* than alternate materials due to the damage it can receive from water and freeze/thaw cycles. Wood was perceived to have low *biological decay resistance* because it is highly susceptible to damage from insects, fungus and bacteria. Wood was perceived to be below average in *fire resistance* because it was flammable. This indicates that manufacturers may need to improve the weathering resistance of wood possibly through improved designs of wood structures. Manufacturers may need to improve the biological decay resistance of wood in railroads through improved chemical preservatives. Finally, it is suggested that manufacturers develop methods to increase woods *fire resistance*, which might be possible with use of fire retardent chemicals.

Perceptional Ratings of Design Factors:

Railroad officials were asked to rate the importance of the following design factors when making a material choice decision: *design standards available, material available, ease of construction, designer's experience with material*, and *construction equipment available.* They had the highest mean importance ratings for *material available* (5.78) and *ease of construction* (5.58), which were significantly higher than their mean importance rating for *design standards available* (5.19). It should be noted that even though differences were present, railroad officials' mean importance ratings for each design factor was above average (Table 47).

Discussion of Design Factors:

Design factors were below average in importance to the railroad officials, but still had importance in material choice decisions and manufacturers may need to consider them in marketing plans. Railroad officials had the most importance for the design factors *material available* and *ease of construction* when making a material choice decision. They had the highest importance for *material available* because a material must be available in order to use it in a structure. *Ease of construction* was important because it reduced risks of structural failure and construction costs. Therefore, manufacturers should be sure to include aspects of *material available* and *ease of construction* in their marketing strategy. *Design standards available* and *designer's experience with material* were above average in importance because they reduced design costs associated with a structure and insured that the structure design was correct. Due to their high importance in a material choice decision, it is suggested that manufacturers include *design standards available* and *designer's experience with material* in their marketing plans. Although *construction equipment available* was not as important as the most important design factors, it still was above average in importance and manufacturers may want to consider this factor in their marketing strategy.

Perceptional Ratings for Design Attributes:

Railroad officials were asked to rate the following materials for perceived possession of design attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among their mean perceived *design* attribute ratings for materials. They had highest mean perceived *design standards available* ratings for steel (5.88) and reinforced concrete (5.47). Their mean perceived *design standards available* rating for steel was significantly higher than prestressed concrete (5.40), wood (5.39), aluminum (4.37) and plastic (3.58). They had wood grouped with reinforced concrete and prestressed concrete for mean perceived *design standards available*. Although their mean rating for wood was significantly lower than the highest rated material, steel, their mean perceived ratings for wood was significantly higher than plastic and aluminum (Table 48).

Railroad officials had highest mean perceived *material available* ratings for steel (5.79), wood (5.71), reinforced concrete (5.59) and prestressed concrete (5.32). Their mean perceived *material available* ratings for these materials were significantly higher than aluminum (4.14) and plastic (3.66). Railroad officials' *mean perceived* material available rating for wood was not significantly different from steel, reinforced concrete, and prestressed concrete (Table 48).

Railroad officials had the highest mean perceived *ease of construction* ratings for wood (5.59) and steel (5.58). Their mean perceived ratings for these materials were significantly higher than reinforced concrete (4.89), prestressed concrete (4.89), aluminum (4.26) and plastic (3.86). Their mean perceived ratings for reinforced concrete and prestressed concrete were significantly higher than aluminum and plastic (Table 48).

Railroad officials had the highest mean perceived *designer's experience with materials* ratings for steel (5.60), wood (5.45), reinforced concrete (5.26) and prestressed concrete (4.81). Their mean perceived *designer's experience with material* ratings for these materials were significantly higher than aluminum (3.50) and plastic (3.16). Their mean perceived *designer's experience with materials* rating for wood was not significantly different from steel, reinforced concrete and prestressed concrete (Table 48).

Railroad officials had the highest mean perceived *construction equipment available* ratings for steel (5.54), wood (5.51), reinforced concrete (5.25) and prestressed concrete (5.16). Their mean perceived *construction equipment available* ratings for these materials were significantly higher than aluminum (4.40) and plastic (3.94). Their mean perceived *construction equipment available* rating for wood was not significantly different from steel, reinforced concrete, and prestressed concrete (Table 48).

Discussion of Design Attributes:

Ease of design was above average in importance to railroad officials which indicates that wood products manufacturers should include these attributes in their marketing strategy. Railroad officials perceived *design standards to be highly available* for wood products. Wood was perceived to be among the most *available structural materials* by officials. Officials perceived *designers to be experienced* with wood in railroad structures. Also, they perceived wood to be the most *easy material in construction* and *construction equipment to be highly available* for wood. Wood was a standard material used in many railroad structures, which was the probable reason railroad officials having high perceptions for wood in each design attribute. Due to railroad officials perceived wood to be well above average in possessing each of these attributes, it is suggested that manufacturers use *design* attributes in promotional efforts. They may wish to promote wood as *easy in construction*. To hold their competitive position, manufacturers may want to make sure that *construction equipment, standard structure designs* and *wood products* continue to be *available*. This indicates that wood products manufacturers may want to work closely with equipment manufacturers/developers and with the technical associations responsible for railroad design standards. Finally, manufacturers may want to continue to educate designers on the proper use of wood products so the designers will increase experience with wood.

Perceptional Ratings of Environmental Factors:

Railroad officials were asked to rate the importance of the following environmental design factors when making a material choice decision: *chemically safe*, *aesthetically pleasing*, *disposable/biodegradable*, *low environmental effects of material production*, *recyclable/reusable* and *percent recycled content of material*. Significant differences were found among their mean importance ratings for environmental factors. They had the highest mean importance rating for *chemically safe* (5.46), which was significantly higher than all other environmental factors. Their mean importance rating for *low environmental effects of material production* (4.45) was significantly higher than their mean importance rating for *percent recycled content of material* (3.59). No significant differences were found among railroad officials' mean importance ratings for *disposable/biodegradable* (4.23), *recyclable/reusable* (4.21), *aesthetically pleasing* (3.96) and *percent recycled content of material* (Table 50).

Discussion of Environmental Factors:

Environmental impact factors were above average in importance to railroad officials, and it is suggested that manufacturers consider including these factors in their marketing plans. Railroad officials had the highest importance for *chemically safe* materials. It is suggested that manufacturers incorporate plans in their market strategy to increase the chemical safety of materials. Also, they had above average importance for *low environmental effects of material* *production*, *disposable/biodegradable*, and *recyclable/reusable*. This indicates that manufactures may want to include objectives in their marketing plans to that reduce *environmental effects of material production*, make materials more *disposable/biodegradable*, and increase the *recyclability/reusability* of materials. Railroad officials had the lowest importance for *aesthetically pleasing* and *percent recycled content of material*. These factors were below average in importance and should not be emphasized as much as other environmental factors in manufacturers' market strategies.

Perceptional Ratings of Environmental Attributes:

Railroad officials were asked to rate the following materials for perceived possession of environmental attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the railroad officials' mean perceived environmental ratings for materials. They had the highest mean perceived *chemically safe* ratings for steel (5.63), prestressed concrete (5.47) reinforced concrete (5.46) and aluminum (5.13). Their mean perceived *chemically safe* ratings for these materials was significantly higher than wood (4.79) and plastic (4.26). Railroad officials had the lowest mean *chemically safe* ratings for wood and plastic, which were not significantly different from each other (Table 51).

Significant differences were found among railroad officials' mean perceived *aesthetically pleasing* ratings for materials. They had no significant difference between the mean perceived *aesthetically pleasing* ratings for prestressed concrete (4.97), reinforced concrete (4.89), aluminum (4.81), steel (4.80) and wood (4.68). Their mean perceived *aesthetically pleasing* rating for plastic (4.33) was significantly lower than prestressed concrete, but not significantly different from the other materials tested. No significant differences were found between railroad officials' mean perceived *aesthetically pleasing* ratings for wood and any of the materials tested (Table 51).

Significant differences were found among railroad officials' mean perceived *disposable/biodegradable* ratings for materials. Railroad officials had the highest mean perceived *disposable/biodegradable* ratings for steel (4.79), aluminum (4.65), wood (4.52) and prestressed concrete (3.98). Their mean perceived ratings for wood were not significantly different from their ratings for steel, aluminum, prestressed concrete and reinforced concrete (3.80), but were significantly higher than plastic (3.34) (Table 51).

One significant difference was found among the railroad officials' mean perceived *low environmental effects of material production* ratings for materials. Their mean perceived *low environmental effects of material production* rating for reinforced concrete (4.29) was significantly higher than plastic (3.35). No significant differences were found among the railroad officials mean perceived *low environmental effects of material production* rating for wood (4.10) and their mean perceived rating for any other materials tested (Table 51).

Significant differences were found among railroad officials mean perceived *recyclable/reusable* ratings for materials. They had the highest mean perceived *recyclable/reusable* rating for steel (5.44) and aluminum (5.00). Their mean perceived ratings for these materials were significantly higher than wood (3.94), plastic (3.88) prestressed concrete (3.49) and reinforced concrete (3.31). Railroad officials mean perceived *recyclable/reusable* rating for wood was not significantly different than plastic, prestressed concrete and reinforced concrete (Table 51).

Significant differences were found among the railroad officials mean perceived *percent recycled content of material* ratings. They had the highest mean perceived *percent recycled content of material* ratings for steel (5.07), aluminum (4.74) and plastic (4.33). Their mean perceived ratings for these materials were significantly higher than wood (3.23), reinforced concrete (3.22) and prestressed concrete (3.07). Railroad officials' mean perceived *percent recycled content of material* rating for wood was not significantly different from reinforced concrete and prestressed concrete (Table 51).

Discussion of Environmental Attributes:

It has been determined that environmental factors are highly important to railroad officials in the material choice decision and should be included in manufacturers market strategies to compete in railroad markets. Railroad officials perceived wood to be among the least *chemically safe* materials. This indicates that manufacturers should improve the chemical safety of wood by developing and using chemical preservatives that are more environmentally safe, as well as more effective. Wood was perceived to be among the least *recyclable/reusable*, *percent recycled content of material* and *disposable/biodegradable* materials. The low perceived *recyclability/reusability* contradicts interview participants who said that they reuse wood ties in low volume tracks and other railroad structures. It is suggested that manufacturers and association develop recycling programs for used solid wood materials and improve the perception that wood is *disposable/biodegradable*. Wood was considered above average in possessing the attributes *low environmental effects of material production* and *aesthetically pleasing*. This indicates that manufacturers should use these higher perceived wood attributes in their promotional efforts to the railroad market.

Perceptional Ratings of Maintenance Factors:

Railroad officials were asked to rate the following maintenance factors in making a material choice decision: *standards structure designs available, field modification easy*, *ease of repair*, *experience in maintenance with material* and *inspection easy*. One significant difference was found among the railroad officials mean importance ratings for these maintenance factors. They had the highest mean importance rating for *ease of repair* (6.04), which was significantly higher than their mean importance rating for *standard structures designs available* (5.39). No significant differences were found among their mean importance ratings for *inspection easy* (5.74), *field modification easy* (5.71), and *experience in maintenance with materials* (5.69) (Table 53).

Discussion of Maintenance Factors:

Maintenance factors overall are highly important to the railroad officials. Wood products manufacturers need to know which maintenance factors are most important in a material choice decision in order to focus their marketing efforts. Railroad officials had highest importance for the maintenance factor *ease of repair* because it lowered maintenance costs. *Inspection easy* was above average in importance because the large railroad structures (track systems, railroad bridges and other structures) require intensive maintenance to maintain safe, efficient operation of the railroad. Materials that possessed the attribute *field modification easy* allowed railroad officials to change more quickly the material to fit a structure, lowering maintenance costs. The more experience these personnel had with a material, the lower the maintenance costs would be. Therefore, railroad officials had above average importance for *experience in maintenance with materials*. Although *standard structure designs available* was less important to railroad officials, they still had had the above average importance for this factor. All of the maintenance factors were determined to be above average in importance to railroad officials, and therefore manufacturers may want to include each of them in their market strategies. Emphasis should be placed on the most important maintenance factors, including *ease of repair, inspection easy* and *field modification easy*.

Perceptional Ratings for Maintenance Attributes:

Railroad officials were asked to rate the following materials for perceived possession of maintenance attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the railroad officials' mean perceived maintenance ratings for materials. Railroad officials had the highest mean perceived *standards structure designs available* ratings for steel (5.57) and wood (5.24). Their mean perceived *standards structure designs available* ratings for steel was significantly higher than reinforced concrete (5.06), prestressed concrete (4.88), aluminum (4.21) and plastic (3.39). Railroad officials mean perceived *standards structure designs available* ratings for wood, reinforced concrete, and prestressed concrete were significantly higher than aluminum and plastic (Table 54).

Significant differences were found among the railroad officials mean perceived *field modification easy* ratings for materials. They had the highest mean perceived *field modification easy* ratings for wood (5.47) and steel (5.15). Their mean perceived field modification ratings for these materials were significantly higher than aluminum (4.06), reinforced concrete (3.96), plastic (3.43) and prestressed concrete (3.35) (Table 54).

Significant differences were found among the railroad officials' mean perceived *ease of repair* ratings for materials. They had the highest mean perceived *ease of repair* ratings for wood (5.26) and steel (5.22). Their mean perceived *ease of repair* ratings for these materials were significantly higher than reinforced concrete (4.21), aluminum (3.90), prestressed concrete (3.63) and plastic (3.38) (Table 54).

Significant differences were found among the railroad officials' mean perceived *experience in maintenance with material* ratings for materials. They had the highest mean perceived *experience in maintenance with material* ratings for wood (5.62) and steel (5.26). Railroad officials' mean perceived *experience in maintenance with material* rating for wood was significantly higher than reinforced concrete (4.65), prestressed concrete (3.95), plastic (2.81) and aluminum (2.81) (Table 54).

Significant differences were found among the railroad officials' mean perceived *inspection easy* ratings for materials. They had the highest mean perceived *inspection easy* ratings for wood (5.23) which was not significantly different from their highest mean perceived rated materials, including steel (5.36), reinforced concrete (5.14) and prestressed concrete (5.10). Their mean perceived *inspection easy* ratings for these materials were significantly higher than aluminum (4.62) and plastic (4.21) (Table 54).

Discussion of Maintenance Attributes:

Railroad officials perceived steel and wood to have the most *standard structure designs available*. These materials were used in nearly all railroad structures therefore, standards were required to be available. Wood and steel were perceived by railroad officials to be the easiest materials to *modify in the field and repair*. Supporting this result, interview participants indicated they had the knowledge and equipment necessary to modify these materials in the field and to repair them. Railroad officials perceived railroad personnel as having the most experience in maintenance with wood and steel. To be sure that the railroad structures were sound, the railroad officials had to have the knowledge and experience required to inspect them efficiently. Consequently, the officials perceived wood to be among easiest materials to inspect.

These perceptions of wood indicate that some improvements may need to be made in manufacturers' marketing strategies. Manufacturers should first include that perception the wood is easy to *inspect, repair,* and *modify in the field* in their promotional efforts. Manufacturers and associations should be sure that *standard structural designs are available* to railroad officials in order to keep their competitive position in the railroad market. Finally, manufacturers and associations should develop educational programs to be sure that railroad officials are experienced on the proper maintenance of wood structures.

Perceptional Ratings of Innovation Factors:

Railroad officials were asked to rate the following innovation factors for importance in making a material choice decision: *innovative in performance*, *innovative in design*, *innovative in maintenance*, *innovative in durability*, and *innovative in the environment*. Significant differences were found among the railroad officials' mean importance ratings for these factors. They had the highest mean importance ratings for *innovative in durability* (5.68) and *innovative in maintenance*

(5.38). Railroad officials' mean importance rating for *innovative in durability* was significantly higher than their mean importance rating for *innovative in performance* (4.99), *innovative in the environment* (4.78), and *innovative in design* (4.30). Railroad officials' mean importance rating for *innovative in maintenance* was significantly higher than their mean importance rating for *innovative in the environment* and *innovative in design*. Their mean importance rating for *innovative in performance* was significantly higher than their mean importance rating for *innovative in design* (Table 56).

Discussion of Innovation Factors:

Innovation factors were least important to railroad officials in their material choice decision, and therefore could be emphasized less by manufacturers' marketing efforts. Railroad officials had the highest importance for *innovative in durability* and *innovative in maintenance*. This indicates that improvements in materials durability and maintenance may need to be emphasized most by wood products manufacturers in marketing strategies. *Innovative in performance, in the environment and in design* were perceived to be above average in importance and should be included in the marketing strategies.

Perceptional Ratings of Innovation Attributes:

Railroad officials were asked to rate the following materials for possession of innovation attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the railroad officials' mean perceived innovation ratings for materials. Although significant differences were indicated to be present among the railroad groups mean perceived *innovative in performance* ratings for materials, no significant differences were located using Tukey's HSD test. Therefore, their mean perceived *innovative in performance* ratings for wood (4.32) were not significantly different from any other materials tested. Their mean perceived *innovative in performance* ratings for prestressed concrete (4.77), steel (4.75), aluminum (4.36) reinforced concrete (4.33), wood, and plastic (4.50) were all slightly above average (Table 57).

Significant differences were found among the railroad officials' mean perceived *innovative in design* ratings for materials. They had the highest mean perceived *innovative in design* ratings for prestressed concrete (4.82), steel (4.71), plastic (4.48), reinforced concrete (4.45) and aluminum (4.44). Their mean perceived *innovative in design* ratings for prestressed concrete and steel were significantly higher than wood (4.17) (Table 57).

Significant differences were indicated to be present among the railroad officials' mean perceived *innovative in maintenance* ratings for materials, but no significant differences were located among their mean perceived ratings using Tukey's HSD test. Consequently, their mean perceived *innovative in maintenance* rating for wood (4.45) was not significantly different from their mean perceived ratings for any other materials tested. Their mean perceived *innovative in maintenance* ratings for steel (4.82), prestressed concrete (4.51), reinforced concrete (4.70), wood, aluminum (4.31) and plastic (4.23) were all slightly above average (Table 57).

Significant differences were indicated to be present among the railroad officials' mean perceived *innovative in durability* ratings for materials, but no significant differences were located among their mean perceived ratings using Tukey's HSD test. As a result, their mean perceived *innovative in durability* rating for wood (4.59) was not significantly different from their mean perceived ratings for any other materials tested. Their mean perceived *innovative in durability* ratings for steel (5.23), prestressed concrete (4.92), reinforced concrete (5.00), wood (4.59), plastic (4.46) and aluminum (4.40) were all above average (Table 57).

No significant differences were present among the railroad officials mean perceived *innovative in the environment* ratings for material. Therefore, their mean perceived *innovative in the environment* ratings for wood (4.23) was not significantly different from any other materials tested. Railroad officials' mean perceived *innovative in the environment* ratings for steel (4.83), prestressed concrete (4.60), reinforced concrete (4.63), plastic (4.61), aluminum (4.60), and wood were all above average (Table 57).

Discussion of Innovation Attributes:

The results indicated that all materials, including wood, were perceived to be above average in *innovativeness in performance, innovativeness in maintenance, innovativeness in design* and *innovative in the environment* . Also, wood did not differ from any material for these innovative attributes. Wood was perceived to be among materials considered least innovative in durability. It is suggested that manufacturers improve the *innovativeness of durability* of wood due to railroad officials' perceptions that it is low in possessing this attribute. Wood is rated the same on the other innovation attributes as other materials, which indicates that manufacturers may need to improve these areas to separate wood from the alternative materials.

Case Study Interviews:

Interviews with railroad officials were conducted in four states, including Georgia, Indiana, Maine and Montana. The participants included structural engineers, track supervisors and managers from national (class I) and regional (class II and III) railroads. In Georgia, two structural engineers from national railroads, one track/structures superintendent and one general manager (both from a regional railroads) were interviewed. In Indiana, one structures superintendent from a national railroad, one track superintendent and one president (both from regional railroads) were interviewed. In Maine, two track/structures superintendents from national railroads and one engineering superintendent from a regional railroad were interviewed. In Montana, three structures maintenance managers from a national railroad and one regional railroad manager were interviewed. The results from the interviews were composed and presented as case studies for each state.

Case Study 1: Georgia

Railroad structures designed, maintained or constructed by Georgia participants included railroad tracks, railroad bridges and retaining walls. Georgia does not have guidelines for the use of wood products in railroad construction, but the railroads follow guidelines set by the American Railway Engineering Association (AREA). In the past three years, interview participants have used wood products in design, construction and/or maintenance of ties/track structures, bridge caps, bridge stringers, retaining walls, crossing signals/signs, road crossings. Participants reported the highest current use of wood products is in crossties. They felt the greatest potential or future use of wood products in railroads continues to be in cross and bridge-ties. In national railroads, bridge materials are being changed from wood to concrete, although wood is still used in bridge-ties. In some smaller railroads, wood has great potential for use in bridge structures. In the next three years, participants said they plan on using wood products in crossties and bridge-ties. Some construction is going to occur in timber bridge structures, but mainly by smaller railroads. Also, wood is going to be used in highway crossings.

Participants have problems with the durability of wood used in railroad construction. They say wood decays readily in the Southeastern US. Currently, wood in railroad bridge construction is only lasting 60 years on average and is not meeting the desired lifespan of 80 to 100 years. Participants have seen splitting and checking problems with bridge members. Durability problems with wood in railroad structures is species specific. Pine is considered too soft, while hardwood is hollow-hearted. Cypress lasts a long time, but it is too soft for the loads on railroads to be a viable tie or bridge member. Construction of timber structures causes many holes to be put into the treated wood. These holes give fungus and insects access to the untreated heartwood, which causes premature decay of the railroad structures. Heavy loads put on bridge structures by trains today cause pilings (either concrete or steel pilings) to cut into timber caps. This causes premature rot and mechanical failure of the timber caps, limiting there use.

Participants cite benefits with the durability of wood used in railroad construction. Wood is superior to steel or reinforced concrete in corrosion resistance. Also, wood is perceived to be good in fatigue resistance in railroad structures.

Participants discussed maintenance benefits and problems in using wood in railroad construction. They say wood is easily handled and easy to work with in the field. The size of railroad structures cause maintenance problems when constructed of wood. Often, large structures with thousands of wood parts which must be inspected and maintained. Adding to the maintenance difficulty of large complex structures in railroads is the fact that railroads do not have much time between scheduled trains to close tracks for maintenance. Therefore, because wood is maintenance intensive, railroad officials in Georgia are looking for economical materials to replace timber in bridge construction. They are choosing primarily steel because of its low maintenance needs, low inspection requirements, and the relative speed with which officials could replace/maintain steel parts (pilings, cross members, etc.) in bridge structures. In place maintenance chemical treatments are a high priority in the Southeastern US because of the climate. The wet climate of the Southeastern US is highly conducive to rot by fungus, so in-place treatments are required and an added expense to using wood products in railroad construction.

Georgia participants identified other problems in using wood in railroad construction. For timber bridge materials, cost is a problem as well as time frame for ordering materials. The large sizes of wood products needed for bridge structures often take a long time to receive, causing problems in bridge maintenance and construction. In one instance it took 12 to 18 months for wood pilings to be delivered, while it only took 2 to 3 months for steel pilings and 2 to 3 weeks for concrete piles. These parts have to be ordered in advance because of the difficulty in acquiring them, which causes problems for a railroad working on a yearly budget. Wood parts are expensive because of their large size, also causing problems for a railroad with a minimal structure maintenance budget. Timber quality is said to be changing. Wood products produced in the 1920s and 1930s are superior to that produced from the second harvest in the 1950s and 1960s. Apparently, timber produced in the 20s and 30s was slowly grown, more dense and therefore stronger than that produced in the 50s and 60s. Finally, creosote treated wood products are seen as becoming an environmental problem.

Participants identified other benefits to using wood in railroad construction. Wood products are frequently the least costly option for bridge structures, signs/signals, retaining walls and road crossings. Wood currently is the least costly option for crossties and bridge-ties. Because of wood's resilience, wood cross and bridge-ties are the best materials at holding gage of track. Wood is very forgiving, or fatigue resistant, unlike steel, and unlike wood, steel does not warn one of failure under stress. Wood is perceived to be easier to work with than concrete (for tie materials) in construction of railroad tracks.

Georgia participants say there are several needs that should be addressed to increase the use of wood products in railroad construction. Smaller railroads need information about applications of wood. Respondents indicated that better promotional and educational efforts are required from the wood products industry. The timber industry is not organized like the steel or concrete industry to back wood for structural applications in industrial markets. A large problem with wood used in bridge structures is the fasteners in bridges and structures working loose with the shrinking and swelling of the wood. This increases maintenance costs for the railroad. There is a need for a better fastening system to eliminate this problem in wood constructed railroad bridges/structures. Price stability in crosstie and bridge materials is needed for wood products to maintain or increase use in railroads. There is a need to improve the durability of wood in railroad construction. Improvements are needed in chemical treatments to make them more environmentally friendly but still adequately protect the wood. Also, there is a need to find ways to prevent checking, splitting and bending of wood under treatment and use. Finally, wood resources are becoming scarce. The availability of wood needs to be improved for wood products use to increase in Georgia.

Case Study 2: Indiana

Indiana interview participants have designed, maintained or constructed the following railroad structures: track structures, bridge structures, buildings, road crossings, switches, fender systems on bridges. Indiana does not have guidelines for the use of wood products in railroad construction and railroad participants followed AREA guidelines. In the past three years, participants have used wood products in design, construction and/or maintenance of the following railroad structures: crossties, bridge-ties, retaining walls, road crossings, bridge decks, bridge stringers, retaining walls, fender wall systems for bridges. Participants say the highest current use of wood products in railroads was crossties, bridge caps, bridge stringers and cross-bucks/road crossings. Indiana railroad officials said the greatest potential or future use of wood products is crossties and cross-bucks/road crossings. Participants had plans in the next three years to use wood in crossties, cross-bucks/road crossings, signs, bridges-ties, bridge stringers, caps and piles.

Participants identified problems with the durability of wood used in railroad construction. The main durability problems with wood in railroads are decay due to poor chemical treatments, tie grades, species, quality of wood and tree diseases. If well maintained, wood crossties should last 25 years, but crossties required proper drainage for adequate service life. Wood railroad bridges have been constructed to shorter spans and receive higher load cycles per span than concrete or steel bridge spans. Therefore, wood bridges have higher fatigue of individual spans than alternate materials.

Interview participants identified durability benefits with the use of wood in railroad construction. Wood in railroad structures weathered well and was fatigue resistance. Even under damage caused by derailment of trains wood crossties perform well.

Maintenance benefits and problems using wood in railroad construction were cited by Indiana participants. Wood is lighter and easier to modify in the field relative to some materials such as concrete. Wood was easier to take out of structures than concrete because it takes less time to remove wood than concrete. Unlike steel, wood in railroads does not have to be painted to prevent corrosion. The main maintenance problem with wood is that creosote treated wood causes handling problems and worker health problems.

Participants identified problems in using wood in railroad construction. The life expectancy of wood in railroad structures had a wide range (5-25 years), and it depended upon many variables, including: wood species, where the wood is in the tree, the grade of wood, treatment process, treatment depth and handling of the wood. They said it is difficult to dispose of treated wood cross-ties. Landfills may not take them and it is becoming difficult to get the public to take them. Cost of new ties is becoming high. Cost estimates for new ties are $13 per tie, while used ties which can be used by the slower moving switch line railroads cost $8 per tie. Bridge spans are shorter with wood than with concrete and steel. Therefore, more piles need to be placed in the streams which catch more drift materials than longer span bridges. This drift material can cause fire and flood problems. This presents the last problem: wood railroad structures are possible fire hazards.

Participants stated there were benefits in using wood in railroad construction. Wood is readily available and inexpensive for railroad track parts and structures. Wood is relatively easy to work with because it is light weight relative to concrete. People are able to lift wood crossties where concrete crossties would have required machinery to handle or move. Timber is fatigue resistant and more forgiving of temporary overloads. Salt does not corrode wood structures, like it does steel or concrete. Finally, railroads are seeing adequate life from wood products.

Indiana interview participants identified several needs which must be addressed to increase the use of wood products in railroad construction. There is a need to improve the treating process so treatments can penetrate the wood more deeply. There needs to be increased federal funding to shortline railroads for wood use. Better wood preservatives are needed which protect wood and cause fewer health and environmental problems. Better wood availability and wood quality are needed. Finally, improved standards for wood retreatment are needed. Retreatments have to be done more often and are expensive. It is suggested that the wood treatment companies should do the retreatments.

Case Study 3: Maine

Maine interview participants have designed, constructed or maintained the following railroad structures: bridges, buildings, track systems, signs and sign systems. Maine does not have guidelines for the use of wood products in railroads, but participants say they follow AREA specifications. In the past three years, participants have used wood products in design, construction and/or maintenance of the following railroad structures: bridges, retaining walls, crossties and bridge-ties. Within railroads, the highest current use of wood products are bridge-ties, crossties, building construction, overhead bridges for pedestrian and highway traffic (made with wood decks). Participants say the greatest potential or future use of wood products in railroads will be bridge-ties and crossties. In the next three years, interview participants plan on using wood products in railroad construction in bridge-ties, crossties, bridge decks, and perhaps some building construction.

Maine participants identified the benefits with the durability of wood used in railroad construction. They are seeing the expected life and performance needed from wood products, especially with southern yellow pine bridge and cross ties. Expected life is around 40 years. They have few decay problems with wood ties and say wood ties are usually destroyed mechanically before they decay in the rail line. Participants say concrete ties can not withstand the repetitive forces like wood ties in rail line construction.

Participants identified maintenance benefits and problems with wood products in railroad construction. In a minor derailment, the bridge and cross ties receive damage from the impact of train-car wheels. Wood ties can absorb this damage and still are useful. It is easy to handle and spike wood ties relative to ties of alternate materials. In railroad structures, wood does not have to be painted to prevent corrosion. One maintenance problem is with treated wood waste. Disposal of the treated wood ties are becoming more of a problem. Derailment can damage a wood tie and if the damage goes deep beyond the treated portion of the tie, the tie will decay prematurely.

Maine participants identified other problems in using wood in railroad construction. Participants stated oak bridge/cross ties are too dense and do not taking chemical treatments well. The treatment (primarily creosote) is not penetrating the wood to the needed depth and these oak bridge/cross ties start decaying prematurely. Also, oak bridge/cross ties are heavy and have a lower elasticity than other wood species used for ties. Southern yellow pine is more elastic and bends more under the heavy train loads, allowing more flexibility in the track. Southern yellow pine is much lighter than oak in ties and therefore is easier to handle. Participants said there are problems with chemical wood treatments. Creosote treatments may someday be banned which can be a problem for the railroad industry primarily using creosote treated wood products in bridge/crossties.

Participants cite some benefits in using wood in railroad construction. Wood is inexpensive relative to other materials such as concrete and steel. Wood ties are elastic and absorb impacts from loads and derailments that can not be absorbed by other materials without breaking the ties. Southern yellow pine crossties are lighter than other wood species ties and do not put as great a load on bridge sub-structures as other tie wood species and materials. Maine participants said there are no decay problems in cold climates and there is a good supply of wood materials. Finally, they said wood is easy to handle and work with.

Maine interview participants suggested several requirements to increase the use of wood products in railroad construction. There should be a good supply of bridge and cross ties for future use, especially southern yellow pine ties. There is a need for an acceptable wood species or engineered wood product that can substitute for southern yellow pine in crossties. Wood products manufacturers should keep quality up, prices low and keep improving services.

Case Study 4: Montana

Montana participants have designed, maintained or constructed the following railroad structures: bridges, crossties/bridge-ties, and railroad structures such as buildings and retaining walls. Montana does not have guidelines for the use of wood products in railroad construction, and generally participants followed the AREA guidelines. In the past three years, participants have used wood products in design, construction and/or maintenance of the following railroad structures: bridge walkways, bridge stringers, diagonal sway braces attached to wood piling in bridges, crossties and bridge-ties. Participants say the highest current use of wood in railroads was in crossties, bridge-ties, road crossings, bridges and general construction of buildings. Participants stated the greatest potential or future use of wood products within railroads is crossties, bridge-ties, ballast retainers on bridges, and road crossings. In the next three years, participants plan on using wood products in railroad construction in crossties and bridge-ties.

Participants identified problems and benefits with wood durability in railroad construction. They say wood does not withstand the freeze/thaw cycles that can be handled by concrete and steel construction. Also, they say wood in bridges can not endure the compressive forces created by today’s heavy train car loads. Wood bridge caps can be crushed with today’s heavier train loads. Although there are problems with wood durability, participants are seeing adequate life from wood crossties, especially in the more arid climates.

Participants identified maintenance benefits and problems with wood in railroad construction. Some perceive wood in railroad bridges as easier to inspect than concrete or steel. One can see the problems with wood structures easier than concrete structures. One problem was that wood structures require greater maintenance. Treated wood can not be drilled/cut without causing decay problems. When using wood deck bridges, the decks have to be raised or lowered to allow the bridge tracks to meet the entering/exiting track level when new ballast was added. Concrete ballast decks allowed railroads just to add more ballast to keep the tracks on bridges level with surrounding tracks. Finally, creosote wood treatments have caused health problems for railroad maintenance and construction workers.

Participants identified other problems and benefits using wood in railroad construction. The cost of wood was high and wood availability is low for the size of pilings required to build railroad bridges. The quality of wood products is perceived to be less than it has been. Also, they say the bottom of soil pans can not be reached with a 60 foot wood piling. Concrete piles are safer to construct because wood piles can blow out when driven. Wood structure bridges cause too many piles to have to be used, which cause higher amount of debris to catch under a wood railroad bridge. Participants perceive treated wood as environmentally unsafe. Wood is flammable, but concrete and steel railroad bridges are not. Wood is considered light weight relative to concrete and steel, but heavy equipment still is required to work with wood in large railroad construction such as bridges.

Montana interview participants have several suggestions which should be addressed to increase the use of wood products in railroad construction. A chemical wood treatment needs to be developed that is less hazardous to workers and less flammable but still protect wood.
Fire retardents need to be developed and implemented for wood use in railroads. Finally, wood products manufacturers need to increase the availability, increase the quality and lower the prices of wood products.

Conclusion

Railroad officials perceive wood to have above average overall performance in structures. They perceive wood to be the same in overall material performance as prestressed concrete and reinforced concrete, but lower in overall performance than steel. This indicates that they perceive wood to be a safe and efficient structural material which has adequate service life in railroad structures.

Railroad officials have the highest importance for *durability*, *maintenance* and *cost* in making a material choice decision in railroad structures. These factors are important to officials due to their influence on a material being able to safely and effectively perform as structural material in railroads. *Environmental impact* of a material is above average in importance because railroad officials are responsible for the effects of materials they use in structures have on the environment. Materials that decrease costs of structure design are desirable to railroad officials, and therefore ease of design is above average in importance to these decision-makers. Both *environmental impact* and *ease of design* do not directly affect the safe and efficient operation of railroad structures. Therefore, they are not as important as *durability, maintenance* and *cost* in a material choice decision in railroad structures. Railroad officials do not want to risk failure of a structure constructed with a new material that is not proven. Therefore, *innovativeness of material* is the least important factor and is perceived to be below average in importance.

Benefits of wood in structures could be utilized by manufacturers to compete more effectively in the railroad market. Wood products are perceived to have the lowest *initial cost* of materials. In durability attributes, wood is perceived to be among the most *corrosion resistant* and *fatigue resistant* of materials. Railroad officials perceive *design standards to be available* for railroad structures, but they may need to be updated. Wood products are perceived to be among the most *available* materials and to be the *easiest material in railroad construction*. *Construction equipment is perceived to be available* for construction with wood in railroad structures and railroad official's perceive *structural designers to have experience* with wood. In environmental attributes, wood is perceived to be among the most *aesthetically pleasing* materials and to have *low environmental effects in production*. Officials perceive wood to be *disposable/biodegradable*, but this attribute may not be desirable if one wants the structure to last the needed service life. In maintenance attributes, railroad officials perceive there to be *standard structure designs available* for wood and railroad maintenance personnel to have *experience in maintenance with wood*. *Field modification, repair* and *inspection* are perceived to be easy with wood in railroad structures. Officials perceived wood to be slightly above average in *innovativeness in performance, maintenance, durability*, and *in the environment*, but not any different from other materials in possessing these innovative attributes. Therefore, manufacturers should improve upon woods *innovativeness* when used in railroads. All these factors should be considered by wood products manufacturers in competition in the railroad market. They should be used in promotional and educational programs. Manufacturers should strive to produce wood with these qualities and attempt to improve these qualities to compete better in the railroad market.

Wood products could be improved in several areas to compete more effectively in the railroad market. Wood products were perceived to be among materials with the highest *maintenance cost* and *life-cycle cost*. In durability attributes, wood is perceived to be among the least mechanical *wear/abrasion resistant*, *fire resistant*, *weathering resistant*, and *biological decay resistant* materials. Wood is perceived to be the least *chemically safe* of materials used in railroad structures. Officials perceived wood to be slightly below average in *recyclability/reusability* and *percent recycled content of material*. Officials perceived wood to be the least innovative in design of all materials. These were the areas manufacturers should improve upon in wood products, their prices and their promotions.

Wood products manufacturers have several strategic options to best compete in the railroad market. Railroads need information about applications of wood and better promotional and educational efforts are required from the wood products industry. There is a need for a better fastening system to eliminate this problem in wood constructed railroad bridges/structures. Fasteners and connectors should be improved in railroad bridge structures to decrease maintenance costs for the railroad. Price stability in crosstie and bridge materials is needed for wood products to maintain use or increase use in railroads. The durability of wood in railroad construction needs to be improved. Improvements need to be made in chemical treatments to make them more environmentally friendly but still adequately protect the wood. Improved standards for wood retreatment may be needed. Improvements to prevent checking, splitting and bending of wood under treatment and use may be needed. Finally, wood resources are becoming scarce. The availability of wood needs to be improved for wood products use to increase.

Literature Cited:

Reynolds, G.R. 1994. Realities in Wood Crosstie Production: Today and Tomorrow. *Crossties*, November/December.