Chapter 7

Determining Decision-Makers' Perceptions of Matrials in the United States Utility Infrastructure Market

The United States Utility Infrastructure Market

The United States utility system provides an opportunity for the wood products industry due to the many possibilities for the use of wood in utility distribution and transmission structures. Utility officials spend $500 million per year for utility pole installation/replacement (Ng 1994). This large market has many opportunities for the wood products industry in construction of utility distribution and transmission lines. Utility structures can be built of wood products, but the utility infrastructure market is highly competitive and many structures are being constructed of alternative materials such as steel, reinforced concrete, prestressed concrete, aluminum and plastic. In order to compete more effectively in the US utility market, wood products manufacturers need information about decision makers in charge of design, construction and maintenance of utility structures. Manufactures need to know why engineers and administrators choose materials implemented in today's utility infrastructure. Once this information is documented, wood products manufacturers can develop strategies to compete more effectively in this market.

The utility market and its decision-makers were assessed using a questionnaire sent to 554 utility officials. After the mail questionnaires were analyzed , personal interviews were conducted with utility 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 utility infrastructure market. The methodology as outlined in chapter 2 is followed in this study.

Study Objectives

This study identified how materials for use in utility structures are 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 utility respondents met the first two objectives: which factors are important in the material choice decision and what are the perceptions of wood in various infrastructure applications by different level of decision makers. The factors 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* may be a factor used by a utility decision-maker when deciding on materials for utility pole construction. The factor, *corrosion resistance*, also could be 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 utility decision-maker, that person would mark a 7 on the importance rating scale. The mean of all ratings by utility decision-makers for this factor was determined.

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

Analysis of Variance (ANOVA) was used to define relationships within the utility group. Tukey's honestly significant difference (HSD) test was used to determine where differences were located among the utility 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 range from one to seven for the mean scores. When any 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 utility respondents demographic data. A total of 152 utility officials' returned the questionnaire for an adjusted response rate of 24.3%. Most of the utility officials worked primarily in design (35.5%) and construction (25.7%) (Table 23). Greater than two-thirds of the utility officials had BA, MA, BS or MS degrees (82.5% combined) (Table 24). A little over one-third of respondents (38.5%) had formal course-work in wood design. Of those who did have formal course-work on wood design, the percentage of utility respondents that said the course(s) was mandatory was 32.3% (Table 25). Utility respondents in the age groups 40 to 49 years (35.5%) and 50 to 59 years (34.8%) represented the largest age categories (Table 26). The 25 or more years of work experience group contained the highest percentage of utility respondents (30.5%) (Table 27). Less than one-half of utility officials said they had guidelines for the use of wood products in utility design, construction or maintenance (45.3%) (Table 28).

Utility respondents said they had designed, constructed or maintained distribution poles (87.2%) and utility line crossarms (76.9%) (Table 29). Materials most used by utility respondents in design, maintenance or construction were wood (96.2%), steel (69.9%) and aluminum (40.4%) (Table 30). Utility respondents were asked if they had used wood in the last three years in design, construction or maintenance of utility structures. A large percentage utility officials (95.4%) said they had used wood in utility structures in the past three years. Utility officials 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. Over one-half of respondents (52.0%) had used engineered wood products in utility structures (Table 31). Glue-laminated timber (34.0%) had the highest use in utility structures in the past three years (Table 32). Utility groups were asked if they had plans to use wood products in structure design, construction or maintenance in the next three years. Most utility officials (92.2%) were planning to use wood in utility structures in the next three years (Table 31).

Overall Factor Importance Ratings:

The utility 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*. *Durability* (6.19), *cost* (5.91) and *maintenance* (5.88) were the highest rated materials by the utility officials. As a group these factors were rated significantly higher in importance than *environmental impact* (4.79), *ease of design* (4.68) and *innovativeness of material* (3.49). Utility officials' mean perceived importance ratings for *environmental impact* and *ease of design* were significantly higher than their rating for *innovativeness of material* (Table 38).

Discussion of Overall Factors:

In order to maintain or improve their competitive position in the utility market, wood products manufacturers need information on what overall factor areas are important to utility officials. Utility officials were responsible for safe and efficient operation of distribution and transmission lines. Therefore, utility officials had the highest importance for *durability* of structural materials. *Cost* and *maintenance* were important to the utility officials because of the size of transmission/distribution lines for which they were responsible. Due to the high importance for durability, cost and maintenance of materials in utility lines, it is suggested that manufacturers center their marketing efforts on these three overall factors.

Environmental impact was less important than the most important factors, but it was still above average in importance to utility officials because utility lines are often in close proximity to people. Although it was above average in importance, *ease of design* was not as important to utility officials because they frequently had highly trained structural design engineers on staff, or they could hire a private consulting engineer if necessary. *Innovativeness of material* was less important since utility officials do not want to take risks with materials that are not proven to perform. These three factors were not as important as durability, maintenance and cost, but they were still above average in importance to the utility officials. This indicates that wood products manufacturers may not want to place as much importance on *environmental impact*, *ease of design* and *innovativeness of material*, but these overall factors should not be omitted from their marketing strategies.

Overall Material Performance Ratings:

Utility 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 ratings for steel (5.80) and prestressed concrete (5.36). Utility officials had a mean rating for steel that was significantly higher than reinforced concrete (5.07), wood (4.92), aluminum (4.84) and plastic (3.43). Utility officials' mean perceived performance ratings for reinforced concrete, wood and aluminum were significantly higher than their lowest rated material, plastic. Utility officials' mean perceived overall performance rating for wood was not significantly different from reinforced concrete and aluminum, which had above average mean perceived overall performance ratings (Table 39).

Discussion of Overall Material Performance:

Manufacturers need to know the perceptions of wood's overall performance to determine if they should adjust their marketing plans. Wood was perceived to be the same as reinforced concrete, aluminum and plastic in overall performance as a structural member in utility infrastructure. Even though utility officials had a lower perception of wood in overall performance than they did for steel and prestressed concrete, utility officials still perceived wood to be above average in overall performance. This indicates that manufacturers may need to improve the overall performance of wood in utility line structures if they want to remain competitive in the utility market. To do this, it is suggested that manufacturers center their efforts on improving the durability, maintenance and cost of wood products.

Perceptional Ratings of Cost Factors:

Utility 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 utility officials' mean importance ratings for the cost factors. Utility groups had the highest mean importance rating for *low life-cycle cost* (5.86), which was significantly higher than mean importance ratings for *low maintenance cost* (5.53) and *low initial cost* (5.05). Also, their mean factor importance rating for *low maintenance cost* was significantly higher than *low initial cost* (Table 41).

Discussion of Cost Factors:

Utility officials have high importance for overall cost factors. To compete effectively in the utility market, wood products manufacturers need to know which cost factors are most important to the utility officials. Utility officials had the highest importance for *low life-cycle cost* of structural materials. Utility officials frequently had to repair structural materials or replace them completely. This caused them to be concerned with structural materials having low disposal costs as well as low initial and maintenance costs. *Life-cycle cost* is composed of these three cost factors therefore, utility officials had the highest importance for *life-cycle cost*. It is suggested that manufacturers make provisions in their marketing strategy to improve initial, maintenance and disposal costs of materials.

Perceptional Ratings of Cost Attributes:

Utility 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 utility officials' mean perceived ratings for each cost attribute ratings for all materials. They had the highest mean perceived *low initial cost* rating for wood (5.39), which was significantly higher than their ratings for all other materials tested. Their mean *low initial cost* ratings for steel (4.64), aluminum (4.20) and reinforced concrete (4.10) were significantly higher than prestressed concrete (4.05) and plastic (3.41).

Utility officials had the highest mean perceived *low maintenance cost* rating for steel (5.30) and aluminum (5.20), which were significantly higher than wood (4.56) and plastic (3.93). Officials had above average mean perceived ratings for prestressed concrete (5.14) and reinforced concrete (4.96). Their mean perceived *low maintenance cost* rating for wood was above average and significantly higher than their mean rating for plastic.

Utility officials had the highest mean perceived *low life-cycle cost* ratings for steel (5.39), which was significantly higher than their rating for wood (4.84). Their mean perceived *low life-cycle cost* ratings for steel, prestressed concrete (5.19), aluminum (5.10), reinforced concrete (5.10) and wood were significantly higher than plastic (3.99). Their mean rating for wood was above average for *low life-cycle cost* (Table 42).

Discussion of Cost Attributes:

In order to compete effectively, manufacturers need to be informed of decision-makers perceptions of wood cost. Utility officials perceived wood to have the lowest initial cost of the materials tested. In most instances, wood poles and crossarms used in distribution/transmission structures were less expensive than other materials. This indicates that manufacturers need to keep the price of wood products competitive with other materials in utility markets. Utility officials perceived wood to have higher maintenance costs than alternative materials, but to still be above average in possessing *low maintenance costs*. It is suggested that manufacturers improve the maintenance requirements of wood products to decrease the maintenance costs. Wood was not perceived to be different than other high *life-cycle cost* materials due to its high maintenance and disposal costs. It is recommended that manufacturers not only improve the maintenance costs of wood, but develop methods to improve wood disposal costs in their market strategy. Reducing these costs should improve the perceptions of wood's *life-cycle cost* in utility structures and improve the competitive position of wood products in the utility market.

Perceptional Ratings of Durability Factors:

Utility 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 utility officials' mean durability factor importance ratings. They had the highest mean importance rating for *weathering resistance* (5.69), which was significantly higher than for *mechanical wear/abrasion resistance* (5.03) and *fire resistance* (4.05). Also, utility officials had significantly higher mean importance ratings for *biological decay* *resistance* (5.58), *fatigue resistance* (5.30), *corrosion resistance* (5.22) and *mechanical wear/abrasion resistance* (5.03) than they had for *fire resistance*. Each durability factor was perceived by the utility officials to be above average in importance in the material choice decision (Table 44).

Discussion of Durability Factors:

Durability factors are most important to utility decision-makers, and manufacturers should include objectives pertaining to durability in their marketing strategies. Utility officials had the highest importance for *weathering resistance* because the distribution/transmission structures that they were responsible for were constantly affected by weathering agents such as sun, rain, ice and wind. The officials had high importance for *biological decay resistance* due to the effect biological decay organisms had on utility structures. They had high importance for *fatigue* resistance in structural materials because the structures were subjected to loads by the utility wires, wind and ice. *Corrosion resistance* was perceived to be important due to the presence of corrosive agents near many utility lines such as road salt and water. *Mechanical wear/abrasion resistance* was not as important to utility because the structures were stationary with few moving parts to mechanically wear. *Fire resistance* was average in importance and less important than the other durability factors because of its infrequent occurrence. It is suggested that manufacturers focus improvements in marketing strategies to include provisions for *weathering, biological decay* and *fatigue resistance*. *Mechanical wear/abrasion* and *fire resistance* should not be disregarded from marketing strategies, but manufacturers should place less emphasis in these areas.

Perceptional Ratings of Durability Attributes:

Utility 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 utility officials' mean perceived ratings for materials with each durability attribute. Utility officials had the highest mean *fatigue resistance* ratings for steel (5.46) and prestressed concrete (5.20). Their mean perceived rating for steel was significantly higher than reinforced concrete (4.88), wood (4.69), aluminum (4.56) and plastic (3.45). Utility officials' mean perceived *fatigue resistance* ratings for reinforced concrete, wood and aluminum were significantly higher than their mean rating for plastic. They perceived wood to be somewhat above average in *fatigue resistance,* but not as fatigue resistant as the highest rated material, steel (Table 45).

Utility officials had the highest mean *mechanical wear/abrasion resistance* rating for steel (5.66), which was significantly higher than all materials tested. Their mean perceived ratings for prestressed concrete (5.07) and reinforced concrete (4.98) were significantly higher than wood (4.30) and plastic (3.32). Utility officials mean perceived *mechanical wear/abrasion resistance* ratings for aluminum (4.69) and wood were significantly higher than plastic, which had the lowest mean perceived *mechanical wear/abrasion resistance* rating (Table 45).

Utility officials had the highest mean perceived *fire resistance* ratings for reinforced concrete (5.96), steel (5.89) and prestressed concrete (5.86). Utility officials' mean perceived *fire resistance* ratings for reinforced concrete and steel were significantly higher than aluminum (5.02), wood (2.88) and plastic (2.58). Utility officials perceived wood not to be significantly different than the least fire resistant material tested, plastic. They perceived both wood and plastic to be well below average in *fire resistance* (Table 45).

Utility officials had the highest mean *corrosion resistance* ratings for prestressed concrete (5.30), plastic (5.24), reinforced concrete (5.21) and wood (4.99). They had mean perceived *corrosion resistance* ratings for these materials that were significantly higher than steel (4.20). Utility officials perceived steel and aluminum (4.80) as a group to be the least corrosion resistant. They perceived wood to be among the most corrosion resistant materials, and they perceived wood's *corrosion resistance* to be above average (Table 45).

The material for which utility officials had the lowest mean perceived *weathering resistance* rating was plastic (3.42). Their mean perceived rating for plastic was significantly lower than all materials tested. Their mean perceived *weathering resistance* rating for wood (4.66) was not significantly different from reinforced concrete (5.42), steel (5.38), aluminum (5.29) and prestressed concrete (5.29). This indicated that wood was perceived by utility officials to be among the most weather resistant materials (Table 45).

Utility officials had the highest mean *biological decay resistance* ratings for steel (5.82), aluminum (5.78) reinforced concrete (5.78) and prestressed concrete (5.61). These ratings were significantly different than plastic (4.34) and wood (4.23). Utility officials' perceived wood to be the least *biological decay resistant* material. Even though it had the lowest mean perceived rating by the utility officials, wood still was given a mean *biological decay resistance* rating above average (Table 45).

Discussion of Durability Attributes:

Durability was very important to utility officials and manufacturers may want to consider including durability aspects of wood in their market strategy. Wood was perceived to be above average and the same in *weathering resistance* as other alternative materials. Officials perceived wood to be the least *biological decay resistant* of materials due to damage it received from decay organisms. Utility officials perceived wood to be no different from prestressed concrete, reinforced concrete, aluminum and plastic in *fatigue resistance*. These were the most important factors and wood was perceived to be low in each of these factors. Therefore, manufacturers may need to develop methods to improve the *weathering resistance* of wood using protective coatings or structural design improvements. Manufacturers may need to develop improvements in the effective chemical treatments of wood products to make it more biological decay resistant. Wood products were perceived to be highly fatigue resistant, but some improvements could be made here as well. It was suggested by interview participants that perhaps improved wood grading rules could make wood more resilient.

Utility officials perceived wood to be somewhat above average in *mechanical wear/abrasion resistance*, and to be among the most *corrosion resistant* materials. Wood was perceived to be below average in *fire resistance* because it was flammable. This indicates that manufacturers may want to promote the *corrosion resistance* of wood products. Also, they may want to develop structural designs that decrease the *mechanical wear/abrasion* of wood and they may want to use fire retardents.

Perceptional Ratings of Design Factors:

Utility 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* (5.76), *ease of construction* (5.61) and *construction equipment available* (5.55). Their mean importance ratings for these materials were significantly higher than their mean importance ratings for *design standards available* (5.35) and *designer's experience with materials* (4.96). Their mean importance ratings for *ease of construction* and *construction equipment available* were significantly higher than *designer's experience with materials* (Table 47).

Discussion of Design Factors:

Manufacturers need to know which design factors were most important in order to direct their marketing efforts more efficiently. Utility officials had the highest importance for *materials available*, *ease of construction*, and *construction equipment available*. *Materials available* was important to the decision-maker because materials must be available to be used in the design of the structure. *Ease of construction* and *construction equipment available* was important to the utility officials because they decrease construction costs and time. *Design standards available* was less important because if the design standards for utility structures were not available, then a trained design engineer could be employed to design the structure. *Designer's experience with material* was less important because a designer who has experience with a material could be employed, or the designer could research the proper designs to gain experience with a material. This indicates that manufacturers should improve their competitive position primarily by including *materials availability*, *construction equipment availability* and *ease of construction* in their marketing strategies.

Perceptional Ratings of Design Attributes:

Utility 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. Utility officials had the highest mean perceived *design standards available* ratings for wood (5.64), steel (5.54) and reinforced concrete (5.09). Their mean perceived *design standards available* ratings for these materials were significantly higher than aluminum (5.01), prestressed concrete (4.95) and plastic (3.70) (Table 48).

Significant differences were located among the utility officials' mean perceived *material available* ratings for materials. They had the highest mean perceived *material available* rating for wood (5.67), which was not significantly different from steel (5.45) and reinforced concrete (5.12). Their mean perceived *material available* ratings for these materials were significantly higher than prestressed concrete (4.97), aluminum (4.86) and plastic (3.88) (Table 48).

Significant differences were located among the utility officials' mean perceived *ease of construction* ratings for materials. They had the highest mean perceived *ease of construction* rating for wood (5.89), which was significantly higher than all other materials tested. Their mean perceived *ease of construction* ratings for aluminum (5.04) and steel (5.03) were significantly higher than prestressed concrete (4.14), reinforced concrete (4.11) and plastic (4.10) (Table 48).

Significant differences were found among the utility officials' mean perceived *designer's experience in material* ratings for materials. They had the highest mean *designer's experience with material* rating for wood (5.72), which was significantly higher than their mean perceived ratings for all other materials tested. Their mean perceived *designer's experience in material* rating for steel (4.85), aluminum (4.52), reinforced concrete (4.26) and prestressed concrete (4.06) were significantly higher than plastic (3.19) (Table 48).

Significant differences were found among the utility officials' mean perceived *construction equipment available* ratings for materials. They had the highest mean perceived *construction equipment available* rating for wood (6.01) and steel (5.36). Their mean perceived *construction equipment available* rating for wood was significantly higher than aluminum (5.16), reinforced concrete (4.87), prestressed concrete (4.64), and plastic (4.11) (Table 48).

Discussion of Design Attributes:

Utility officials perceived the most *design standards to be available* for wood, steel and reinforced concrete. Wood, steel and reinforced concrete were perceived by utility officials to be the *most available materials* for distribution/transmission line structures. Officials perceived wood to be the *easiest material in construction* of utility line structures. They perceived designers to have the *most experience* with wood in design of utility structures. Utility officials perceived *construction equipment to be most available* with wood and steel. Utility officials perceived wood to highly possess each of these attributes therefore, manufacturers may want to use this in their promotional campaigns. To remain competitive, manufacturers may want to be sure that wood products remain available and that current design standards are available.

Perceptional Ratings of Environmental Factors:

Utility officials were asked to rate the importance of the following environmental factors in a material choice decision: *chemically safe*, *aesthetically pleasing*, *disposable/biodegradable*, *low environmental effects of material production*, *recyclable/reusable* and *percent recycled content of material*. Utility officials had the highest mean importance rating for *chemically safe* (5.45), which was significantly higher than their mean importance ratings for all other environmental factors. Their mean factor rating for *aesthetically pleasing* (4.91) was significantly higher than *disposable/biodegradable* (4.32), *low environmental effects of material production* (4.27), *recyclable/reusable* (3.51) and *percent recycled content of material production* (2.97). Utility officials' mean importance ratings *for disposable/biodegradable* and *low environmental effects of material production* were significantly higher than *recyclable/reusable* and *percent recycled content of material production* (Table 50).

Discussion of Environmental Factors:

Manufacturers will need to know how the environmental impact factors rank with utility officials so they can direct marketing efforts more effectively. Utility officials had the highest importance for *chemically safe* and *aesthetically pleasing*. To improve competitive position, manufacturers may want to place emphasis on these factors in their marketing plans. *Disposable/biodegradable* and *low environmental effects of material production* were less important than *chemically safe* and *aesthetically pleasing*, but still were above average in importance to the utility officials. *Recyclable/reusable* and *percent recycled content* were below average importance to utility officials which indicated they had the least importance for these environmental factors in a material choice decision.

Perceptional Ratings for Environmental Attributes:

Utility 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 their mean perceived ratings for materials with each environmental attribute except *low environmental effects of material production*. Their mean perceived *low environmental effects of material production* ratings for steel (4.38), aluminum

(4.36), wood (4.32), reinforced concrete (4.27) and prestressed concrete were slightly above average, while their mean perceived rating for plastic (3.70) was slightly below average (Table 51).

Utility officials had the highest mean perceived *chemically safe* rating for steel (5.55). Their mean perceived *chemically safe* rating for steel was significantly higher than wood (4.83) and plastic (4.30). Utility officials' mean perceived *chemically safe* rating for wood was not significantly different than prestressed concrete (5.38), aluminum (5.37), reinforced concrete (5.25) and plastic (Table 51).

No significant differences were found among utility officials mean perceived *aesthetically pleasing* ratings for wood (4.76) and other highest mean rated materials. These highest mean rated materials included aluminum (5.08), prestressed concrete (5.07), steel (5.07) and reinforced concrete (4.37). Their mean perceived *aesthetically pleasing* ratings for these materials were significantly higher than plastic (4.16) (Table 51).

Utility officials perceived wood (4.46) to be the most *disposable/biodegradable* material. Their mean perceived *disposable/biodegradable* rating for wood was not significantly different than their mean ratings for aluminum (4.45) and steel (4.05). Their mean *disposable/biodegradable* ratings for these materials were significantly higher than reinforced concrete (3.12), prestressed concrete (3.12) and plastic (3.02) (Table 51).

Utility officials had the highest mean perceived *recyclable/reusable* ratings for aluminum (4.85) and steel (4.52). Their mean perceived *recyclable/reusable* ratings for aluminum were significantly higher than plastic (3.54), wood (3.41), prestressed concrete (3.32) and reinforced concrete (3.17). Their mean perceived *recyclable/reusable* ratings for steel was significantly higher than wood, prestressed concrete and reinforced concrete. Utility officials had third lowest mean perceived *recyclable/reusable* ratings for wood, which was not significantly different than their mean ratings for plastic, prestressed concrete and reinforced concrete (Table 51).

Significant differences were found among the utility officials mean perceived *percent recycled content of materials* ratings for materials. They had the highest mean perceived ratings for aluminum (3.94) and steel (3.80). Their mean perceived *percent recycled content of material* ratings for these materials were significantly higher than wood (2.86) and reinforced concrete (2.74). Their mean perceived ratings for wood were not significantly different from their other lowest mean perceived rated materials, including plastic (3.48), prestressed concrete (2.89) and reinforced concrete (Table 51).

Discussion of Environmental Attributes:

Wood used in utility line structures generally was treated with preservative chemicals therefore, it was perceived to be the second lowest material in possessing the attribute *chemically safe*. Wood, aluminum, prestressed concrete, steel and reinforced concrete were all perceived by utility officials to be equal and above average in possessing the attribute *aesthetically pleasing*. In order to increase competitive position, manufacturers may want to develop wood preservative chemicals that are more environmentally safe, but are still effective are repelling decay organisms. They also may need to improve the aesthetics of wood products in order to separate wood from the alternative materials in the utility market.

Utility officials perceived wood to be above average and the same as all materials in possessing the attribute *low environmental effects of material production*. Wood, aluminum and steel were perceived to be the most *disposable/biodegradable* materials by utility officials. Officials perceived wood to be average in *recyclability/reusability* because their are some reuse programs for solid wood products, but they are not as prevalent as with other materials. Wood was perceived to be below average in *percent recycled content of materials*. It is suggested that manufacturers use the above average perception of *low environmental effects* of wood production in promotional campaigns directed toward utility officials. Also, they may want to continue improving timber harvesting and wood manufacturing practices to improve the perceptions of wood products with this attribute. To increase the competitive position of wood in utilities, manufacturers and associations may wish to improve recycling/reuse programs of used solid wood poles and crossarms.

Perceptional Ratings of Maintenance Factors:

Utility officials were asked to rate the importance of the following maintenance factors in making a material choice decision: *standard structure designs available*, *field modification easy*, *ease of repair*, *experience in maintenance with material*, and *inspection easy*. No significant differences were found among the utility officials' mean importance ratings of maintenance factors. Their mean importance rating for each maintenance factor was above average with the lowest mean importance rating being for *inspection easy* (5.30) (Table 53).

Discussion of Maintenance Factors:

Maintenance factors were highly important to utility officials in making a material choice decision. Manufacturers need to know which maintenance factors are important to utility officials. As determined from the results, *standard structure designs available, field modification easy*, *ease of repair*, *experience in maintenance with materials* and *inspection easy* were equally important to utility officials. Each factor was above average in its importance, and therefore, manufacturers should include each maintenance factor in their marketing strategies.

Perceptional Ratings of Maintenance Attributes:

Utility officials were asked to rate the following materials for possession of maintenance attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the utility officials' mean perceived maintenance attribute ratings for materials. They had the highest mean perceived *standard structure designs available* rating for wood (5.69), which was significantly higher than all other materials tested. Utility officials had the lowest mean perceived *standard structure designs available* rating for plastic (3.57), which was significantly lower than all materials tested. No significant differences were found among the utility officials' mean perceived *standard structure designs available* ratings for steel (5.07), prestressed concrete (4.53), and aluminum (4.51) (Table 54).

Significant differences were found among the utility officials' mean perceived *field modification easy* rating for materials. They had the highest mean perceived *field modification easy* rating for wood (5.70), which was significantly higher than their mean perceived ratings for all other materials tested. They had the lowest mean perceived *field modification easy* ratings for plastic (3.53) reinforced concrete (3.09) and prestressed concrete (3.04), which were significantly lower than wood, aluminum (4.28) and steel (4.21) (Table 54).

Significant differences were found among the utility officials' mean perceived *ease of repair* ratings for materials. They had the highest mean perceived *ease of repair* rating for wood (4.92), which was significantly higher than their mean perceived ratings for all other materials. Utility officials' had the lowest mean perceived *ease of repair* ratings for reinforced concrete (3.32), plastic (3.01) and prestressed concrete (2.96), which were significantly lower than wood, steel (4.07) and aluminum (3.93) (Table 54).

Significant differences were found among the utility officials' mean perceived *experience in maintenance with materials* ratings for materials. They had the highest mean perceived *experience in maintenance* with materials rating for wood (5.72), which was significantly higher than their mean perceived rating for all materials tested. Utility officials had the lowest mean perceived *experience in maintenance* with materials rating for plastic (2.72), which was significantly lower than wood, steel (4.42), aluminum (4.09) and reinforced concrete (3.75), but was not significantly different from their mean perceived rating for prestressed concrete (3.38) (Table 54).

Significant differences were found among the utility officials' mean perceived *inspection easy* ratings for materials. They had the highest mean perceived ratings for steel (4.95), wood (4.90), aluminum (4.76), reinforced concrete (4.50) and prestressed concrete (4.34), which were not significantly different from one another. Utility officials had the lowest mean perceived *inspection easy* rating for plastic (3.63), which was not significantly different from their mean perceived ratings for reinforced concrete and prestressed concrete, but was significantly lower than their mean perceived ratings for steel, wood and aluminum (Table 54).

Discussion of Maintenance Attributes:

Utility officials perceived maintenance personnel to have the most *experience in maintenance* with wood. This was supported by interview participants who said they had the most experience and knowledge with wood in utility lines. Officials perceived wood to have the most *available standard structure designs in maintenance*. This was due to the NESC providing standards for materials that are used in utility lines. Officials perceived wood as the most *easily repaired and modified material in the field*. This was because they had the most experience with wood, they had the tools available to work with wood and wood could be cut/drilled easily unlike other materials. Utility officials perceived wood to be among the *easiest materials to inspect* and above average at possessing this attribute.

The perceptions of wood indicate that it is among the easiest materials to maintain. Therefore, manufacturers may want to use perceptions of wood maintenance attributes to improve promotions of wood products. Manufacturers may wish to promote wood as easy to inspect, repair and modify in the field. Manufacturers of wood products may wish to make sure the standard structural design standards for wood continue to be available and current. Also, they may want to be sure that wood products continue to be highly available for use in the utility structures.

Perceptional Ratings of Innovation Factors:

Utility officials were asked to rate the importance of the following innovation factors 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 utility officials' mean importance ratings for innovation factors. They had the highest mean importance ratings for *innovative in durability* (4.84), *innovative in maintenance* (4.66), and *innovative in performance* (4.45). Utility officials had the lowest mean perceived importance rating for *innovative in design* (4.22) and *innovative in the environment* (3.86). Their mean importance rating for *innovative in durability* was significantly higher than *innovative in design* and *innovative in the environment*. Utility officials' mean importance ratings for *innovative in maintenance* was significantly higher than *innovative in the environment*. Utility officials' mean importance ratings for *innovative in performance*, *innovative in design* and *innovative in the environment* were not significantly different (Table 56).

Discussion of Innovation Factors:

Manufacturers need to know which innovation factors are most important to the officials in order to compete more effectively. Utility officials had the most importance for *innovative in durability, innovative in maintenance* and *innovative in performance*. *Innovative in design* only was slightly above average in importance to utility officials and less important than other innovation factors due to the high standardization of utility structures. *Innovative in the environment* was less important to the utility officials, which indicates that they did not value improvements in a material's environmental attributes more than other innovations. It is suggested that manufacturers my want to focus their marketing efforts on *innovative in durability, innovative in maintenance* and *innovative in performance*. Manufacturers could place less emphasis on *innovative in design and in the environment*, but they should not disregard these factors in their marketing strategy.

Perceptional Ratings for Innovation Attributes:

Utility 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 utility officials' mean perceived innovation ratings for materials for each innovation attribute except *innovative in maintenance* and *innovative in the environment*. No significant differences were found among the utility officials' mean perceived *innovative in maintenance* and *innovative in the environment* ratings for any materials. Utility officials' mean perceived *innovative in maintenance* ratings for all materials were slightly above average with the lowest mean perceived rating for plastic (4.05). Utility officials' mean perceived *innovative in the environment* ratings for all materials were very close to average with the lowest mean perceived rating for wood (3.69) (Table 57).

Significant differences were found among the utility officials' mean perceived *innovative in performance* ratings for materials. Utility officials had the highest mean perceived *innovative in performance* ratings for steel (4.57), aluminum (4.42), prestressed concrete (4.40) and reinforced concrete (4.01), which were not significantly different from each other. They had the lowest mean perceived *innovative in performance* rating for wood (4.00), which was not significantly different from aluminum, prestressed concrete, plastic (4.29) and reinforced concrete. Their mean perceived *innovative in performance* rating for steel was significantly higher than wood (Table 57).

Significant differences were found among the utility officials mean perceived *innovative in design* ratings for materials. They had the highest mean perceived *innovative in design* ratings for steel (4.73), prestressed concrete (4.58), aluminum (4.56), plastic (4.32) and reinforced concrete (4.16), which were not significantly different from each other. Utility officials had the lowest mean perceived *innovative in design* ratings for wood (3.99), which was significantly lower than steel, prestressed concrete and aluminum. Their mean perceived *innovative in design* rating for wood was not significantly different from plastic and reinforced concrete (Table 57).

Significant differences were found among the utility officials mean perceived *innovative in durability* ratings for materials. They had the highest mean perceived *innovative in durability* ratings for prestressed concrete (4.94), steel (4.92), aluminum (4.77) and reinforced concrete (4.65), which were not significantly different from one another. They had the lowest mean perceived *innovative in durability* ratings for wood (4.14) and plastic (4.08). Utility officials' mean perceived *innovative in durability* ratings for prestressed concrete and steel were significantly higher than their mean perceived rating for wood. Their mean perceived *innovative in durability* rating for wood was not significantly different from their mean perceived ratings for aluminum, reinforced concrete and plastic (Table 57).

Discussion of Innovation Attributes:

Utility officials perceive wood to be least *innovative in design* and among the least *innovative materials in the environment*. Wood was not perceived to be different from other materials in possessing the attributes *innovative in maintenance and in the environment*. Officials did not perceived wood to be less *innovative in performance* than steel and wood rated average in possessing this attribute. This indicates that manufacturers may need to make improvements in wood products' design and environmental attributes to increase competitive advantage. To separate themselves from the other materials, manufacturers may wish to improve wood products maintenance and environmental attributes.

Case Study Interviews:

Electric utility interviews were conducted in four states, including Georgia, Indiana, Maine and Montana. The interview participants included superintendents and engineers working in electricity transmission and distribution. The number of interview participants from each state were: six in Georgia, six in Indiana, six in Maine and five in Montana. The results from these interviews were composed and presented as case studies for each state.

Case Study 1: Georgia

Utility structures designed, maintained or constructed by Georgia interview participants are distribution systems including poles and crossarms. Georgia does not have guidelines for the use of wood products in utility construction, but participants said they use Rural Electrification Association (REA) and National Electric Safety Code (NESC) guidelines. Participants said in the past three years they have used wood products in design, construction and/or maintenance of distribution lines including poles, crossarms and crossarm braces. Within utilities, they said the highest current use of wood products is in wood poles and crossarms for distribution lines. Participants said the greatest potential or future use of wood products in utilities is in poles and crossarms for distribution lines. Participants said in the next three years they plan on using wood poles, crossarms and crossarm braces for utility distribution lines.

Georgia participants identified problems with the durability of wood used in utility construction. There is a problem with the early decay of wood crossarms, which often fail because they decay much earlier than the supporting utility poles. This depends on the shrinking/swelling of the wood, stress/fatigue problems and moisture levels surrounding the distribution line. Most utilities have seen adequate life (20-30 years) of wood products, but some of the older poles have checking, splitting and rot. There is a problem with ground-line rot in wood poles which cause expensive retreatments to be used against fungus. The CCA treated wood poles rot more quickly than the pentachlorophenol treated poles. Knots in wood poles are a problem causing the poles to break easier under stress. Wood poles, unlike some stronger materials such as concrete and steel, snap off when hit by cars and trees. Concrete poles are becoming more competitive with wood products in distribution line construction. They are stronger in many cases (especially on impact with cars and trees), they do not decay and they are becoming cost competitive. Also, as more competitive materials such as fiberglass and steel are implemented, wood crossarms may be eliminated as a means to attach lines to poles. Interview participants cite no benefits with the durability of wood used in utility construction.

Georgia participants cited maintenance benefits in using wood in utility construction. Compared to steel or concrete poles, wood poles are easily modified in the field with low tech equipment. Wood poles are light relative to concrete poles, but are not as light as steel poles. In general, wood poles are easier to climb than concrete or steel poles, but CCA treated poles are very brittle which make them difficult to climb at times. Wood poles are easier to dispose of than concrete or steel poles and utilities often could give the wood poles away.

Georgia interview participants have maintenance problems in using wood products in utility construction. Maintenance cost is high with wood poles. Utilities spend large amounts of money on inspections and in-place treatments of wood poles which they do not have to spend with alternative materials. Hollow steel poles are perceived to be easier to handle/replace than heavier wood or concrete poles.

Georgia interview participants identified other problems in using wood in utility construction. Some people do not like the appearance of treated wood distribution poles. Fire has been a problem especially for wood distribution poles around pine plantations. CCA treated wood is reported to be especially flammable. Wood poles burn completely but the line remains intact, which presents a public safety problem by putting a 25,000 volt power line within reach. Utility officials will not know the line is down because there is no power failure. Wood poles break readily when hit with a large object such as a car or tree, and a minor problem of lightening strikes can break wood poles. Often there are problems with woodpeckers cutting holes in wood distribution poles. Participants report wood poles produced today are not as strong as those produced from virgin growth trees. Therefore, the poles produced today do not match the strength tables created 50 years ago using virgin growth trees.

Participants cited benefits in using wood in utility construction. Initial cost of wood poles and crossarms are lower than that of concrete or steel. Participants report that wood poles and crossarms are readily available. Wood poles are lighter relative to concrete poles and wood poles do not have as much of a conductivity problem as concrete or steel poles.

Georgia participants cited several needs that should be addressed to increase the use of wood products in infrastructure construction. Wood products have to stay cost competitive. The price of steel poles is becoming competitive to wood poles. To remain competitive, wood products manufacturers should reduce the price of pole materials. Wood materials (poles and crossarms) have to comply with environmental and safety issues. The quality of wood poles and crossarms have to be kept high. The quality of the product is in direct relation to the durability of the product in the field. There is a continued need to make wood products more insect, fungus, fire and woodpecker resistant.

Case Study 2: Indiana

Indiana interview participants have designed, maintained or constructed primarily distribution and transmission lines, but some distribution engineers have worked with retaining walls to keep pole structures in place. Utility engineers/superintendents in Indiana have to follow National Electric Safety Code (NESC) for wood poles and crossarms. The state of Indiana does not have its own guidelines for wood products used in utility line construction. Indiana interview participants have used wood products in design, construction and/or maintenance of transmission and distribution lines (poles and crossarms), platform facilities and retaining walls. Within utilities, the highest current use of wood products is in poles and crossarms. Participants report the greatest potential or future use of wood products will be in wood poles. It will be a long time before wood is replaced in distribution lines, but there is a trend towards steel poles and aluminum poles in certain situations. Also, distribution lines are being put underground by some utilities for aesthetic reasons. In the next three years interview participants have plans to use wood products in pole and crossarm construction.

Indiana participants identified problems with the durability of wood used in utility construction. Weathering damages poles and crossarms, and infrequently problems are caused by woodpeckers. Wood poles and crossarms decay (biological decay from fungus, bacteria and insects) if not maintained. Although decay has occurred, participants see adequate service life from wood in utility line construction for the most part. Wood poles often have cracking, which leads to decay caused by fungus. Usually the decay is at the ground line. Plantation grown wood poles have wider growth rings because they are produced in conditions which allow them to grow quickly. These wider growth rings make the plantation grown wood poles less dense and less strong.

Indiana participants stated benefits with the durability of wood used in utility construction. In comparing durability with cost of alternative materials, they are getting the durability they want for the dollar invested in wood poles and crossarms. For instance, one participant states he can replace three wood crossarms for one of any other material. Wood is perceived to be *fatigue resistant* and new treatments are extending the life of wood poles in some instances.

Participants cited maintenance benefits in using wood in utility construction. Wood is said to have better installation properties and can protect a maintenance worker from electric shock. Utilities have the tools and distribution line hardware available to work with wood materials because wood is the industry standard for poles and crossarms. Wood is highly durable and less maintenance is needed with wood. Wood is perceived to be easy to work with in the field and can be easily modified (holes can be drilled without harming the strength of the wood pole or crossarm). Wood poles are more available than concrete and steel poles, which makes it easier to maintain utility lines constructed of wood. This is changing as steel poles are becoming more available and cost competitive. Wood poles do not have to be painted to prevent corrosion like steel poles.

Maintenance problems were identified by Indiana participants in using wood products in utility construction. It is difficult to repair a broken pole and that wood poles can not be splinted well when broken. Repairs of wood poles are difficult because the wood poles are under large stresses, especially when bad weather occurs. It is difficult and expensive to re-treat poles in service. Nails from signs put on wood poles can be a problem sometimes for climbers and maintenance crews. Wood poles are much heavier than hollow steel poles, which make it more difficult to set a wood pole than a steel pole. The steel poles may have saved labor costs in maintenance of utility lines because they were easier to set in place.

Indiana participants identified other problems with wood in utility construction. Life expectancy is short in some wood species and materials in these species are susceptible to weather wearing. Crossarms' life expectancies are short in some areas (20 years life) therefore, some utilities are switching to fiberglass crossarms. In wood crossarms, there is a splitting problem with pine. Douglas fir does not have the splitting problems seen with pine in crossarms. Cost for re-treatment of wood is high, and disposal of treated wood is becoming a problem as the EPA has started to regulate treated wood in landfills. Wood quality is a problem at times. Major concerns with wood poles are the depth of pole chemical treatment and warping of poles under loads. Concerns with laminated wood in utilities pertain to how well the wood is glued together, what type of glue is used and if the laminated wood can meet the NESC Standards. It is difficult to get data on wood poles and to get the correct standards for all wood pole species. There have been delivery problems with wood poles in bigger sizes, and a utility has to know its wood pole needs ahead of time to be sure of having adequate supply. Finally, the cost of wood poles is becoming high.

Participants identified benefits with using wood in utility construction. Wood is reported to have adequate strength and is elastic. For example, wood can withstand wind loads and return to its original shape. Wood is reliable and has a long life. Also, wood is more economical in certain structures such as poles and crossarms, but this is changing. Wood is more available than other materials, and one can get wood poles in the needed time frame or borrow the wood poles from other utilities. Also, wood is a renewable resource. No special tools are required to work with wood and wood poles are the industry standard. Special hardware is not needed to climb a wood pole such as steps on the pole or ladders required for steel poles.

Indiana participants cited several needs that should be addressed to increase the use of wood products in infrastructure construction. Wood has to be more cost competitive especially in the long run. Wood poles need lower installation and *life-cycle costs* than steel and concrete to remain competitive. Participants say wood pole/crossarm manufacturers should plan ahead as lead times and delivery times are very important to the utility industry. They reported that wood poles/crossarms producers have to meet demand on time. There are supply fluctuations with wood poles. The wood products have to remain available at the needed time for wood to remain competitive. The wood products industry must continue improving life expectancy of wood poles and crossarms. There is a need for better predictive maintenance of wood poles. Also, wood treatments need to become less toxic to the environment but still remain effective. Environmental problems occur with disposal of treated wood. Environmental impacts of preservatives need to be minimized. Problems affecting longer wood pole supply need to be documented and research conducted on growing/producing longer poles. There is a need for a single source of information on wood poles/materials and structural standards.

Case Study 3: Maine

Maine interview participants have designed, constructed or maintained utility distribution lines and transmission lines. Distribution line construction in Maine is primarily done with wood poles and crossarms. Maine does not have guidelines for the use of wood products in utilities, but utilities did follow NESC Standards. Participants have used wood products in the past three years in design, construction and/or maintenance of distribution poles and crossarms. They report the highest current use of wood products is in pole line construction, particularly distribution poles. Within utilities, participants say the greatest potential or future use of wood products is in wood poles, but this may change. Prices of steel poles are becoming more competitive for large transmission poles. Also, the lead time or delivery time for steel poles is dropping and becoming more competitive. Wood treatment may cause disposal problems which can cause a push for steel poles. If disposal of wood poles becomes a problem, then utilities may be forced to switch to alternative materials like steel and concrete. In the next three years participants have plans to use wood in poles and crossarms.

Maine participants identified problems with the durability of wood used in utility line construction. They are uncertain about the lifespan of newly treated (CCA) poles. Second cycle growth wood poles are considered weaker than first cycle growth wood poles because second cycle grown wood has been grown faster with bigger, less dense growth rings. Some participants said the grading system for wood poles and materials needs to be changed to accommodate the differences in second and first growth wood. Some minor problems with ground line decay occurs in northeastern Maine.

Maine participants identified benefits with the durability of wood used in utilities. They are observing adequate life (40 to 50 years) with wood products, especially of creosote treated wood poles. There are perceived problems with alternative materials not seen with wood: steel can rust and fiberglass can have problems with sun/heat and weathering.

Maine participants reported maintenance benefits in using wood products in utility construction. It was easy to modify a wood pole or crossarm; one could drill it or cut it with available tools. Steel poles required special tools to drill or cut them. Also, they said wood has adequate service life and requires little maintenance.

Participants cited maintenance problems in using wood products in utility construction. Wood is heavy and more difficult to transport/handle than steel or fiberglass. This is especially true for transmission lines or in distribution areas where it is difficult to bring in heavy equipment for transporting and setting heavy wood poles. High maintenance is associated with filling holes caused by woodpeckers. Participants stated CCA treated poles are brittle and difficult to climb with conventional climbing gear.

Maine participants reported other problems outside of maintenance and durability in using wood in utility construction. Wood poles are reported to splinter when they become old and dry out. Sometimes there are problems with trees impacting wood poles, but this can be remedied if the right-of-way is clear. Decay of wood poles is reported to occur in heavily bushed or densely covered tree areas. Wood is considered to be less uniform and less predictable than an engineered product like steel. The quality of wood is declining and participants are beginning to see more crooked wood poles. It is hard to get the size required for transmission structures (85 foot poles). Also, the lead time is becoming too great and too variable which causes some problems with construction and/or maintenance. Environmental problems associated with chemical wood treatments can become a problem, especially in disposal of used wood poles. There are no disposal costs with used treated wood, but there can be disposal problems if the EPA classified used chemically treated wood as a hazardous waste. Older creosote poles have leached chemicals at their base, which can cause both environmental problems and problems with the re-use of wood poles.

Maine participants stated benefits in using wood in utility construction. Wood is durable and has an adequate life with wood. Wood is easy to work with and crews have the equipment/knowledge needed to work with wood. Participants said wood has low electrical conductivity which can protect maintenance/construction workers. Maintenance workers can climb wood poles easily, however, with steel, concrete, or fiberglass poles they have to provide steps on the poles. This can cause a safety issue since the public has the ability to climb steel poles using these steps. Otherwise, the power company must have specialized ladders or bucket trucks to access the power lines on construction materials besides wood. Participants report they have easy access to materials. They state wood poles can be delivered in 1-2 days, but steel poles can be delivered in 6 weeks. Wood is relatively inexpensive compared to steel, and wood is a natural product that can take less energy than steel or concrete to manufacture into poles and crossarms. Finally, wood is considered more aesthetically pleasing and it is easier to tell people that one is going to put up a wood pole or structure than a steel pole or structure.

Participants cited several concerns that need to be addressed to increase the use of wood products in utility construction. Wood products manufacturers should keep researching wood preservatives. A better preservative that lengthens life and is more environmentally friendly should be developed. Disposal/storage of treated wood poles is becoming a problem. Utilities need to be able to dispose of treated wood products or store treated wood products safely for both the employees and the environment. Wood material availability should be kept high and the pole/crossarm prices kept low. Wood pole quality needs to be increased. There is a need for stiffer grading systems to improve the quality of straight poles.

Case Study 4: Montana

Montana participants have designed, constructed or maintained utility distribution lines and transmission lines. Montana does not have guidelines for the use of wood products in utilities, but utilities do follow REA codes and NESC. Participants have used wood products in the past three years in design, construction and/or maintenance of distribution poles and crossarms. The highest current use of wood products is in pole line construction, particularly distribution poles. Within utilities, participants say the greatest potential or future use of wood products is in wood poles. Poles and crossarms will continue to be used in distribution lines and some transmission lines in the next three years because of proven durability. This could change if prices of wood poles increase and more underground lines are used.

Montana participants reported problems with the durability of wood used in utility construction. This depends on the applications of wood. Some wood poles decay too fast because of the conditions in which they are used. Ground line decay caused by fungus a durability problem in some areas. Fire damage to wood poles occurs when people are burning debris close to wood poles.

Montana participants identified benefits with the durability of wood used in utility construction. Western Montana has a very dry climate which allows wood poles to perform very well. Certain species of wood poles, like cedar, are reported to last much longer than other wood species. Utilities generally are seeing adequate life from wood poles and crossarms. Many utilities will not switch to concrete or steel poles because there is no proven service life for these materials. Participants stated that steel poles will corrode in the alkali soils found in much of Montana, but wood poles will not be affected.

Montana participants cited maintenance benefits in using wood in utility construction. Wood poles are easy to climb relative to concrete and steel poles, making maintenance easier with the equipment available to utilities. Wood is perceived to be lighter than concrete poles, which make handling and replacement easier. Participants indicated that wood is less conductive than steel, which makes it safer for utility maintenance workers. There is an adequate supply of wood poles in Montana with a two to three week order time, which decreases maintenance costs relative to other materials. It is easier to retrofit/modify wood poles in times of damage relative to other materials. Wood poles can be cut and drilled with the currently available equipment.

Montana participants stated maintenance problems in using wood products in utility construction. Some wood poles decay too fast, which result in higher maintenance then will be seen with other materials. Wood poles have to be regularly inspected for decay, while it is perceived that steel poles may not have these decay problems. Wood poles frequently are struck by lightening especially in the plains areas of western Montana. This requires that the whole wood pole to be replaced.

Montana participants cited benefits in using wood in utility. Wood poles do not have as much of a conductivity problem as concrete or steel poles which protect both line workers and wildlife. Wood is lower in cost relative to concrete and steel. No foundation is required for wood poles, less equipment is needed to handle wood in back country areas, and less knowledge is required to work with wood. This all serves to lower the cost of wood relative to other materials. Wood poles are easier to climb relative to steel poles. Steel poles require steps, special equipment ladders or bucket trucks to reach the power lines. Finally, they report that vehicle impact with wood poles is better than steel or concrete poles because the wood breaks away. Wood poles therefore lower utilities liability.

Montana participants identified several needs that should be addressed to increase the use of wood products in infrastructure construction. Better chemical wood preservatives are needed to keep wood from rotting and still protect the environment. Also, fire retardents are needed for wood poles. There is a need for increased availability of wood poles. Prices of wood poles needs to be kept low for wood to remain competitive in utilities. Quality control is very important to utilities. For wood to remain competitive, the quality control must be high and the specifications of the wood poles by the utilities must be met.

Conclusion

Utility officials perceive wood to have above average overall performance in structures. They perceive wood to be the same in overall material performance as reinforced, aluminum and plastic, but lower in overall performance than steel. This indicates that they perceive wood to be a safe and efficient structural material with satisfactory service life in utility structures.

Utility officials have the highest importance ratings for *durability, cost* and *maintenance* in making a material choice decision in structures. These factors are important to officials due to their influence on a material safety and effectiveness in performance as structural material in utilities. *Environmental impact* of a material is above average in importance because utility officials are responsible for their structural materials' effects on the environment. Materials that decrease costs of structure design are desirable to utility officials, and therefore they have above average importance for ease of design. *Environmental impact* and *ease of design* do not directly affect the operation of utility structures and are not as important as *durability, maintenance* and *cost* in a material choice decision in utility structures. Utility officials do not want to risk failure of a structure constructed with a new material that is not proven, and therefore, *innovativeness of material* is the least important factor in a material choice decision.

Benefits of wood in utility structures could be employed by manufacturers to compete more effectively in the utility market. Wood products are perceived to have the lowest *initial cost* of materials. Also, officials perceived wood to be among materials with the lowest maintenance costs and life-cycle costs. In durability attributes, wood is perceived to have high *corrosion* *resistance, fatigue resistance* and *weathering resistance* of materials. Utility officials perceive *design standards to be available* for utility structures and wood products are perceived to be among the most *available* materials. Officials perceive wood to be the *easiest material in utility construction* and *construction equipment is perceived to be available* for construction with wood in utility structures. Utility officials 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 the most *disposable/biodegradable* materials, but this attribute may not be desirable if one wants the utility line material to meet the needed service life. In maintenance attributes, utility officials perceive there to be the most *standard structure designs available* for wood and maintenance personnel to have the most *experience in maintenance with wood*. Wood is perceived to be among the easiest materials in *field modification, repair* and *inspection.* All these factors should be considered by wood products manufacturers competing in the utility 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 more effectively in the utility market.

Wood products could be improved in several areas to better compete effectively in the utility market. In durability attributes, utility officials perceive wood to be among the least *mechanical wear/abrasion resistant*, *fire resistant* and *biological decay resistant* materials. Wood is perceived to be among the least *chemically safe* of materials used in utility structures, but it was still above average in possessing this attribute. Wood is perceived to be below average in *recyclability/reusability* and *percent recycled content of material.* Utility officials perceived wood to be average or below average in *innovativeness in performance, maintenance, durability, design* and *in the environment.* Officials perceived wood to be among the least innovative for all these innovation attributes. These were the areas manufacturers should improve upon in wood products, their prices and their promotions.

Wood products manufacturers have several strategic options to compete more effectively in the utility market. Wood products have to stay cost competitive. The price of steel poles is becoming competitive to wood poles and to remain competitive, wood products manufacturers may want to reduce the price of pole materials. There are supply fluctuations with wood poles. Wood pole/crossarm manufacturers should plan ahead as lead times and delivery times are very important to the utility industry. The quality of wood poles and crossarms may need to be improved. There may need to be stiffer grading systems in place for wood utility poles to improve the quality of straight poles. The wood products industry may need to improve the durability of wood utility materials. Chemical wood preservative treatments need to become less toxic to the environment but still remain effective. There is a continued need to make wood products more insect, fungus, fire and woodpecker resistant.

Literature Cited:

Ng, Harry. 1994. Wood Technology Research Program of the Electric Power Research Institute. *Proceedings of the First Southeastern Pole Conference.* Forest Products Society, Madison, WI. number 7314, pages 13-18.