# Chapter 3

# Determining Decision Makers' Perceptions of Materials in United States Infrastructure Markets

## Introduction to the United States Infrastructure

The infrastructure of the United States represents an opportunity for the forest products industry. This market includes the highway, railroad, marine and inland waterway, and the electric systems. Transportation officials spend 60 billion dollars per year for highway construction (US department of Transportation, Federal Highway Administration 1993), 7 billion dollars per year for railroad track maintenance/crosstie replacement (Reynold 1994), 500 million dollars per year for marine structures replacement (National Strategic Planning Study 1991) and 500 million dollars per year for utility pole installation/replacement (Ng 1994). This large market has many opportunities for the wood products industry in construction of highway guardrails, highway signs, highway sound barriers, road salt storage buildings, railroad structures/crossties, bulkheads, wharves, docks, piers, utility poles and crossarms. Transportation structures are built of wood products, but the 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 in the US infrastructure market, wood products manufacturers need information about decision-makers in charge of design, construction and maintenance of transportation structures.

The United States infrastructure market and its decision-makers were assessed using a mail questionnaire sent to 2344 infrastructure officials in four distinct groups. These groups included highway officials (912), marine/inland waterway officials (411), railroad officials (467) and utility officials (554). The methodology as outlined in chapter 2 was followed in this study.

## Study Objectives

This study identified how materials for use in infrastructure 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. To reach this goal, several hypotheses were tested. First, it was hypothesized that many decision-makers in infrastructure markets were not educated in using wood in design and construction. This lack of education could cause the decision-makers to have poor perceptions of wood products in infrastructure design and construction. Second, it was hypothesized that infrastructure decision-makers without standards for wood products designs in infrastructure would have a lower perception of wood in infrastructure than those with standards for wood. Third, it was hypothesized that decision-makers in the infrastructure markets with greater work experience would have a different perception of wood in infrastructure than decision-makers with less work experience. Finally, it was hypothesized that infrastructure decision-makers in different infrastructure markets (highway, marine/inland waterway, railroad and utility officials) would have different perceptions of wood as a infrastructure material. Specific objectives used to meet the overall purpose and test the hypotheses 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 respondents met two objectives: first, which factors were important in the material choice decision; second, what were 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* may be a factor used by a infrastructure decision-maker when deciding on materials for structural application. The factor, *corrosion resistance*, also can 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 decision-maker, that person would mark a 7 on the importance rating scale.

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 a material did not possess the attribute at all and a 7 rating indicated the material possessed the attribute to a high degree. For example, if the decision-maker thought plastic highly possessed the attribute, *corrosion resistance*, then that person may give a 7 rating for plastic possessing that attribute.

Weighted mean ratings for material attributes were used to attach importance to each materials attribute ratings. If a factor is not important to an individual, then the perceived attribute rating corresponding to that factor should not be important. Weighted mean perceived attribute ratings provide an individual's material attribute rating and the importance of that attribute to the individual's group at the same time. Weighted mean perceived attribute ratings were determined by multiplying a mean factor importance rating for a infrastructure group with each respondents perceived attribute rating corresponding to that factor and then calculating the mean of these individual weighted ratings. The scale possibilities could then range from 1, which indicated a material did not possess the attribute at all, to 49, which indicated a material possessed the attribute to a high degree. For example, an infrastructure group's mean factor importance rating for *corrosion resistance* was 6.55, meaning this was a very important factor to the group. One individual in that group gave plastic a 7 rating for possessing the attribute *corrosion resistance*, indicating the person thought plastic possessed that attribute very highly. The mean factor rating for *corrosion resistance* (6.55) and individual's perceived attribute rating for plastic possessing *corrosion resistance* (7.00) were multiplied together for a weighted mean perceived *corrosion resistance* rating for plastic of 45.85. This single weighted mean perceived attribute rating demonstrates that plastic highly possessed the attribute corrosion resistance and that the attribute was important to the infrastructure group.

Multivariate Analysis of Variance (MANOVA) was used to simultaneously explore the relationship between several categorical independent variables (the four infrastructure groups) and two or more metric dependent variables (four infrastructure groups' factor and perceived material attribute ratings). Once relationships had been determined using MANOVA, Analysis of Variance (ANOVA) was used to define relationships within each infrastructure group and among each infrastructure group. Tukey's honestly significant difference (HSD) test was used to determine where differences were located between infrastructure groups and within infrastructure groups. 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 and one to forty-nine for weighted mean scores. When any mean ratings or ranges were found not within these known ranges, the individual survey(s) in question was located and corrections were made.

This study tested perceptions of attributes and importance of factors to decision-makers across four different infrastructure markets. Covering every factor and related attribute important to decision-makers in each infrastructure market required two separate surveys to be utilized. The two surveys were randomly distributed within the sample: one-half the sample received survey one and one-half received survey two. Because the same types of respondent should have received the two surveys, the hypothesis was that no difference would be present among the two samples' answers for the same questions that were on both surveys. If the hypothesis was correct and there were no differences among the two sample groups' answers for the same questions, then it could be assumed that they would answer similarly on the different questions. Table 21 shows the results of the multivariate Hotellings tests among the factor and material perception ratings between the two surveys. Significant differences were indicated to be present among the two survey groups' mean ratings for materials possessing the attribute *ease of repair*. No other significant differences were indicated to be present among the two survey groups' mean factor importance and material attribute ratings. The hypothesis could be rejected for only one out of twenty-four tests, and it could be assumed that the two survey groups were similar. Therefore, it is assumed that the two groups would answer similarly on all questions for this study.

Non-response bias was tested using multivariate tests among respondents and non-respondents answers to the following questions: overall material performance ratings for prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic; overall factor importance ratings for *cost*, *durability*, *maintenance*, *design*, *environmental impact* and *innovativeness of material*. The hypothesis was that respondents and non-respondents would have significantly different mean overall material performance ratings or mean overall factor importance ratings. No significant differences were found among the two groups' mean overall material performance ratings or mean overall factor importance ratings (Table 22). The hypothesis was rejected and it could be said that respondents and non-respondents were similar in their perceptions of overall factor importance and overall material performance. Therefore, it could be assumed that the respondents and non-respondents were similar in their perceptions of materials and factor used in material choice decisions.

To further test for non-response bias, relationships between early and late respondents were examined. The early respondents were assumed to be similar to the respondents, and the late respondents were assumed to be similar to the non-respondents. The hypothesis was that significant differences would be present among the two groups' perceptions of material attributes and importance of factors used in material choice decisions. The early and late respondents were tested for differences among their mean ratings for the following questions: overall material performance ratings for prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic; overall factor importance ratings for *cost*, *durability*, *maintenance*, *ease of design*, *environmental impact* and *innovativeness of material*. No significant differences were found among the two groups mean perceptions of overall material performance or mean overall factor importance ratings (Table 22). The hypothesis was rejected and it could be assumed that there was no difference in early versus late respondents. The early and late respondents were assumed to be similar to the respondents and non-respondents. Therefore, it could be assumed that no differences were present among respondents and non-respondents. Both of these tests indicate that respondents to the questionnaire represent the population being studied.

This study utilized 1 to 7 scale questions to determine factor importance in material choice decisions and perceptions of materials. The equation given by Ballenger and McCune (1990) found in chapter 2 of this study was used to determine precision levels for the means of these factors and perceptional ratings. Using this equation, it was determined that 96 respondents were needed to achieve the desired precision level of +-0.20. The most important overall factors to the infrastructure respondents combined were *durability*, *cost*, and *maintenance*. The precision levels for mean importance ratings for *durability*, *cost* and *maintenance* were each +-0.06. The most important factors to the respondents within each of these overall factor groups were *weathering resistance*, *low life-cycle cost*, and *ease of repair*. The precision-level for *weathering resistance* was +-0.09, *low life-cycle cost* was +-0.06 and *ease of repair* was +-0.06. The mean perceived overall performance rating for wood by infrastructure respondents had a precision-level of +-0.07. The precision level for wood possessing *weathering resistance* was +-0.10, *low life-cycle cost* was +-0.07, and *ease of repair* was +-0.07. This demonstrates that the desired precision-level was achieved for the most important mean factor ratings and mean perceived wood attribute ratings.

**Demographics and Material Use:**

Data analysis began with summary statistics from infrastructure officials demographic data. Responses were separated into four groups: highway group (536 respondents); marine/inland waterway group (99 respondents); railroad group (166 respondents); utility group (152 respondents). The adjusted response rates for each infrastructure groups were: highway group 58.8%; marine/inland waterway group 24.3%; railroad group 35.8%; utility group 28.2%; combined group's response rates 40.9%. The infrastructure respondents chosen for this study were the leaders in infrastructure markets and set policy for material use in transportation structures.

Officials were asked if they worked in design, construction, maintenance or other types of work. The majority of the highway group (48.3%) and marine/inland waterway group (60.6%) worked in design. The railroad group worked primarily in maintenance (72.9%). The utility group was more evenly spread across all types of work than other groups, but predominantly worked in design (35.5%) and construction (25.7%). The combined groups worked primarily in design (40.5%) and maintenance (27.3%) (Table 23). The highest percentage of officials had a BS degree (56.6%)or MS degree (22.2%) (Table 24). Less than one-half of the combined officials (42.3%) had formal course-work on wood design. Railroad officials had the lowest percentage of formal course-work discussing wood design (35.8%), while marine/inland waterway officials had the highest percentage (53.1%) saying they had course-work in wood design. Of those who did have formal course-work on wood design, the percentage of infrastructure officials that said the course(s) were mandatory was 32.9%. Railroad officials had the lowest percentage officials claiming they had mandatory course-work discussing wood design (30.2%), while the highest percentage was in the marine/inland waterway officials group (Table 25). Officials in the age groups 40 to 49 years (36.0%) and 50 to 59 years (36.3%) represented the largest age categories (Table 26). The 25 or more years of work experience group contained the highest percentage of officials in all groups (41.8%) (Table 27). More than one-half (58.2%) of officials said they had guidelines for the use of wood products in infrastructure design, construction or maintenance. The highway group (66.9%) had the largest percentage of officials stating that they have guidelines for wood use, while the railroad group had the lowest percentage (42.2%) (Table 28).

Officials in highway groups worked primarily on highway guardrails (77.2%), signs/sign posts (53.9%), pedestrian bridges (45.7%) and noise barriers (38.6%). Many highway officials said they worked with formwork and falsework (34.5%), which was expected because of the large amount of concrete construction in the US highway system. The marine/inland waterway group worked primarily with bulkheads (80.0%), marine pilings (75.0%), piers (72.0%), wharves (59.0%) and boat docks (58.0%). The railroad group worked primarily with crossties (91.0%), railroad bridges (79.0%) and signs/sign posts (44.9%). These three groups each had crossover between structures they had worked on in their current area and structures they had worked with in other infrastructure areas. Highway group officials had not only worked with highway structures, but also had worked with marine structures (21.5%, piers) and railroad bridges (22.4%). Marine/inland waterway officials had worked with water related structures, but had worked with highway structures (22.0% highway guardrails) and railroad structures (15.0%, railroad bridges). Railroad group officials had worked with marine structures (12.6%, piers). Cross-over among officials in the different infrastructure areas may be useful in wood products manufacturers' promotional or educational campaigns (Table 29).

Materials most used by officials in construction were steel (80.7%), wood (79.1%) and reinforced concrete (74.5%). These three materials were followed closely by prestressed concrete which was used by 60.0% of officials. Railroad (97.6%) and utility group officials (96.2%) had the highest use of wood in construction. Highway officials had the lowest use of wood in construction (69.2%) (Table 30).

Officials were asked if they had used wood in the last three years in design, construction or maintenance of highway structures. Many officials (78.3%) said they had used wood in infrastructure construction in the past three years. The lowest percentage use of wood was the highway group (69.0%). The highest percentage use of wood was the railroad group (98.2%) (Table 31).

Officials were asked if they had used engineered wood products for highway construction in the past three years and if so, what type of engineered wood products they had used. Less than one-half of the officials (48.3%) had used engineered wood products in infrastructure applications (Table 31). The highest percentage use of engineered wood products in the past three years was the utility group (52.0%). The lowest percentage use of engineered wood products was the railroad group (44.1%) (Table 31). Glue-laminated timber (29.9% of officials) and plywood panels (18.2% of officials) had the highest percentage use in infrastructure in the past three years. Highway group officials had the highest percentage use of glue-laminated timber (33.8%) while marine inland waterway officials had the highest percentage use of plywood panels (25.0%). Railroad group officials had the lowest percentage use of glue-laminated timber (15.6%) and utility group officials had the lowest percentage use of plywood (9.6%) (Table 32).

Officials were asked if they had plans to use wood products in structure design, construction or maintenance in the next three years. More than two-thirds of officials (67.9%) were not planning to use wood in infrastructure construction in the next three years. Railway group officials had the highest percentage responding that they had plans to use wood in infrastructure (96.3%). Highway officials had the lowest percentage for having plans for using wood in infrastructure (57.4%) (Table 31).

**Testing of Hypotheses:**

Differences in the infrastructure decision-makers' education levels could cause differences in perceptions of wood in infrastructure construction. It was first hypothesized that officials with more education would have had a different perception of wood products in infrastructure construction than officials with lower education. Officials were tested for differences in their mean perceptions of wood's overall material performance according to their education level. They were grouped according to their college degree: group one had bachelor of arts (BA) degrees, group two had master of arts (MA) degrees, group three had bachelor of science (BS) degrees and group four had master of science (MS) degrees. There were not enough highway officials who had doctorate degrees or high school diplomas as their highest education level to include them in the test. Wood products had mean overall material performance ratings above average for each education level.

Officials with MA degrees had the highest mean perceived overall performance rating for wood (4.90) while officials with MS degrees had the lowest mean perceived overall material performance ratings for wood (4.07). No differences were found among repondents' education levels and we rejected the hypothesis. The results indicate that differing education levels did not cause the officials to have different in perceptions of overall performance of wood.

Effects of officials' education on their perceptions of wood in infrastructure applications was further defined by examining relationships among those officials who had and did not have coursework in design with wood products. The second hypothesis was that those officials without education in design with wood products would have a lower perception of wood than officials with coursework in design with wood products. Table 34 illustrates the mean perceived overall material performance rating for wood between the two groups. No significant differences were found between those officials who did and did not have coursework in wood design and the hypothesis was rejected. The results indicate that respondent's education in design with wood did not affect their perception of wood's overall performance in highway structures. These two findings about education of highway officials showed that education level and education in wood design had little effect on decision-maker's perceptions of wood in infrastructure construction.

Guidelines for materials were used to set minimum requirements for use of materials in infrastructure applications and to lower the risk of failure in those structures. Therefore, having guidelines for wood in infrastructure applications could affect a decision-maker's perception of wood those structures. The third hypothesis was that infrastructure decision-makers without standards, or guidelines, for wood products designs in structural applications would have a lower perception of wood in those structures than decision-makers with standards. Officials with guidelines for wood in highway structures gave wood a perceived overall material performance rating just above average (4.31), while those without guidelines had similar mean ratings (4.36). These ratings were not significantly different and the hypothesis that infrastructure decision-makers without guidelines for wood products would have a lower perception of wood in structural applications than those with guidelines was rejected (Table 35). These results indicate that infrastructure decision-makers' perceptions of wood products used in highway structures may not change if guidelines for the use of those wood products were or were not present.

The age of an infrastructure decision-maker could affect that person's perceptions of different materials used in structural applications. The fourth hypothesis was that perceptions of wood products would be different among the infrastructure decision-makers of different ages. No significant differences among the age groups of officials were found and the hypothesis that there would be differences among the different age groups of officials was rejected (Table 36). One possible reason for this could be that older officials trained younger officials within an organization. This caused the younger officials to have similar perceptions of wood in highway structures as older officials.

Work experience may have had an effect on infrastructure decision maker's perceptions of structural materials. A decision-maker with greater work experience may have worked with more material types or seen more materials in use. This person may have higher or lower perceptions of wood because that person has had experience with more materials. The fifth hypothesis was that infrastructure decision-makers with greater work experience will have different perceptions of wood than decision makers with less work experience. The mean perceived overall material performance ratings for wood were determined for five experience groups and can be seen in Table 37. All mean ratings were very close to average (close to 4), and no significant differences were found between any infrastructure respondent experience group. The hypothesis that infrastructure decision-makers in different age groups would have different perceptions of wood in infrastructure was rejected. The results indicate that just because a decision-maker has been working longer, this person's perceptions of wood's overall performance in infrastructure was no different from a person who had not worked as long. One possible reason for this finding was those who have more work experience usually were the leaders in an industrial organization. These leaders may have decided which materials would be used in infrastructure and they may have trained those decision-makers with less work experience. This supports results of a timber bridge study by Smith and Bush (1995) that indicated that peers are the number one way engineers hear of new information. Therefore, those more experienced decision-makers may have influenced the less experienced decision-makers, causing the two groups not to be significantly different on their perceptions of wood in infrastructure.

The sixth hypothesis was that different markets would have different perceptions of wood as a construction material. The United States infrastructure market was separated into four distinct markets: the highway market, the marine/inland waterway market, the railroad market and the utility market. The next sections of this study discussed factors important in material choice decisions for structural applications and perceptions of wood these applications by different levels of decision-makers (highway officials, marine/inland waterway officials, railroad officials and utility officials). These results were used to test the hypothesis that different infrastructure markets would have different perceptions of wood as a construction material.

**Perceptional Ratings of Overall Factor Importance:**

The overall factors rated for importance in decisions regarding infrastructure construction materials were: *cost, durability, maintenance, ease of design, environmental impact* and *innovativeness of material*. Significant differences were present among the groups on the factor *ease of design*. Utility officials' had the highest mean overall factor importance ratings for *ease of design* (4.68) which was significantly higher than highway officials (4.21) and waterway officials (3.80) ratings. Also, railroad officials (4.44) and highway officials had significantly higher ratings for *ease of design* than waterway officials (Table 38).

Significant differences were found within the combined infrastructure groups mean overall factor importance ratings. *Durability* was the most important overall material decision factor to the combined officials with a mean importance rating of 6.28. The mean importance rating for *durability* was significantly higher than all other overall factors. *Maintenance* (5.99) and *cost* (5.90) had the next highest mean factor importance ratings by the combined groups, which were significantly higher than *environmental impact* (4.81), *ease of design* (4.28) and *innovativeness of material* (3.41). The combined groups had a mean importance rating for *environmental impact* that was significantly higher than *ease of design* and *innovativeness of material*. Combined groups had a mean importance rating for *innovativeness of material* that was significantly lower than all other overall factor ratings (Table 38).

In order to compete more effectively in the infrastructure market, decision-makers will want to know what factors in a material choice decision are most important to infrastructure officials. Structures were subjected to many damaging agents such as corrosive chemicals, weather and decay organisms. Materials must be able survive these damaging agents for a structure to remain intact, and therefore *Durability* was the most important overall factor in a material choice decision. *Maintenance* was a highly important factor because it reduced decision-makers' risk of a structure failing and influenced the structure cost. *Cost* was important because many decision-makers were on limited budgets and materials are frequently expensive. *Environmental impact*, *ease of design* and *innovativeness of materials* were less important because they did not affect material failure in infrastructures. This indicates that manufacturers should focus on improvements in durability, maintenance and cost of wood products to compete better in the infrastructure market. Although manufacturers should devote less effort to improving wood's *environmental impact*, *ease of design*, and *innovativeness of material*, these factors were still above average in importance and should not be ignored.

**Discussion of Overall Factor Importance:**

Wood products manufacturers may wish to focus their marketing efforts on one specific area within the infrastructure market. If so, the manufacturer will need information about each infrastructure groups' importance for overall material choice factors. As stated in the Indiana interviews, utilities may not have a source of information on distribution/transmission line structure materials except the National Electric Safety Code (NESC). Therefore, utility officials want to use materials that will not complicate a utility line design so it will meet the NESC, and officials had higher importance for *ease of design* than highway or marine/inland waterway officials. This indicates as well as durability, maintenance and cost, wood products manufacturers should consider the ease of design with wood or engineered wood products when they are competing in the utility market. In highway and marine/inland waterway markets, *ease of design* is less important and may not need to be considered. No other differences were found among infrastructure groups' overall factor importance ratings that should be considered by wood products manufacturers.

**Perceptional Ratings of Overall Material Performance:**

The materials rated for perceived overall material performance by the officials were prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic. The combined officials group had significant differences among their mean perceived overall material performance ratings. Their ratings for reinforced concrete (5.42), steel (5.34) and aluminum (4.53) were significantly higher than wood (4.35) and plastic (3.64). Their mean rating for wood was significantly higher than plastic. Wood had the second lowest mean perceived overall material performance ratings for the combined officials group (Table 39). Significant differences were present among the four respondent groups' mean perceived overall material performance ratings for wood. Railroad (5.01) and utility officials (4.92) had significantly higher mean perceived overall performance ratings for wood than did highway (4.02) and waterway officials (3.84) (Table

39). Based on the differences in infrastructure groups' mean perceived overall performance ratings for wood, we failed to reject the hypothesis that different infrastructure markets would have different perceptions of wood as a construction material. Railroad and utility officials perceive wood differently than highway and marine/inland waterway officials for overall performance.

Overall performance meant that a material carried out an action or fulfilled a task. Infrastructure officials required materials to perform as a structural material by being durable, requiring low maintenance and having low costs. Wood products manufacturers need to know how wood performed overall in order to know if they need to change or improve wood to compete better in the infrastructure market. Wood was second lowest in perceived overall performance, which indicates that there is a problem with its durability, maintenance requirements and/or cost. Wood products manufacturers may wish to improve wood in one or more of these factors to improve decision-makers perceptions of wood and better compete in the infrastructure market.

Wood products manufacturers need to know the differences among infrastructure groups' perceptions of overall performance of wood to better compete in individual markets. Railroad and utility officials perceived wood to have good overall performance because it was resilience, had long service life, low cost and completed the required tasks in these two markets. Highway and marine/inland waterway officials had low perceptions of wood's performance because in these two markets, it was not as durable, required more maintenance and was often as costly as other materials. Therefore, wood products manufacturers may want to concentrate their marketing efforts on improving highway and marine/inland waterway officials' perceived overall performance of wood.

**Comparisons of Overall Factor Importance in Different United States Regions':**

Different regions of the United States have different cultures, climates and geography that may cause infrastructure decision-makers to use different factors in material choice. In order to best compete in infrastructure markets in different regions of the US, wood products manufacturers need to know what factors are most important to which region. The US was separated into five regions for comparison of overall factors importance of the factors in the material choice decision. The US regions and states contained in those regions are listed in Table 40. The overall factors rated for importance in decisions on infrastructure construction materials were: *cost, durability, maintenance, ease of design, environmental impact* and *innovativeness of material*. No significant differences were found among the five US regions' mean importance ratings for any overall material choice decision factor. The combined US regions had the highest mean importance rating for *durability* (6.28) which was significantly higher than *maintenance* (5.99), *cost* (5.90), *environmental impact* (4.81), *ease of design* (4.28), and *innovativeness of material* (3.41) (Table 40). This indicates wood products manufacturers marketing efforts may not need to change depending on their region of operation in the US. They should focus their marketing efforts on durability, maintenance and cost of wood to best compete in infrastructure in all regions of the US.

**Comparisons of Overall Material Performance in Different United States Regions:**

Materials may perform differently in different regions because of the different environmental influences. To best compete in infrastructure markets, manufacturers need to know if differences were present among perceived overall performance of wood by separate region's infrastructure decision-makers. The materials rated for perceived overall material performance by officials separated into five US regions were prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic. The combined US regions' mean ratings for prestressed concrete (5.61), reinforced concrete (5.42) and steel (5.34) were significantly higher than aluminum (4.53), wood (4.35) and plastic (3.64). No significant differences were found among the five US regions mean perceived overall performance ratings for any materials tested (Table 40). These results indicate that no differences are present among infrastructure officials perceptions of overall performance of wood, even when they are in different US regions. Therefore, manufacturers in all regions of the US need to focus on improving the performance of wood in infrastructure to compete better in these markets.

**Perceptional Ratings of Cost Factors:**

Respondents 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 officials mean importance ratings for *low maintenance cost*. Railroad officials had significantly higher mean importance ratings for *low maintenance cost* (5.84) than did highway officials (5.54) and utility officials (5.53). No significant differences were found among the officials' mean importance ratings for *low initial cost* or *low life-cycle cost*. The combined officials had significantly higher mean importance ratings for *low life-cycle cost* (5.71) and *low maintenance cost* (5.59) than their mean rating for *low initial cost* (5.09) (Table 41).

**Discussion of Cost Factors:**

Wood products manufacturers need to know what cost factors are used by infrastructure decision-makers when they make a material choice decision. This information will allow manufacturers to focus their marketing efforts to reduce decision-makers costs and keep them purchasing wood products. Combined officials perceived all cost factors to be above average in importance and therefore *low life-cycle cost* was the most important cost factor. This is because *life-cycle cost* includes *initial, maintenance and disposal costs*. Therefore, wood products manufacturers should consider each costs factor when developing marketing strategies. Railroad officials had higher importance for *low maintenance cost* than did highway and utility officials due to the fact that railroad officials invested more resources in maintenance than did the highway or utility groups. Wood products manufacturers should place the most emphasis on reducing maintenance costs when competing in the railroad market than when competing in highway and utility markets.

**Perceptional Ratings of Cost Attributes:**

Officials were asked to rate the following materials for possession of cost attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean cost attribute ratings for wood. Significant differences were found among the infrastructure groups' mean perceived ratings for each cost attribute ratings for materials. Based on infrastructure groups' perceptions of wood's *initial, maintenance and life-cycle costs,* we failed to reject the hypothesis that different infrastructure markets have different perceptions of wood as a construction material. This research indicates that the groups have different perceptions of the cost of wood.

Railroad (5.41) and utility (5.39) officials had significantly higher mean perceived *low initial cost* ratings for wood than marine/inland waterway (4.63) and highway officials (4.49). The combined officials had the highest mean perceived *low initial cost* rating for wood (4.83), which was significantly higher than all other materials tested. Their mean perceived *low initial cost* ratings for steel (4.59), reinforced concrete (4.55) and prestressed concrete (4.49) were significantly higher than aluminum (3.95) and plastic (3.76) (Table 42).

Significant differences were found among the four infrastructure groups' mean perceived *low maintenance cost* ratings for materials. Railroad officials had significantly higher mean perceived *low maintenance cost* ratings for wood (5.05) than did utility officials (4.56), highway officials (3.97) and marine/inland waterway officials (3.92). Combined officials had the highest mean *low maintenance cost* ratings for prestressed concrete (5.49) and reinforced concrete (5.43), which were significantly higher than aluminum (4.85), steel (4.80), wood (4.27) and plastic (4.22). Their mean perceived *low maintenance cost* ratings for aluminum and steel were significantly higher than wood and plastic (Table 42).

Significant differences were found among the four infrastructure groups' mean perceived *low life-cycle cost* ratings for materials. Railroad (5.15) and utility officials (4.84) had significantly higher mean perceived *low life-cycle cost* ratings for wood than did marine/inland waterway (4.03) and highway officials (3.98). Combined officials had highest mean perceived *low life-cycle cost* ratings for prestressed concrete(5.42) and reinforced concrete (5.39), which were significantly higher than steel (5.02), aluminum (4.78), wood (4.35) and plastic (4.10). Their mean rating for steel was significantly higher than aluminum, wood and plastic. Their mean rating for aluminum was significantly higher than wood and plastic. The combined officials mean perceived *low life-cycle cost* ratings for wood was significantly higher than plastic (Table 42).

The combined officials weighted mean perceived cost ratings for wood differed significantly for each cost attribute. Railroad (27.97) and electricity officials (27.19) had significantly higher weighted mean perceived *low initial cost* ratings for wood than did marine/inland waterway (23.38) and highway officials (22.87). Also, railroad (29.53) and electricity officials (28.39) had significantly higher weighted mean perceived *low life-cycle cost* ratings for wood than did marine/inland waterway (23.12) and highway officials (22.52). Railroad officials had significantly higher weighted mean perceived *low maintenance cost* ratings for wood (29.47) than did utility officials (25.24), highway officials (22.00) and marine/inland waterway officials (21.72). The combined officials had the highest weighted mean perceived *low initial cost* rating for wood (24.60), which was significantly higher than all other materials tested. Their weighted mean perceived *low maintenance cost* rating for wood (23.89) was not significantly different from the other lowest weighted mean rated material, plastic (23.56). The combined officials had weighted mean perceived *low life-cycle cost* ratings for wood (24.87) that were significantly higher than plastic (23.37), but significantly lower than all other materials tested (Table 43).

**Discussion of Cost Attributes:**

Wood products manufacturers need information about decision-makers perceptions of wood costs to determine if they need to change wood prices, increase maintenance education about wood, and develop/promote less expensive disposal methods for used wood products. This will allow the manufacturer to improve market position of the wood products compared to other materials in infrastructure. Combined officials perceived wood to have the lowest initial cost of all materials tested. This may be because smaller, less specialized size wood products (crossties, lumber or panels) are considered less expensive. Contradicting this, interview participants said larger, often more specialized wood products (poles, pilings and timbers) were as expensive as alternate materials. Combined highway groups perceived wood to have the high maintenance cost. Interview participants in each infrastructure area said that wood required high maintenance and had high disposal cost (except crossties). Therefore, wood was perceived to have high life-cycle costs.

Wood products manufacturers have several cost options to increase their competitive advantage. They may want to lower the initial price of large wood products (poles, piles, large timbers, decks) and keep the price of smaller wood products low (crossties and boards). They may wish to lower wood maintenance costs by increasing wood durability, educating structural designers on low maintenance designs for wood, and educate/promote best maintenance practices for wood structures. Manufacturers should develop ways to lower disposal costs of treated wood products such as a recycling program or an engineered composite that reuses old treated wood.

Manufacturers should be informed of differences among infrastructure markets cost perceptions for wood to know if they should have different pricing and information strategies. Railroad and utility officials perceived wood to have lower initial, maintenance and life-cycle costs than did marine/inland waterway officials. Wood had the lowest initial costs for wood crossties and wood poles, while it was perceived expensive in the size of wood products (large pilings and timbers, for instance) needed for highway and marine/inland waterway construction. This indicates that wood products manufacturers may wish to lower the initial costs of large wood timber used in highway and marine/inland waterways. Railroad officials perceived wood to have lower maintenance and life-cycle cost costs than did the other infrastructure groups due to wood having the least maintenance requirements of crosstie materials. Utilities perceived the maintenance costs for wood to be lower possibly because they have more maintenance experience with wood. Wood was perceived to require higher maintenance by highway and marine/inland waterway officials which caused them to perceive wood as higher in maintenance costs. This indicates that wood products manufacturers should develop new maintenance education programs for highway and marine/inland waterway officials. Perhaps the manufacturers may wish to offer a maintenance service for larger wood structures such as inspections or re-treatments with chemicals. Railroad groups said it was easier to dispose of their used wood products (they could sell used crossties) than the other infrastructure groups. This caused the wood disposal costs for railroad officials to be lower than wood disposal costs for other infrastructure areas. To help reduce wood disposal costs in highway and marine/inland waterway markets, manufacturers may want to develop solid wood products recycling/reuse programs.

**Perceptional Ratings of Durability Factors:**

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 four infrastructure groups for each durability rating except *weathering resistance*. Also, significant differences were indicated to be present among the four infrastructure groups mean importance ratings for *fire resistance* by the univariate p-value, but no relationships were found with Tukey's HSD test. Railroad officials had significantly higher mean importance ratings for *fatigue resistance* (6.11) than did highway officials (5.76), utility officials (5.30) and marine/inland waterway officials (5.23). Highway officials had significantly higher mean importance ratings for *fatigue resistance* than did utility officials and marine/inland waterway officials. Railroad officials had significantly higher mean importance ratings for *mechanical wear/abrasion resistance* (5.76) than did highway officials (5.31), marine/inland waterway officials (5.27) and utility officials (5.03). Marine/inland waterway (5.94) and highway officials (5.76) had significantly higher mean importance ratings for *corrosion resistance* than did utility (5.22) and railroad officials (4.86). Utility (5.58) and railroad officials (5.51) had significantly higher mean importance rating for *biological decay resistance* than did highway (4.69) and marine/inland waterway officials (4.64) (Table 44).

Combined officials had the highest mean importance ratings for *weathering resistance* (5.71) and *fatigue resistance* (5.69). They had had significantly higher mean importance ratings for these factors than *mechanical wear/abrasion resistance* (5.34), *biological decay resistance* (4.98) and *fire resistance* (4.23). Also, combined officials' mean importance rating for *corrosion resistance* (5.55) was significantly higher than *biological decay resistance* and *fire resistance* (Table 44).

**Discussion of Durability Factors:**

Wood products manufacturers need to know which durability attributes are most important when used in a material choice decision so they can focus their product improvement efforts. Combined officials had the highest importance for *weathering resistance* and *fatigue resistance*. Highway officials, marine/inland waterway officials, railroad officials and utility officials are responsible for structures that carry large loads and have to perform for long time periods. Therefore, the *fatigue resistance* of construction materials was highly important to the combined officials. Also, each of the infrastructure groups are responsible for structures that are constantly being weathered therefore, they had a high importance rating for *weathering resistance*. *Corrosion resistance* was highly important to each infrastructure group because they built structures using materials susceptible to corrosion (mainly steel). *Biological decay resistance* and *fire resistance* were of less importance to the combined officials due to the fact that biological decay and fire damage occurred less to structures than other types of damage. Wood products manufacturers should focus marketing efforts about product durability primarily in the area of fatigue, weathering and corrosion resistance. Although less important, biological decay and fire are highly important to wood products manufacturers and should not be disregarded in manufacturers strategic marketing plans.

**Perceptional Ratings of Durability Attributes:**

Officials were asked to rate the following materials for perceived possession of durability factors: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean durability attribute ratings for wood. Significant differences were found among the infrastructure groups mean perceived durability ratings for wood.

Railroad officials (5.29) had significantly higher mean perceived *fatigue resistance* ratings for wood than utility (4.69), highway (4.17) and marine/inland waterway officials (4.17). Also, utility officials had a significantly higher mean perceived *fatigue resistance* rating for wood than did highway and marine/inland waterway officials. Railroad (4.61) and utility officials (4.30) had significantly higher mean perceived *mechanical wear/abrasion resistance* ratings for wood than did highway (3.45) and marine/inland waterway officials (3.34). Utility (4.66) and railroad officials (4.56) had significantly higher mean perceived *weathering resistance* ratings for wood than did marine/inland waterway (3.90) and highway officials (3.82) (Table 45). Based on the infrastructure groups' perceptions of wood's *fatigue, mechanical wear/abrasion*, *weathering* and *biological decay resistance*, we failed to reject the hypothesis that different infrastructure markets had different perceptions of wood as a construction material. No significant differences were found among the infrastructure groups mean perceived *fire and corrosion resistance* ratings for wood. Based on the infrastructure groups' perceptions of wood's *fire resistance*, we reject the hypothesis that different infrastructure markets had different perceptions of wood as a construction material.

Combined officials had significant differences among their mean perceived durability ratings for materials with each durability attribute. They had the highest mean perceived *fatigue resistance* ratings for prestressed concrete (5.54), steel (5.39), and reinforced concrete (5.35). These mean perceived ratings were significantly higher than ratings for wood (4.46), aluminum (4.35)and plastic (3.76). Their mean perceived *fatigue resistance* ratings for wood and aluminum were significantly higher than plastic. Combined officials had grouped wood with the second to lowest materials rated for *fatigue resistance*, but its rating was still above average. This indicates that wood was *fatigue resistant*, but not as *fatigue resistant* as concrete or steel. Significant differences were found among the four transportation groups' mean perceived *fatigue resistance* ratings for wood (Table 45).

Combined officials had the highest mean perceived *mechanical wear/resistance* ratings for steel (5.53), which was significantly higher than their mean ratings for all other materials tested.

Their mean ratings for prestressed concrete (5.25) and reinforced concrete (5.21) were significantly higher than aluminum (4.31), wood (3.79) and plastic (3.45). Combined officials mean *mechanical wear/abrasion resistance* ratings for aluminum were significantly higher than wood, and their mean ratings for wood were significantly higher than plastic. Combined officials had the second to lowest mean rating for wood (3.79 is below average), which indicates they felt as a group that wood had low *mechanical wear/abrasion resistance* (Table 45).

Combined officials had the highest mean perceived *fire resistance* rating for reinforced concrete (5.91) and prestressed concrete (5.77), which were significantly higher than all other material tested. Their mean perceived rating for steel (5.24) was significantly higher than aluminum (4.29), wood (2.71) and plastic (2.34). Their mean perceived rating for aluminum was significantly higher than wood and plastic. Also, their mean perceived *fire resistance* rating for wood was significantly higher than plastic. Combined highway groups' mean perceived *fire resistance* ratings for wood was well below average and implies that they perceive wood as not *fire resistant* (Table 45).

The highest mean perceived *corrosion resistance* rating for the combined officials was plastic (5.41), which was significantly higher than wood (5.07), aluminum (4.92) and steel (4.00). Their mean perceived rating for prestressed concrete (5.29) was significantly higher than aluminum and steel. Combined highway groups mean perceived *corrosion resistance* ratings for reinforced concrete (5.21), wood and aluminum were significantly higher than their mean rating for steel. They had a mean perceived *corrosion resistance* rating for wood above average (5.07), which was not significantly different than prestressed concrete, reinforced concrete, and aluminum. Wood was still perceived to be less *corrosion resistant* than plastic (Table 45).

Combined officials rated materials for *weathering resistance*, and they had the highest mean perceived ratings for prestressed concrete (5.53) and reinforced concrete (5.39). Their mean perceived ratings for prestressed and reinforced concrete were significantly higher than steel (5.12), plastic (4.32) and wood (4.11). Combined officials mean perceived *weathering resistance* ratings for aluminum (5.31) and steel were significantly higher than plastic and wood. Therefore, wood was perceived by the combined officials to have average *weathering resistance* and to be lower in *weathering resistance* than all materials tested except plastic (Table 45).

Combined highway officials were also asked to rate materials for possession of the attribute *biological decay resistance*. They had the highest mean perceived ratings for the following group of materials: prestressed concrete (5.80), reinforced concrete (5.78), aluminum (5.67) and steel (5.65). Their mean perceived *biological decay resistance* ratings for these materials were significantly higher than plastic (5.10) and wood (3.58). Also, their mean perceived rating for plastic was significantly higher than wood. Combined officials had the lowest mean perceived *biological decay resistance* rating for wood, which was below average and indicated that they felt wood has low *biological decay resistance* (Table 45).

The weighted mean perceived durability ratings for wood were very similar to those seen with the normal mean perceived durability ratings. Significant differences were found among the infrastructure groups' weighted mean perceived ratings for wood for each durability attribute. Railroad officials had significantly higher weighted mean perceived *fatigue resistance*, (32.33) *mechanical wear/abrasion resistance* (26.58) and *fire resistance* ratings for wood (14.87) than did all other infrastructure groups. Utility officials had a significantly higher weighted mean perceived *fatigue resistance* rating for wood (24.79) than did marine/inland waterway officials (21.82). Also, utilities (21.64) had a significantly higher weighted mean perceived *mechanical wear/abrasion resistance* rating for wood than did highway (18.35) or marine/inland waterway officials (17.63). Marine/inland waterway (30.33) and highway officials' (29.44) weighted mean perceived *corrosion resistance* ratings for wood were significantly higher than utility (26.02) and railroad officials' (24.37. Utility (26.54) and railroad officials' (25.78) weighted mean perceived *weathering resistance* ratings for wood were significantly higher than highway (21.98) and marine/inland waterway officials' (21.91) weighted mean perceived ratings for wood. Also, utility (23.60) and railroad officials' (22.51) weighted mean perceived *biological decay resistance* ratings for wood were significantly higher than highway (15.35) and marine/inland waterway officials' (14.93) (Table 46).

Combined officials had the second to lowest weighted mean perceived ratings for wood for *fatigue resistance* (25.45), *mechanical wear/abrasion resistance* (20.32) and *fire resistance* (11.53). Their weighted mean perceived *fatigue resistance* rating for wood was grouped with their rating for aluminum (24.72) and was significantly higher than plastic (21.43), but was significantly lower than all other materials. Their weighted mean perceived *mechanical wear/abrasion resistance* and *fire resistance* ratings for wood were significantly higher than plastic, but significantly lower than all other materials. Combined officials had weighted mean perceived *corrosion resistance* rating for wood (28.09) that was significantly lower than plastic (30.31) and prestressed concrete (29.54), but were significantly higher than steel (22.12). They had lowest weighted mean *weathering resistance* (23.47) and *biological decay resistance* ratings (18.05) for wood, which were significantly lower than all other materials tested (Table 46).

**Discussion of Durability Attributes:**

Durability of structural materials determines the length of their service life to infrastructure decision-makers. In order to adjust marketing strategies and the durability of their products, it is necessary for manufacturers to be informed on the infrastructure decision-makers perceptions of wood's durability. Wood was perceived to be less able than other materials at holding loads for extended times and greater load cycles. Therefore, combined officials perceived wood to be less *fatigue resistant* than other materials. Wood was still perceived to be above average in *fatigue resistance* due to its high resilience in such products as crossties, poles, posts and timbers. Wood is a softer material and less able to withstand abrasive forces by vehicles, water and dirt/debris than other materials. Therefore, officials perceived wood to be below average in possessing *mechanical wear/abrasion resistance.* Wood was perceived among combined officials to be among the least *fire resistant* materials because wood was flammable. Wood is not affected by corrosive elements and therefore officials perceived it to be highly *corrosion resistant*. Wood was perceived to be more highly affected by freeze/thaw, water and ultraviolet light damage than other materials. Therefore, they perceived wood to be the least *weathering resistant* of materials tested. Combined highway groups perceived wood to be low in *biological decay resistance* because many biological decay agents can attack wood. Even preservative treated wood in infrastructure may be affected by wood decay organisms.

Durability of wood was perceived to be different by officials in separate infrastructure markets. Manufacturers will want to be informed on the different perceptions if they are planning to entering a new infrastructure market. In general, railroad and utility officials reported a higher perceptions of wood possessing the attributes *fatigue*, *mechanical wear/abrasion*, *weathering,* and *biological decay resistance* than did highway and marine/inland waterway officials. Wood has proven to support heavy loads for a long duration and many cycles in both railroads (crossties) and utilities (poles and crossarms), while in highway (primary road bridges) and industrial marine/inland waterway structures it is perceived to have less strength than alternate materials. Wood had high resistance to *mechanical wear/abrasion* in railroad crosstie and utility pole materials, but low resistance in highway and marine/inland waterway structures such as bridge decks, pilings, and pier decks. Interview participants in utilities and railroads said they had to fight biological decay with higher maintenance, but were receiving adequate service life with wood products. Highway and marine/inland waterway interview participants had mentioned a greater incidence of *biological decay* than railroad and utility officials. This higher incidence of decay could be caused by inferior designs, improper construction and less maintenance in highways and marine/inland waterways than was in railroads and utilities.

The decision-makers perceptions of durability attributes of wood reveal several issues that should be considered for wood products manufacturers competing in infrastructure markets. Manufacturers may wish to improve competitive position in the infrastructure market by increasing the durability of wood products primarily in highway and marine/inland waterway structures. To do this, manufacturers may want to increase the *fatigue, mechanical wear/abrasion, weathering,* and *biological decay resistance* of wood products. This could be accomplished by increasing wood quality, better connectors/fasteners, improving wood designs and promoting structure maintenance. To increase their competitive advantage in all infrastructure areas, manufacturers may want to investigate improving the fire resistance of wood. In general, utility and railroad officials perceived wood to have adequate durability. Although wood products manufacturers should not ignore durability issues in these area, they may want to de-emphasize marketing resources to increasing wood durability if competing in these markets.

**Perceptional Ratings of Design Factors:**

Officials were asked to rate the importance of the following design factors: *design standards available, material available, ease of construction, designer's experience with material* and *construction equipment available*. Significant differences were located among the infrastructure groups' mean design factor importance ratings. Highway officials' mean importance rating for *design standards available* (5.52) was significantly higher than did marine/inland waterway officials (5.19). Also, highway officials mean importance rating for *material available* (5.99) was higher than utility officials (5.76). The ANOVA p-value for *construction equipment available* indicates that the infrastructure groups differ significantly on their mean importance rating for that factor, but no significant differences were located using Tukey's HSD. It should be noted that even though differences were present among the infrastructure groups mean design factor importance ratings, almost all mean design factor ratings were well above average. Only the utility officials' mean importance rating for *designer's experience available* (4.96) was below 5.00 (Table 47).

The combined officials had the highest mean design factor importance rating for *material available* (5.90), followed by *ease of construction* (5.58), *design standards available* (5.40), *construction equipment available* (5.29) and *designer's experience with material* (5.23). Their mean importance rating for *material available* was significantly higher than their mean importance ratings for all other design factors. Combined officials' mean importance rating for *ease of construction* was significantly greater than their rating for *design standards available*, *construction equipment available* and *designer's experience with material*. Their mean importance rating for *design standards available* was significantly higher than their mean importance rating for *designer's experience with material* (Table 47).

**Discussion of Design Factors:**

Combined officials had the highest design factor importance for *material available* in material choice decisions. If a material was not available, then the decision-maker would immediately eliminate that material as a choice in the design of a structure. Combined officials had higher importance for *ease of construction* than *design standards available*, *construction equipment available*, and *designer's experience with material*, but it should be noted that each of these factors had an importance well above average in making a material choice. If a material was *easy in construction*, construction workers would make less mistakes in construction, reducing construction costs and the risk of structure failures. Having *design standards available* for a material reduced the cost in research and designs for a structure. Having *construction equipment available* for a material type reduced costs in construction with that material by speeding up construction. It kept construction in-house instead of a decision-maker having to hire an outside, specialized contractor for construction. *Designer's experience with a material* would speed up design of a structure, reduce design research costs, and keep a designer from having to employ more costly, outside designer. Highway officials had higher importance for *design standards available* than did marine/inland waterway officials because highway officials were dealing with more standardized structures than were marine/inland waterway officials. Highway officials had higher importance for *materials available* than did utility officials, but both ratings were well above average importance.  This means that the highway officials had only slightly more importance for *material available* in material choice decisions than did utility officials.

**Perceptional Ratings of Design Attributes:**

Officials were asked to rate the following materials for perceived possession of design attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean design attribute ratings for wood.  Significant differences were found among the four transportation groups' mean perceived design ratings for wood.

Utility and railroad officials had significantly higher mean perceived ratings for wood than did marine/inland waterway and highway officials for the following design attributes: *design standards available*, *material available, ease of construction* and *designer's experience with material* (Table 48).  No significant differences were found among the respondent groups' mean perceived *construction equipment available* rating for wood.  It should be noted that even though differences were present among the infrastructure groups' mean design attribute ratings for wood, each group had mean ratings for wood above average.  The highway officials' mean *designer's experience with material* rating was the lowest mean design attribute rating for wood (4.66) (Table 48).  Based on the different infrastructure groups mean perceived *design standards available, material available, ease of construction*, *designer's experience with material* ratings for wood, we failed to reject the hypothesis that different infrastructure markets had different perceptions of wood as a construction material.

Combined officials had the highest mean *design standards available* ratings for steel (6.01) and reinforced concrete (5.93).  Their mean perceived *design standards available* rating for steel was significantly higher than prestressed concrete (5.82), wood (5.24), aluminum (4.92) and plastic (3.63).  Officials mean perceived *design standards available* ratings for reinforced concrete and prestressed concrete were significantly higher than wood, aluminum and plastic.  Their mean ratings for wood were significantly higher than aluminum and plastic.  Officials mean perceived *design standards available* ratings for aluminum were significantly higher than plastic.  Their mean perceived *design standards available* rating for wood was above average (Table 48).

Officials reported the highest mean *material available* ratings for reinforced concrete (6.07) and steel (5.91). Their mean perceived *material available* rating for reinforced concrete was significantly higher than prestressed concrete (5.81), wood (5.44), aluminum (4.89) and plastic (4.03). Officials mean perceived *material available* ratings for steel and prestressed concrete were significantly higher than wood, aluminum and plastic. Their mean ratings for wood were significantly higher than aluminum and plastic. Officials mean perceived *material available* ratings for aluminum were significantly higher than plastic. Their mean perceived *material available* rating for wood was above average (Table 48).

Officials highest mean perceived *ease of construction* ratings were for steel (5.56) and wood (5.45). Their mean perceived *ease of construction* ratings for these materials were significantly higher than prestressed concrete (5.23), reinforced concrete (5.22), aluminum (4.92) and plastic (4.31). Officials' mean perceived *ease of construction* ratings for prestressed concrete and reinforced concrete were significantly higher than aluminum and plastic. Their mean perceived rating for aluminum was significantly higher than plastic. Officials perceived wood to be among the easiest materials with which to construct and rated it above average in *ease of construction* (Table 48).

Officials had the highest mean *designer's experience with material* ratings for reinforced concrete (5.72) and steel (5.65), which were significantly higher than prestressed concrete (5.36), wood (5.04), aluminum (4.15) and plastic (3.10). Their mean perceived rating *designer's experience with material* rating for prestressed concrete was significantly higher than wood, aluminum and plastic. Officials mean perceived rating for wood was significantly higher than aluminum and plastic. Officials mean perceived *designer's experience with material* rating for aluminum was significantly higher than plastic. Their mean perceived *designer's experience with material* rating for wood was above average (Table 48).

Officials had the highest mean perceived *construction equipment available* ratings for steel (5.73), reinforced concrete (5.72) and wood (5.71). Their mean perceived ratings for these materials were significantly higher than prestressed concrete (5.43), aluminum (5.11) and plastic (4.53). Officials mean perceived *construction equipment available* rating for prestressed concrete was significantly higher than aluminum and plastic. Their mean perceived rating for aluminum as significantly higher than plastic. Wood was not significantly different from the highest rated materials by officials for *construction equipment available* (Table 48).

Significant differences were found among the infrastructure groups' weighted mean perceived design attribute ratings for wood. Utility officials had significantly higher weighted mean *ease of construction* ratings for wood (33.03) than did marine/inland waterway officials (30.18) and highway officials (29.31). Railroad officials had significantly higher weighted mean perceived *ease of construction* ratings for wood (31.20) than did highway officials. Railroad officials (29.45), utility officials (28.38) and marine/inland waterway officials (27.92) had significantly higher weighted mean perceived *designer's experience with material* rating for wood than did highway officials (24.40). No significant differences were found among the infrastructure groups' weighted mean perceived ratings for wood possessing the following attributes: *design standards available, material available* and *construction equipment available* (Table 49).

Combined officials had third lowest weighted mean for wood for the following attributes: *design standards available* (28.29), *material available* (32.05) and *designer's experience with material* (26.33). Their weighted mean perceived *design standards available* rating for wood was significantly lower than steel (32.51), reinforced concrete (32.14) and prestressed concrete (31.58), but significantly higher than their ratings for aluminum (26.65) and plastic (19.66). Officials weighted mean *material available* rating for wood was significantly lower than reinforced concrete (35.94), steel (34.94) and prestressed concrete (34.42), but it was significantly higher than aluminum (28.92) and plastic (23.82). Their weighted mean *designer's experience with material rating* for wood was significantly lower than reinforced concrete (30.07), steel (29.66) and prestressed concrete (28.12), but significantly higher than their ratings for aluminum (21.67) and plastic (16.26). Officials' weighted mean *ease of construction* rating for wood was grouped with steel as the highest weighted perceived ratings for materials tested. They had weighted mean perceived *ease of construction* ratings for these two materials that were significantly higher than prestressed concrete (29.13), reinforced concrete (29.08), aluminum (27.44) and plastic (24.00). Officials had the highest weighted mean *construction equipment available* rating for wood, which was significantly higher than prestressed concrete (28.55), aluminum (26.96) and plastic (23.84) (Table 49).

**Discussion of Design Attributes:**

From the overall design factor importance ratings, it was determined that wood having ease of design was not as important as possessing other attributes. Even though it had less importance, infrastructure officials had enough importance for ease of design that manufacturers should not disregard design attributes of wood in formulating/improving market strategies. Results demonstrated that combined officials perceived *design standards to be available* for wood, but the largest problem as noted by interview participants was that the design standards may be obsolete. Officials had mean perceived *material availability* ratings for wood that were above average due to wood being a standard material in structures in all infrastructure areas. This was contradictory to the interview participants who said that there were supply problems with wood, but supply problems may be specific to the sizes, prices and species that the interview participants required. Wood was perceived to be the easiest material in construction, which was supported by interview participants who said they have the knowledge, have the required equipment, and wood can be used in construction in any season. Officials perceived designers to have above average *experience* with wood, but less experience than with alternate materials. Wood was a standard material in all infrastructure areas used in more simple structures not requiring design engineers. Therefore, design engineers were perceived to have less experience with wood than other materials. In order to use wood in construction, officials would need the proper *construction equipment to be available* for wood. Officials perceived that construction equipment was highly available for wood, which was supported by the wide use of wood in each infrastructure area as shown in Table 30. All these design attributes for wood should be carefully considered by manufacturers when competing in the infrastructure market.

To compete more effectively in an individual infrastructure market, manufacturers require knowledge about different perceptions in the separate infrastructure groups. Differences were determined to be present among the four infrastructure groups perceptions of wood design attributes that manufacturers may need to include in their infrastructure market strategies. It was said that utility and railroad officials perceived that more *design standards were available* for wood than perceived by highway and marine/inland waterway officials. Supporting this, interview participants said the NESC had standards for the utility poles and the American Railway Engineers Association had standards for wood crossties. As stated by the highway and marine/inland waterway interview participants, guidelines for wood were not as well known by decision-makers, were not centrally located, and may be obsolete. Highway and marine/inland waterway officials had lower perceptions of wood being available than did utility and railroad officials. This was due to utility and railroad officials primarily using wood in two structural members that form the bulk of their structures, distribution poles and railroad crossties. Utility and railroad officials perceived wood to be *easy in construction* because they had the knowledge, standards, equipment and the experience necessary to use wood in infrastructure. Highway and marine/inland waterway officials did not have as much knowledge, did not have as current standards and did not have as much experience in using wood, which caused them to perceive wood to be more difficult in construction. Wood was used more in simple or temporary highway structures not requiring a designer. In marine/inland waterway structures, wood was used more in recreational structures that did not require a design engineer. Railroads and utilities utilized wood in more complex structures which require structural design engineers (the railroad track systems; transmission and distribution lines). Therefore, highway and marine/inland waterway officials perceived designers to have less experience with wood than did utility and railroad officials.

It is suggested that wood products manufacturers may improve market position in infrastructure markets by first making sure that design standards are available and current for wood structures. Manufacturers should be sure that supply is not a problem particularly with large wood products used in the highway and marine/inland waterway markets. In order to increase designers experience with wood, manufacturers may need to increase education efforts about wood structure design to infrastructure decision-makers. Due to highway and marine/inland waterway officials having lower perceptions of wood in these attributes, it is suggested that manufacturers improve these design attributes for wood especially in these two markets. To improve promotional efforts across all infrastructure markets, manufacturers may wish to capitalize on the infrastructure officials' perceptions of wood being easy in construction and their having construction equipment available for wood.

**Perceptional Ratings of Environmental Factors:**

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 the four infrastructure groups' mean importance ratings for these environmental factors. Highway officials' mean importance rating for *aesthetically pleasing* (5.11) was significantly higher than marine/inland waterway (4.68) and railroad officials' (3.96). Also, utility (4.91) and marine/inland waterway officials' mean importance ratings for *aesthetically pleasing* were significantly higher than railroad officials. Railroad officials had significantly higher mean importance ratings for *recyclable/reusable* (4.21) than did utility (3.51) and marine/inland waterway officials (3.33). Railroad (3.59) and highway officials (3.33) had significantly higher mean importance ratings for *percent recycled content of material* than did marine/inland waterway officials (2.67). No significant differences were found among the four infrastructure groups mean importance ratings for *chemically safe, disposable/biodegradable* or *low environmental effects of material production* (Table 50).

Significant differences were located among the combined officials mean importance ratings for environmental factors. Their highest mean importance rating was for *chemically safe* (5.52), which was significantly higher than all other materials tested. Officials mean importance rating for *aesthetically pleasing* (4.84) was significantly higher than their mean importance ratings for *low environmental effects of material production* (4.26), *disposable/biodegradable* (4.10), *recyclable/reusable* (3.80), and *percent recycled content of material* (3.25). Their mean importance ratings for *low environmental effects of material production* and *disposable/biodegradable* were significantly higher than *recyclable/reusable* was significantly higher than *percent recycled content of material* (Table 50).

**Discussion of Environmental Factors:**

Different environmental factors held higher or lower importance to infrastructure decision-makers. Wood products manufacturers should be informed of these differences in order to understand which environmental areas should have the highest importance in their infrastructure market strategies. Also, manufacturers should know why these factors are important so they are able to change their strategy to meet the decision-makers needs. *Chemically safe* was the highest in importance because infrastructure decision-makers were responsible for their structures and would not want to use materials that produced chemicals harmful to the environment or to people. *Aesthetically pleasing* had high importance because officials were responsible for their structures aesthetic effects on the environment. Interview participants stated that the public was more receptive to changes in the environment, for instance a sound barrier or a new pier, if the structure was *aesthetically pleasing*. *Low environmental effects of material production, recyclable/reusable* and *disposable/biodegradable* were above average in importance to officials, but were relatively new concepts in most infrastructure areas.  Therefore, they were not as important as *chemically safe* and *aesthetic pleasing*.  This suggests that wood products manufacturers should focus their marketing efforts in *chemical safety* and *aesthetics*, but less in *low environmental effects of material production*, *recyclable/reusable* and *disposable/biodegradable.*

Manufacturers should know what differences are present among infrastructure groups so they can adjust their marketing strategies to best meet the individual markets.  Railroad officials had lower importance for *aesthetically pleasing* than highway, utility and marine/inland waterway officials because railroad structures were in industrial settings or settings where people were not in contact with the structures.  Railroad officials had higher importance for *recyclable/reusable* than did utility and marine/inland waterway officials due to the large amount of used materials railroads had in disposal (used crossties, for example).  As determined in the interviews, materials used in other infrastructure areas generally could not be reused once they were broken or decayed.  This indicates that wood products manufacturers may need to have less importance for *aesthetically pleasing* when marketing in the railroad market, but more importance for this factor in the other infrastructure markets.  Also, it was suggested that manufacturers have more importance for *recyclable/reusable* in their marketing efforts to railroads than other infrastructure areas.

**Perceptional Ratings of Environmental Attributes:**

Officials were asked to rate the following materials for perceived possession of environmental attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean environmental attribute ratings for wood. Significant differences were found among the four transportation groups' mean perceived environmental ratings for wood.

Highway officials had a mean perceived *chemically safe* rating for wood (5.29) significantly higher than utility officials (4.83) and railroad officials (4.79).  Highway officials (5.49) and marine/inland waterway officials (5.27) had significantly higher mean perceived *aesthetically pleasing* ratings for wood than utility officials (4.76) and railroad officials (4.68). Railroad officials (3.94) had a significantly higher mean perceived *recyclable/reusable* rating for wood than did highway officials (3.21).  Also, railroad officials (3.24) had a significantly higher mean *percent recycled content of material* rating for wood than did highway officials (2.66) (Table 51). Based on the different infrastructure groups mean *chemically safe, aesthetically pleasing, recyclable/reusable* and *percent recycled content of material* ratings for wood, we failed to reject the hypothesis that different infrastructure markets had different perceptions of wood as a construction material. No significant differences were found among infrastructure groups mean perceived *disposable/biodegradable* and *environmental effects of material production* ratings for wood. Based on the different infrastructure groups mean ratings for wood possessing these attributes, we rejected the hypothesis that different infrastructure markets had different perceptions of wood as a construction material (Table 51).

Significant differences were found among the combined officials mean perceived *chemically safe* ratings for materials. Officials had the highest mean perceived *chemically safe* ratings for prestressed concrete (5.75), reinforced concrete (5.70) and steel (5.56). Their mean perceived *chemically safe* ratings for these materials were significantly higher than aluminum (5.52), wood (5.09) and plastic (4.72). Their mean perceived *chemically safe* rating for wood was significantly lower than prestressed concrete, reinforced concrete, steel and aluminum, but significantly higher than their mean perceived rating for plastic (Table 51).

Significant differences were found among the officials' mean perceived *aesthetically pleasing* ratings for materials. Officials had the highest mean perceived *aesthetically pleasing* ratings for prestressed concrete (5.40) and reinforced concrete (5.29). Their mean perceived *aesthetically pleasing* rating for wood (5.20) was not significantly different than reinforced concrete, steel (5.19) and aluminum (5.14). Officials' mean perceived ratings for these materials were significantly higher than plastic (4.49). Their mean perceived *aesthetically pleasing* ratings for wood, steel, aluminum and plastic were significantly lower than prestressed concrete (Table 51).

Significant differences were located among the officials' mean perceived *disposable/biodegradable* ratings for materials. They had the highest mean perceived *disposable/biodegradable* rating for wood (4.82), which was significantly higher than all other materials tested. Their mean perceived *disposable/biodegradable* ratings for aluminum (4.15) and steel (4.10) were significantly higher than reinforced concrete (3.55), prestressed concrete (3.51) and plastic (2.96) (Table 51).

Significant differences were found among the officials' mean perceived *low environmental effects of material production* ratings for materials. They had the highest mean perceived *low environmental effects of material production* ratings for reinforced concrete (4.61), prestressed concrete (4.58) and wood (4.41). Their mean perceived *low environmental effects of material production* rating for wood was significantly higher than aluminum (4.10) and plastic (3.59) (Table 51).

Significant differences were found among the officials' mean perceived *recyclable/reusable* ratings for materials. They had highest mean *recyclable/reusable* ratings for aluminum (5.04) and steel (4.94), which were significantly higher than plastic (4.01), reinforced concrete (3.89), prestressed concrete (3.47) and wood (3.39). Their mean perceived *recyclable/reusable* rating for wood was the lowest of all mean perceived ratings for materials (Table 51).

Significant differences were found among the officials' mean perceived *percent recycled content of material* ratings for materials. They had the highest mean perceived *percent recycled content of material* ratings for aluminum (4.37), steel (4.27), and plastic (4.10). Their mean perceived *percent recycled content of material* ratings for these materials was significantly higher than reinforced concrete (3.12), prestressed concrete (3.01) and wood (2.77). Their mean perceived *percent recycled content of material* rating for wood was the lowest of all materials tested (Table 51).

Weighted mean environmental attribute ratings were developed from officials' environmental attribute ratings for materials. Significant differences were found among the four infrastructure groups' weighted mean perceived environmental attribute ratings for wood. Highway officials (29.21) had a significantly higher weighted mean perceived *chemically safe* rating for wood than did utility officials (26.33) and railroad officials (26.14). Highway officials (28.06) had a significantly higher weighted mean perceived *aesthetically pleasing* rating for wood than did marine/inland waterway officials (24.66), utility officials (23.34) and railroad officials (18.54). Also, marine/inland waterway officials and utility officials had significantly higher weighted mean perceived *aesthetically pleasing* ratings for wood than did railroad officials. Railroad officials had significantly higher weighted mean perceived *recyclable/reusable* ratings for wood (16.56) than did highway officials (12.34), utility officials (12.00) and marine/inland waterway officials (10.94). Railroad officials had significantly higher weighted mean perceived *percent recycled content of material* ratings for wood (11.61) than did highway officials (8.84), utility officials (8.50) and marine/inland waterway officials (6.43) (Table 52).

Significant differences were found among combined officials weighted mean perceived environmental attributes ratings for materials. Their weighted mean perceived *chemically safe* ratings for wood (28.09) was second lowest and significantly lower than prestressed concrete (31.74), reinforced concrete (31.49), steel (30.69), and aluminum (30.49). Officials weighted mean perceived *aesthetically pleasing* rating for wood (25.27) was significantly lower than the highest rated material, prestressed concrete (26.36), but significantly higher than plastic (21.84). They had the highest weighted mean perceived *disposable/biodegradable* rating for wood (19.76), which was significantly higher than all other materials tested. Officials weighted mean perceived *low environmental effects of material production* rating for wood (18.75) was not significant different from reinforced concrete (19.59) and prestressed concrete (19.46). They had the lowest weighted mean perceived *recycled/reusable* rating for wood (12.93), which was significantly lower than aluminum (19.13), steel (18.87) and plastic (15.25). Also, officials had the lowest weighted mean perceived *percent recycled content of material* rating for wood (9.06), which was significantly lower than aluminum (14.23), steel (13.97) and plastic (13.40) (Table 52).

**Discussion of Environmental Attributes:**

Decision-makers perceptions of environmental attributes possessed by materials affect their material choice decisions. Manufacturers need to know how decision-makers perceived wood environmentally to best compete in the infrastructure market. Combined officials perceived wood to be less *chemically safe* than other materials due to wood being treated with preservatives perceived harmful to the environment. This was supported by the interview participants' desires for wood products to have more environmentally friendly chemical treatments. Officials perceived wood to be among the most *aesthetically pleasing* materials and gave it an above average rating. They perceived wood to be the highly *disposable/biodegradable* because in some instances, wood was easy in disposal (for instance people would buy used ties and take used utility poles) and decay organisms would attack wood. Officials perceived wood to be among the materials with *low effects of material production*. This indicates that they felt the production of wood was managed in a more environmentally friendly manner. Wood products were natural products that did not contain recycled materials, so they were perceived to be the *lowest in percent recycled content of materials* tested. Recycling campaigns and industries were not conducted for solid wood products. Often, when wood structures were damaged, the structural members were no longer sound and could not be reused. These perceived environmental attributes of wood should be included in manufacturers infrastructure market strategies.

The four infrastructure groups had different perceptions of the wood's environmental attributes. Manufacturers should understand the differences among the separate groups' environmental attribute ratings for wood to best compete in a single infrastructure market. Highway and marine/inland waterway officials' perceived wood to be less *chemically safe* due to their structures being in greater contact with people (pedestrian and roadway bridges) and with water environments (piers and wharves). Railroad and utility officials wood structures were in relatively less contact with people and water, and therefore, they perceived wood to be more *chemically safe*. Highway and marine/inland waterway participants stated that wood was more accepted than alternate materials and was often considered a cultural requirement. Therefore, highway and marine/inland waterway officials perceived wood to be more *aesthetically pleasing* than utility and railroad officials. Railroads perceived wood to be more *recyclable/reusable* than did all other industry groups due to their reuse of wood crossties in railroad structures for tracks and retaining walls. Manufacturers should assume that infrastructure groups have the same perceptions of wood being *disposable/biodegradable* and having *low environmental effects in production*.

To improve competitive position in a market, wood products manufacturers may wish to use or develop wood preservative chemicals that are more environmentally friendly or wood species that do not require treatment (some cedars and redwood). This is more important in highway or marine/inland waterway market where wood is perceived to be less *chemically safe*. They may want to capitalize on the importance of aesthetic appeal and the perceived aesthetics of wood. To do this, manufacturers may want to promote wood's aesthetic appeal to highway and marine/inland waterway markets more than railroad and utility markets. *Disposability/biodegradability* of wood could be advantageous in certain areas where structures are more temporary, but for the most part decision-makers would want structures to have permanence. Therefore, it is suggested that manufacturers emphasize woods *disposability/biodegradability* in marketing temporary structures only. Manufacturers could capitalize on decision-makers perceptions of wood having *low* *environmental effects in production* in promotional efforts to infrastructure decision-makers. They may want to continue promoting best management practices in timber harvesting and wood products manufacturing to maintain this perception of wood products. To increase competitive standing of wood, manufacturers and associations may wish to consider developing recycle/reuse programs similar to those present in railroads. Manufacturers may also wish to develop engineered materials for infrastructure use which contain a percentage of recycled materials.

**Perceptional Ratings of Maintenance Factors:**

Officials were asked to rate the following factors' importance in making a material choice decision: *standard structure designs available*, *field modification easy*, *ease of repair*, *experience in maintenance with material* and *inspection easy*. Significant differences were found among the four infrastructure groups' mean importance ratings for the maintenance factors. Utility officials had significantly higher mean importance ratings for *standard structure designs available* (5.52) than did highway officials (5.22) and marine/inland waterway officials (4.88). Railroad officials (5.39) had significantly higher mean importance ratings for *standard structure designs available* than did marine/inland waterway officials. Railroad officials (5.71) and utility officials (5.59) had significantly higher mean importance ratings for *field modification easy* than did highway officials (5.30) and marine/inland waterway officials (5.09). Railroad officials (6.04) had significantly higher mean importance ratings for *ease of repair* than did utility officials (5.72), highway officials (5.60) and marine/inland waterway officials (5.54). Also, railroad officials (5.74) had significantly higher mean importance ratings for *inspection easy* than did highway officials (5.06) and marine/inland waterway officials (4.75). No significant differences were located among the four infrastructure groups mean importance ratings for *experience in maintenance* with materials (Table 53).

Combined officials had the highest mean maintenance factor importance rating for *ease of repair* (5.69). Their mean importance rating for *ease of repair* was significantly higher than their mean importance ratings for all other maintenance factors. Officials' mean importance ratings for *experience in maintenance with material* (5.47) and *field modification easy* (5.39) were not significantly different from one another. Officials' mean importance rating for *experience in maintenance with material* was significantly higher than their mean importance ratings for *standard structure designs available* (5.26) and *inspection easy* (5.19). Their mean importance rating for *field modification easy* was significantly higher than their mean importance rating for *inspection easy* (Table 53).

**Discussion of Maintenance Factors:**

Maintenance was indicated to be one of the most important overall factors to decision-makers in a material choice decision. Therefore, wood products manufacturers may want to focus their marketing efforts on maintenance factors, and to do this, they will require information on which maintenance factors were most important to the decision-makers. Also, manufacturers will want to know why certain maintenance factors are important to adjust better their efforts to improve each maintenance factor in their marketing strategies. Combined officials perceived *ease of repair* to be the most important maintenance factor because of the high maintenance costs in many infrastructure areas. If a material was *easy to repair* in a structure, then the structure would be repaired more quickly which could reduce maintenance labor, material, equipment and operations costs. *Experience in maintenance with materials* and *field modification easy* were highly important due to their increasing the efficiency of maintenance. This suggests that manufacturers should improve marketing efforts in maintenance of infrastructure primarily in *ease of repair*, *field modification easy* and *experience in maintenance with materials*. S*tandard structure designs available* and *inspection easy* were less important than these maintenance attributes, but were still above average in importance and should be considered in market strategy formulation.

Maintenance factors may have different importance to the separate infrastructure markets. Manufacturers may wish to consider these differences when formulating strategies for a single infrastructure market or when competing across several markets. Utility officials and railroad officials had higher importance for *standard structure designs in maintenance available* and *field modification easy* than did highway and marine/inland waterway officials. This was due to utilities regularly maintaining distribution/transmission lines (poles and crossarms) and railroad officials constantly replaced individual parts in their railroad tracks (crossties). Railroad and utility officials had to perform more maintenance on structures that are difficult to reach with equipment than did highway and marine/inland waterway officials. This may have caused railroad and utility officials to have higher importance for *ease of field modification* than highway or marine/inland waterway officials. The railroad official would want to be able to inspect this railroad line easily for damages and be able to make repairs easily to keep train traffic from being stopped. Therefore, railroad officials had greater importance for *inspection easy* and *ease of repair* than other groups. This indicates that manufacturers especially should emphasize *standard structure designs in maintenance available, field modification easy, ease of repair, and ease of inspection* when competing in the railroad and utility markets. Manufacturers should not ignore these factors when competing in the highway and marine/inland waterway markets, but they should place less emphasis on them than they do in railroad and utility markets. Replacement of parts was performed more efficiently when the parts were made to a *standard structure design*. Highway and marine/inland waterway officials had standardized parts (posts and pilings) for replacement, but probably not as often as railroad and utility officials. Therefore, highway and marine/inland waterway officials had higher importance for *standard structure designs available* than did railroad and utilities. This indicates that manufacturers perhaps should have greater emphasis for *standard structure designs in maintenance available* in highway and marine/inland waterway marketing efforts than in railroad and utility markets.

**Perceptional Ratings of Maintenance Attributes:**

Officials were asked to rate the following materials for perceived possession of maintenance attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean maintenance attribute ratings for wood. Significant differences were found among the four transportation groups' mean perceived maintenance ratings for wood.

Utility officials (5.69) had significantly higher mean perceived *standard structures designs available* ratings for wood than did railroad officials (5.24), marine/inland waterway officials (5.02) and highway officials (4.61). Railroad officials and marine/inland waterway officials had significantly higher mean perceived *standard structure designs available* ratings for wood than did highway officials. Utility officials (5.70), marine/inland waterway officials (5.54) and railroad officials (5.47) had significantly higher mean perceived *field modification easy* ratings for wood than did highway officials (5.15). Utility officials (5.72), railroad officials (5.62) and marine/inland waterway officials (5.48) had significantly higher mean perceived *experience in* *maintenance with material* ratings for wood than did highway officials (4.76). Railroad officials (5.23) had significantly higher mean perceived *inspection easy* ratings for wood than did highway officials (4.69) (Table 54). Based on the infrastructure groups' mean perceived *field modification easy, standard structure designs available, experience in maintenance,* and *inspection easy* ratings for wood, we failed to reject the hypothesis that different infrastructure markets have different perceptions of wood as a construction material. No significant differences were found among the four infrastructure groups mean perceived *ease of repair* ratings for wood. Based on the different infrastructure groups' mean perceived *ease of repair* ratings for wood, we rejected the hypothesis that different infrastructure markets had different perceptions of wood as a construction material.

Significant differences were found among the combined officials' mean perceived maintenance ratings for materials. Officials had the highest mean perceived *standard structure designs available* ratings for steel (5.44) and reinforced concrete (5.35). Their mean perceived *standard structure designs* available rating for steel was significantly higher than prestressed concrete (5.21), wood (4.95), aluminum (4.53) and plastic (3.55). Their mean perceived *standard structure designs available* ratings for reinforced concrete and prestressed concrete were significantly higher than wood, aluminum and plastic. Their mean perceived *standard structure designs available* rating for wood was significantly higher than aluminum and plastic (Table 54).

Officials had the highest mean perceived *field modification easy* ratings for wood (5.34), which was significantly higher than all other materials tested. Their mean perceived *field modification easy* rating for steel (4.81) was the next highest and was significantly higher than aluminum (4.26), reinforced concrete (4.25), plastic (3.61) and prestressed concrete (3.43). Their lowest mean perceived *field modification easy* ratings were for plastic and prestressed concrete, which were significantly lower than all materials tested
(Table 54).

Officials had the highest mean perceived *ease of repair* rating for wood (5.09), which was significantly higher than all materials tested. Their mean perceived *ease of repair* for steel (4.86) was the next highest and was significantly higher than reinforced concrete (4.40), aluminum (4.12) prestressed concrete (3.66) and plastic (3.46). Officials lowest mean perceived *ease of repair* ratings were for prestressed concrete and plastic, which were significantly lower than all materials tested (Table 54).

Significant differences were found among officials mean perceived *experience in maintenance with material* ratings for materials. They had the highest mean perceived *experience in maintenance with material* ratings for steel (5.19), wood (5.15) and reinforced concrete (5.10), which were significantly higher than prestressed concrete (4.63), aluminum (3.89) and plastic (2.90). The lowest mean perceived *experience in maintenance with material* rating was for plastic, which was significantly lower than all other materials tested. Officials mean perceived *experience in maintenance with material* rating for wood was not significantly different from steel and reinforced concrete (Table 54).

Significant differences were found among the officials' mean perceived *inspection easy* ratings for materials. They had the highest mean perceived *inspection easy* rating for steel (5.20) and reinforced concrete (5.06). Officials mean perceived *inspection easy* rating for steel was significantly higher than wood (4.83), aluminum (4.77), prestressed concrete (4.76) and plastic (4.10). Their mean perceived ratings for reinforced concrete were significantly higher than aluminum, prestressed concrete and plastic, but not significantly different than the rating for wood. Officials mean perceived *inspection easy* rating for wood was not significantly different than their mean perceived ratings for reinforced concrete, aluminum, and prestressed concrete, but was significantly higher than plastic (Table 54).

Significant differences were found among the four infrastructure groups weighted mean perceived maintenance ratings for wood. Utility officials (31.42) had significantly higher weighted mean perceived *standard structure designs available* ratings for wood than did railroad officials (28.25), marine/inland waterway officials (24.52) and highway officials (24.08). Also, railroad officials had significantly higher weighted mean perceived *standard structure designs available* ratings for wood than did marine/inland waterway officials and highway officials. Utility officials (31.83) and railroad officials (31.21) had significantly higher weighted mean perceived *field modification easy* ratings for wood than did marine/inland waterway officials (28.18) and highway officials (27.29). Railroad officials (31.79) had a significantly higher weighted mean perceived *ease of repair* rating than did highway officials (28.20) and utility officials (28.14). Railroad officials (32.02), utility officials (30.99) and marine/inland waterway officials (30.63) had significantly higher weighted mean perceived *experience in maintenance with material* rating for wood than did highway officials (25.71). Railroad officials (29.95) had significantly higher weighted mean perceived *inspection easy* ratings for wood than did utility officials (25.98), highway officials (23.72) and marine/inland waterway officials (22.65) (Table 55).

Combined officials' weighted mean perceived *standards structure designs available* rating for wood (26.13) was significantly lower than steel (28.42), reinforced concrete (28.01) and prestressed concrete (27.30), but significantly higher than their weighted mean perceived ratings for aluminum (23.77) and plastic (18.63). Officials had the highest weighted mean perceived *field modification easy* ratings for wood (28.86), which was significantly higher than steel (25.91), aluminum (22.89), reinforced concrete (22.80), plastic (19.39) and prestressed concrete (18.43). Officials had the highest weighted mean perceived *ease of repair* ratings for wood (28.98), which was significantly higher than steel (27.63), reinforced concrete (24.93), aluminum (23.37), prestressed concrete (20.75) and plastic (19.62). Officials' weighted mean perceived *experience in maintenance with material* rating for wood (28.21) was not significantly different from steel (28.39) and reinforced concrete (27.87). Their weighted mean perceived *inspection easy* rating for wood (25.18) was significantly lower than steel (26.98), but significantly higher than plastic (21.26) (Table 55).

**Discussion of Maintenance Attributes:**

Manufacturers need to know decision-makers' perceptions of wood pertaining to its maintenance so they can compete better in the infrastructure market. The following information describes how combined infrastructure grouped perceived wood products and manufacturers may want to use this information to improve their marketing strategy. Combined officials perceived *standard structure designs in maintenance* for wood to be available, but less than alternative materials. This may be due to indications that standard designs for wood may be obsolete or too difficult to use. Officials perceived wood to be the easiest material to *repair and modify in the field*. Interview participants stated that wood was *easy to repair and modify* due to maintenance personnel having knowledge with wood, tools being available to work with wood, and the ability to maintain wood structures in any season. Officials perceived decision-makers to have high *experience in maintenance* with wood because it was a standard infrastructure material. Wood was perceived to be somewhat difficult to inspect due to wood appearing at times sound from the outside, but actually decayed on the inside. These perceptions indicate that some adjustments may need to be made to manufacturers' market strategies in order for wood to compete better in the infrastructure market.

Separate infrastructure groups perceived wood differently in maintenance due to different applications for wood and different environments in which the groups work. Wood products manufacturers should realize that these different perceptions exist and may wish to change their marketing strategies according to the infrastructure market in which they are competing. Utility officials perceived *standard structure designs in maintenance available* for wood more than other infrastructure groups due to standards set by the NESC. Other infrastructure areas may have had maintenance standard designs for wood in some but not all structural applications. This may indicate why railroad (using standard crossties) and marine/inland waterway officials (using standard piles) had higher perceptions of *standard structure designs available* for wood than did highway officials. Highway officials had lower perceptions of *ease of field modification* for wood than other infrastructure groups which may be due to highway officials having less experience in maintenance with wood products than of the other groups. Also, highway groups may have experienced decay problems caused by improper modifications of treated wood products. Highway officials had lower perceptions for decision-makers having experience in maintenance with wood than did the other infrastructure groups. Because of their structure types, railroad officials had to inspect more wood products than did highway officials, and railroad officials perceived that wood was easier to inspect than highway officials. It is suggested that wood products manufacturers may want to account for these group differences when competing in different infrastructure markets.

Wood products manufacturers may want to make several changes to maintenance aspects of their infrastructure. They should first consider increasing the availability of *standard structure designs* for maintenance in infrastructure, especially in the highway market. Manufacturers should assume that infrastructure groups have the same perceptions of wood's *ease of repair* and may wish to promote this wood attribute to each infrastructure group. They may wish to increase *ease of field modification* promotions in the highway and marine/inland waterway market. Manufacturers and associations may wish to increase inspection training programs in the marine/inland waterway and highway markets to improve their perceptions of ease of inspections of wood structures. Finally, manufacturers and associations may want to increase wood structure maintenance education programs in highway and marine/inland waterway markets.

**Perceptional Ratings of Innovation Factors:**

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 four infrastructure groups' mean importance ratings for these factors.

Railroad officials (4.99) had significantly higher mean importance rating for *innovative in performance* than did utility officials. Railroad officials (5.38) had significantly higher mean importance ratings for *innovative in maintenance* than did highway officials (4.79), marine/inland waterway officials (4.72), and utility officials (4.66). Railroad officials (5.68) had significantly higher mean importance ratings for *innovative in durability* than did highway officials (5.09) and utility officials (4.84). Also, railroad officials (4.78) had significantly higher mean importance ratings for *innovative in the environment* than did utility officials (3.86). No significant differences were found among the combined groups' mean importance ratings for *innovative in design* (4.27) (Table 56).

Significant differences were found among the combined officials mean importance ratings for innovation factors. They had the highest mean importance rating for *innovative in durability* (5.14), which was significantly higher than mean importance ratings for all other innovation factors. Officials mean importance ratings for *innovative in maintenance* (4.86) and *innovative in performance* (4.74) were significantly higher than *innovative in the environment* (4.30) and *innovative in design* (4.27) (Table 56).

**Discussion on Innovation Factors:**

Innovativeness of materials was below average in importance to officials. Therefore, wood products manufacturers should place less emphasis on the innovation factor group's influence on material choice decisions when developing their marketing strategy. If they are going to consider innovation aspects in their marketing strategy, manufacturers will need to know which innovation factors are most important, why it is important and what it means to their marketing strategy. Combined officials had the highest importance for *innovative in durability* due to their high importance for durability. Also, combined officials had high importance for *innovative in maintenance* and *innovative in performance*. Examining the durability factors that rated most important by the officials, it appeared that manufacturers may wish to emphasize innovations in weathering, fatigue and corrosion resistant. The most important maintenance factors suggest that innovations should be made in ease to repair, ease of field modification and education in maintenance so decision-makers will have experience in maintenance with materials. High importance for innovative in performance indicated that materials needed improvements so they could better perform their required tasks.

If manufacturers choose to include innovation factors in their marketing strategies, they need to be aware of what differences exist among the infrastructure groups' importance for these factors. This would allow them to stress different innovation attributes that are more important to the separate groups in their marketing strategy. Railroad officials had higher importance for innovations than did the other infrastructure groups, especially for *innovations in durability, maintenance, performance* and *in the environment.* This indicates that if wood products manufacturers are competing in the railroad market, they should place more emphasis on these innovation factors than if they are competing in the other infrastructure markets.

**Perceptional Ratings of Innovation Attributes:**

Officials were asked to rate the following materials for perceived possession of innovation attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. The hypothesis that different infrastructure groups would have different perceptions of wood as a construction material was tested using mean innovation attribute ratings for wood. No significant differences were found among the four transportation groups' mean perceived ratings for wood with any innovation attributes. Combined officials mean perceived ratings for wood possessing the attributes *innovative in performance* (4.13), *innovative in design* (4.17), *innovative in maintenance* (4.10), *innovative in durability* (4.13) and *innovative in the environment* (4.02), were all slightly above average (Table 57). Based upon the mean innovation attribute ratings for wood by the four infrastructure groups, we rejected the hypothesis that different infrastructure groups had different perceptions of wood as a construction material.

Significant differences were found among the combined officials' mean *innovative in performance* ratings for materials. They had the highest mean *innovative in performance* rating for plastic (4.75), which was significantly higher than any other materials. Their mean perceived *innovative in performance* ratings for prestressed concrete (4.50), steel (4.40) and aluminum (4.39) were significantly higher than reinforced concrete (4.16) and wood (4.13). Officials had the lowest mean perceived *innovative in performance* ratings for reinforced concrete and wood, which were not significantly different form each other (Table 57).

Officials had the highest mean perceived *innovative in design* ratings for plastic (4.74) and prestressed concrete (4.58). Their mean perceived *innovative in design* rating for plastic was significantly higher than steel (4.52), aluminum (4.49), reinforced concrete (4.30) and wood (4.17). Their mean perceived *innovative in design* rating for prestressed concrete and steel were significantly higher than reinforced concrete and wood. Their mean perceived *innovative in design* rating for aluminum was significantly higher than wood. Officials had the lowest mean perceived *innovative in design* ratings for wood, which was significantly lower than all materials tested except reinforced concrete (Table 57).

Significant differences were found among officials mean perceived *innovative in maintenance* ratings for materials. They had the highest mean perceived *innovative in maintenance* ratings for plastic (4.43), steel (4.31), aluminum (4.30), prestressed concrete (4.27), and reinforced concrete (4.24). Their mean perceived *innovative in maintenance* ratings for these materials were not significantly different from one another. Officials mean perceived *innovative in maintenance* ratings for plastic and steel were significantly higher than wood (4.10). They had the lowest mean perceived *innovative in maintenance* rating for wood, but it was not significantly lower than aluminum, prestressed concrete, and reinforced concrete (Table 57).

Significant differences were found among officials' mean perceived *innovative in durability* ratings for materials. Officials had the highest mean *innovative in durability* ratings for prestressed concrete (4.81), reinforced concrete (4.73), steel (4.59), aluminum (4.53) and plastic (4.53). Their mean perceived *innovative in durability* ratings for these materials were significantly higher than wood (4.13). Officials had the lowest mean perceived *innovative in durability* rating for wood (Table 57).

Significant differences were found among the officials mean perceived *innovative in the environment* ratings for materials. They had the highest mean perceived *innovative in the environment* ratings for plastic (4.44), aluminum (4.27), steel (4.23), prestressed concrete (4.18) and reinforced concrete (4.11), which were not significantly different from one another. Their mean perceived *innovative in the environment* ratings for plastic was significantly higher than wood (4.02). Their mean perceived *innovative in the environment* rating for wood was not significantly different from their mean perceived ratings for aluminum, steel, prestressed concrete and reinforced concrete (Table 57).

Significant differences were found among the four infrastructure groups weighted mean perceived innovation ratings for wood. Railroad officials (21.55) and highway officials (19.98) had significantly higher weighted mean perceived *innovative in performance* ratings for wood than did utility officials (17.80) and marine/inland waterway officials (17.62). Railroad officials (23.92) had significantly higher weighted mean perceived *innovative in maintenance* ratings for wood than did highway officials (19.29), utility officials (18.98)and marine/inland waterway officials (18.82). Railroad officials (26.10) had significantly higher mean *innovative in durability* ratings for wood than did highway officials (20.87), utility officials (20.04) and marine/inland waterway officials (18.13). Railroad officials (20.21) had significantly higher weighted mean perceived *innovative in the environment* ratings for wood than did highway officials (17.46) and utility officials (14.26). Also, highway officials had significantly higher weighted mean perceived *innovative in the environment* ratings for wood than did utility officials. No significant differences were found among the four infrastructure groups' weighted mean perceived *innovative in design* ratings for wood (Table 58).

Significant differences were found among the combined officials' weighted mean innovation ratings for wood. They had the lowest weighted mean perceived *innovative in performance* rating for wood (19.62), which was not significantly different than reinforced concrete (19.79). Their weighted mean *innovative in performance* rating for wood was significantly lower than plastic (22.58), prestressed concrete (21.38), steel (20.89) and aluminum (20.82). Officials had the lowest weighted mean *innovative in design* rating for wood (17.81), which was not significantly different from their weighted mean rating for reinforced concrete (18.37). Their weighted mean *innovative in design* rating for wood was significantly lower than plastic (20.22), prestressed concrete (19.54) steel (19.27) and aluminum (19.16). Officials had the lowest weighted mean *innovative in maintenance* rating for wood (19.99), which was not significantly different from aluminum (20.89), prestressed concrete (20.78) and reinforced concrete (20.64). Their weighted mean perceived *innovative in maintenance* rating for wood was significantly lower than plastic (21.52) and steel (21.00). Officials had the lowest weighted mean *innovative in durability* rating for wood (21.27), which was significantly lower prestressed concrete (24.62), reinforced concrete (24.37), plastic (23.29) steel (23.21) and aluminum (23.21). Finally, officials had the lowest weighted mean *innovative in the environment* rating for wood (17.37), which was not significantly different from aluminum (18.42), steel (18.28), prestressed concrete (18.08) and reinforced concrete (17.79). Their weighted mean perceived *innovative in the environment* rating for wood was significantly lower than plastic (19.19) (Table 58).

**Discussion of Innovation Attributes:**

It was determined that innovation factors were not highly important to infrastructure decision-makers, and therefore, their corresponding innovation attributes for materials may not need to be emphasized in wood products manufacturers' marketing strategies. If a manufacturer wishes to include innovation attribute for wood in their strategic plans, they will need to know the decision-makers' perceptions of innovativeness of wood. Combined officials perceived wood as less *innovative in performance, maintenance, design, durability* and *in the environment* than the other materials tested. This indicates that manufacturers could make changes to wood in each of these areas if they want wood to be considered an innovative product.

If manufacturers are considering adding innovativeness of wood to their marketing strategies, they should know that significant differences were not found among the four infrastructure groups perceptions of wood for any innovation attribute ratings. This indicates when used in infrastructure, the four infrastructure groups had similar perceptions of wood being an improvement in performance, design, maintenance, durability or the environment. This indicates that the same changes should be made to include innovation in strategies for each infrastructure market.

## Conclusions

No differences were found among the infrastructure groups in different US regions for overall performance ratings for wood. The combined infrastructure groups perceived prestressed concrete to have the highest overall material performance, while wood and plastic were lowest in overall perceived material performance. Wood still was above average in its perceived overall performance ratings by the infrastructure groups.

No differences were found among infrastructure officials in different US regions for overall factor ratings, while the infrastructure groups combined had different importance for the factors used when making a material choice decision. *Durability*, *maintenance* and *cost* were the most important factors in a material choice decision. *Environmental impact*, *ease of design* and *innovativeness of material* were the least important factors. This may be due to the fact that durability, maintenance and cost influence the effectiveness with which a material performs it required task, while *environmental impact*, *ease of design* and *innovativeness of material* had less of an affect on a material's performance.

This study determined that the education level of the decision-makers did not affect the infrastructure officials perceptions of wood's overall performance as a construction material. Their perceptions of wood's overall perceived performance in infrastructure were affected by their education type. It was determined that officials who had course-work in design of structures with wood did not have different perceptions of wood's overall performance in infrastructure than those that did have coursework in wood design. Having standards for wood design did not affect the infrastructure officials perceptions of wood's overall performance in infrastructure. Finally, age of infrastructure officials and their years of work experience did not affect their perceptions of wood's overall material performance in infrastructure.

It was hypothesized that different infrastructure decision makers would have different perceptions of wood as a construction material. Railroad and utility officials perceived wood to be lower in cost than did highway and marine/inland waterway officials. This may be due to fact that wood products used in railroads and utilities less specialized than those used in highways and marine/inland waterways. Less specialization may have caused the wood products to be less expensive. Railroad and utility officials perceived wood to be more durable than did highway and marine/inland waterway officials. Wood had adequate service life for many utility and railroad applications, while in highways and marine/inland waterways the service life of wood was frequently shorter than expected. Utility and railroad officials had higher perceptions of wood in design of infrastructure than did highway and marine/inland waterway officials. Utility and railroad officials had higher perceptions of wood in maintenance of infrastructure than did highway and marine/inland waterway officials. These differences in maintenance and design attribute ratings by the infrastructure groups may be caused by the higher wood use in structures by railroad and utility officials. Highway, utility, and marine/inland waterway officials had higher environmental perceptions of wood than did railroad officials. Highway, utility and marine/inland waterway officials often worked with structures that had greater contact with people than did railroad officials and therefore may have greater concerns for the effect wood has on the environment. Finally, no differences were found among the infrastructure groups perceptions of wood being innovative in infrastructure. Differences were found among the infrastructure groups mean perceived *cost*, *durability*, *design*, *environment*, *maintenance* and *innovation* attributes ratings for wood. Therefore, we failed to reject the hypothesis and there are differences present among the groups perceptions of wood as a construction material.

Benefits of wood in infrastructure could be utilized by manufacturers to best compete in the infrastructure market. First, wood products were perceived by infrastructure groups to have the lowest initial cost of materials tested. Second, wood was perceived to be highly durable in *corrosion resistance* and somewhat durable in *fatigue resistance, mechanical wear/abrasion resistance* and *weathering resistance*. Third, in design attributes, wood was perceived to be highly available, easy in construction and construction equipment was said to be available for wood. Infrastructure officials perceived design standards to be available for wood, but they often were obsolete. Fourth, in the environmental attributes, wood was perceived to be *aesthetically pleasing*, which was supported by interview participants that said wood was a requirement or most desired in aesthetic settings. Also, wood was perceived to be *disposable/biodegradable* due to damage inflicted upon it by decay organisms. *Disposability/biodegradability* is good when disposing of wood, but not always desirable if the structure needs to have a long service life. Fifth, infrastructure officials perceived wood very well in maintenance attributes. Infrastructure officials perceived wood to be *easy to repair* and *easy to modify* in the field. Infrastructure officials perceived maintenance personnel in infrastructure generally to have experience in maintenance with wood. Sixth, in the innovative attributes, wood was perceived to be as *innovative in the environment* as other standard structural materials. All these attributes should be considered by wood products manufacturers in competition in the infrastructure market and 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 infrastructure markets.

Wood products could be improved in several areas to compete better in the infrastructure market. First, in cost attributes, infrastructure groups perceived wood as an expensive material in *maintenance cost* and *life-cycle cost*. Second, wood was perceived to have poor durability in *fire* *resistance* and *biological decay resistance*. This was supported by interview participants statements that wood should be made more fire resistant and the chemical preservatives should be developed that were more effective at controlling biological decay. Third, in design attributes, structural designers were perceived to have *low experience* with wood. Fourth, in the environmental attributes, wood was perceived to be less *environmentally friendly* because of its chemical treatments. Supporting this, interview participants said that treated wood should be developed that had more environmentally safe treatments. Fifth, wood was perceived by most infrastructure officials not to be *recyclable/reusable*, not to have *low environmental effects of material production*, and not to have a high *percent recycled content of material*. Infrastructure officials did not perceive wood to be *easy to inspect* and *standard structure designs in maintenance* were not perceived to be available for wood in most infrastructure areas. Sixth, wood was perceived to be the among the least *innovative material in performance, design, maintenance* and *durability*. These were the areas manufacturers should improve upon in wood products: their prices and their promotions.

Wood products manufacturers who plan to enter or are in the infrastructure market should consider the following strategies to compete better. There should be a greater market approach by the wood products industry. Manufacturers needed to direct market efforts at infrastructure decision-makers through financial, educational and promotional support of a cohesive, financed, wood industry technical group/association in transportation markets. This supports current efforts led by the National Wood in Transportation Information Center. The wood products associations should emphasize education of infrastructure decision-makers on proper use of wood in infrastructure and inform them where suppliers are located. The wood products industry should improve timber construction design details for infrastructure applications that require less maintenance. There is a need for a textbook of wood design in infrastructure applications. Wood must become more cost effective: the benefits received by using wood in infrastructure must be greater than the costs. The prices of large wood products need to be competitive with concrete and steel. The durability of wood needs to be improved. This could be accomplished through improving chemical treatments for wood to make them more environmentally friendly but still lengthen wood's service life. The quality of wood products needs to be improved. Wood products manufactured today are perceived to be lower in quality than those produced in the past. There is a need for improved and standardized wood grading rules that can be easily used by non-wood products people.  Finally, wood products need to be made widely available to infrastructure decision-makers.  There was a general feeling that supply problems existed for wood in infrastructure markets which caused decision-makers to switch to other materials.

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