Chapter 5

Determining Decision Makers' Perceptions of Materials in the United States Marine/Inland Waterway Infrastructure Market

The United States Marine/Inland Waterway Infrastructure Market

The United States marine/inland waterway system provides an opportunity for the wood products industry due to the many possibilities for the use of wood in marine/inland waterway structures. The United States Army Corps of Engineers alone spend 500 million dollars per year for marine structures replacement (National Transportation Strategic Planning Study 1991). This large market has many opportunities for the wood products industry in construction of bulkheads, wharves, docks, piers, lock and dam facilities. Marine/inland waterway structures can be built of wood products, and many structures are being constructed of materials such as steel, reinforced concrete, prestressed concrete, aluminum and plastic. In order to compete in the US marine/inland waterway market, wood products manufacturers need information about the decision makers in charge of design, construction and maintenance of marine/inland waterway structures. Manufacturers need to know why engineers and administrators choose materials implemented in today's marine/inland waterway system. Once this information is identified, wood products manufacturers can develop strategies and compete more efficiently in the marine/inland waterway infrastructure market.

Decision-makers from the marine/inland waterway market were assessed using a mail questionnaire sent to 411 marine/inland waterway officials. After the questionnaires were analyzed, personal interviews were conducted with marine/inland waterway officials in four states (Georgia, Indiana, Maine and Montana). These interviews were used to clarify results found with the questionnaire and to further understand the US marine/inland waterway market. The methodology as outlined in chapter 2 was followed in this study.

Study Objectives

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

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

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

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

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

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

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

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

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

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

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

Each factor is an attribute when possessed by a material. For example, *corrosion resistance* may be a factor used by a marine/inland waterway decision-maker when deciding on materials for pier construction. 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 marine/inland waterway 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 marine/inland waterway decision-maker thought plastic highly possessed the attribute, *corrosion resistance*, then that person may give a 7 rating for plastic possessing that attribute.

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

Results and Discussion:

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

Demographics:

Data analysis began with summary statistics from marine/inland waterway respondents demographic data. A total of 100 marine/inland waterway officials' returned the questionnaire for an adjusted response rate of 24.3%. More than one-half of the respondents worked primarily in design (60.0%) (Table 23). The majority of these respondents held a bachelor of science (BS) degree (49.0%) or master of science (MS) degree (41.8%) (Table 24). More than one-half of these respondents (53.1%) had formal course-work in wood design. Of those who did have formal course-work on wood design, the percentage of marine/inland waterway respondents that said the course(s) were mandatory was 35.1% (Table 25). Marine/inland waterway respondents in the age groups 40 to 49 years (40.4%) and 50 to 59 years (38.4%) represented the largest age categories (Table 26). The 25 or more years of work experience group contained the highest percentage of

marine/inland waterway respondents (38.4%) (Table 27). Over one-half of marine/inland waterway officials (55.7%) said they had guidelines for the use of wood products in marine/inland waterway design, construction or maintenance (Table 28).

Marine/inland waterway respondents said they had designed, constructed or maintained bulkheads (80.0%), marine pilings (75.0%), wharves (59.0%), piers (72.0%), and boat docks (58.0%). Many respondents said they had used formwork and falsework (29.0%), which was expected due to the large amount of concrete construction in the US marine/inland waterway system. The percentage of marine/inland waterway respondents who have worked on structures in other transportation areas was not expected. Many marine/inland waterway respondents worked on highway guardrails (22.0%) and railroad bridges (15.0%) (Table 29). Materials most used by marine/inland waterway respondents in design, maintenance or construction were reinforced concrete (95.0%), steel (91.0%), wood (75.0%) and prestressed concrete (71.0%) (Table 30).

Marine/inland waterway respondents were asked if they had used wood in the last three years in design, construction or maintenance of marine/inland waterway structures. A large percentage (69.1%) of marine/inland waterway respondents said they had used wood in marine/inland waterway structures in the past three years. Marine/inland waterway respondents were asked if they had used engineered wood products for design, construction or maintenance in the past three years and if so, what type of engineered wood products they had used. Less than one-half of respondents (46.4%) had used engineered wood products in marine/inland waterway structures (Table 31). Glue-laminated timber (27.0%) and plywood panels (25.0%) had the highest use in marine/inland waterway structures in the past three years (Table 32). Marine/inland waterway groups were asked if they had plans to use wood products in structure design, construction or maintenance in the next three years. Over one-half of respondents (58.8%) were planning to use wood in marine/inland waterway structures in the next three years (Table 31).

Overall Factor Importance Ratings:

The marine/inland waterway officials rated the following factors for overall importance in a material choice decision: *cost*, *durability*, *maintenance*, *ease of design*, *environmental impact* and *innovativeness of material*. Significant differences were found among their mean factor importance ratings. The factors with the highest mean importance ratings were *durability* (6.26) and *cost* (5.97), which had mean ratings significantly higher than *environmental impact* (5.02),

maintenance (4.89), *ease of design* (3.80) and *innovativeness of material* (3.24). The marine/inland waterways mean importance ratings for *environmental impact* and maintenance were significantly higher than *ease of design* and *innovativeness of material* (Table 38).

Discussion of Overall Factor Ratings:

These results demonstrated that *durability* and *cost* were the most important factors to a marine/inland waterway decision-maker in choosing a structure material. The interview case studies indicated that *durability of materials* was highly important to decision makers because of the damaging forces that surround wood in a marine/inland waterway environment. *Cost of materials* was highly important for the efficient operation of marine/inland waterway structures. This indicates that manufacturers should consider durability and cost most carefully when developing a marine/inland waterway market strategy. *Environmental impact, maintenance, ease of design* and *innovativeness of material* did have a part in the decision on marine/inland waterway materials, but not nearly as great as *durability* and *cost*. The interview case studies demonstrated that *environmental impact* of materials was becoming more important as more environmental regulations were being implemented for both disposal of treated wood and its use in structures near water. Therefore, manufacturers may want to include *environmental impact of materials*.

Overall Material Performance:

Marine/inland waterway officials rated the following materials for perceived overall performance in structures: prestressed concrete, reinforced concrete, steel, aluminum, wood and plastic. Prestressed concrete (5.56) and reinforced concrete (5.52) had the highest mean perceived overall performance, which were significantly higher than steel (5.16), aluminum (4.20), wood (3.84) and plastic (3.58). Their mean perceived performance rating for steel was significantly higher than aluminum, wood and plastic. Their rating for wood was not significantly different from the lowest rated materials, aluminum and plastic (Table 39).

Discussion of Overall Material Performance:

Marine/inland waterway officials perceived wood to be among the materials with the lowest overall material performance. Wood was not perceived to have high overall performance because of its low resistance to *biological decay*, and *mechanical wear/abrasion*, which caused to

have high maintenance needs. Large wood products were also perceived to be expensive, which increased the cost of wood structures. Being that performance includes each of these aspects, wood was thought to have poor overall performance by marine/inland waterway officials. To strengthen wood's competitive position in the marine/inland waterway market, manufacturers need to improve wood's perceived overall performance.

Perceptional Ratings of Cost Factors:

Marine/inland waterway officials were asked to rate 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 these officials' mean cost factor importance ratings. They had mean importance ratings for *low life-cycle cost* (5.73) and *low maintenance cost* (5.54) which were significantly higher than *low initial cost* (5.05) (Table 41).

Discussion of Cost Factors:

Marine/inland waterway officials had the highest importance for *low maintenance cost* and *low life-cycle cost* because they used a great deal of resources maintaining a structure. If a material was less durable, then it could lead to higher maintenance costs. To be more competitive, wood products manufacturers may need to include development of methods to reduce wood maintenance cost. Also, *low life-cycle cost* was important because of the initial cost, maintenance cost and disposal costs were involved in *life-cycle cost*, each of which had above average importance to the marine/inland waterway officials. It is suggested that that manufacturers include material price reduction and development of inexpensive wood disposal methods in their marketing strategies.

Perceptional Ratings of Cost Attributes:

Marine/inland waterway officials were asked to rate the following materials for possession of cost attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the marine/inland waterway officials' mean perceived ratings for each cost attribute ratings for all materials. They had the highest mean *low initial cost* ratings for reinforced concrete (4.70), steel (4.65), and wood (4.63). Their mean perceived ratings for these materials were significantly higher than aluminum (3.89) and plastic (3.35) (Table 42).

Significant differences were found among the marine/inland waterway officials' mean perceived *low maintenance cost* ratings for materials. They had the highest mean perceived *low maintenance cost* rating for reinforced concrete (5.61) and prestressed concrete (5.51), which were significantly higher than all other materials tested. Their mean *low maintenance cost* rating for wood (3.92) was not significantly different than plastic (4.37) (Table 42).

Significant differences were found among the marine/inland waterway officials' mean perceived *low life-cycle cost* ratings for materials. They had the highest mean *low life-cycle cost* rating for reinforced concrete (5.40), which had a significantly higher rating than steel (4.80), aluminum (4.51), plastic (4.17) and wood (4.03). Marine/inland waterway officials had the lowest mean *low life-cycle cost* rating for wood, which was not significantly different from the other lowest mean rated materials, plastic and aluminum (Table 42).

Discussion of Cost Attributes:

Marine/inland waterway officials perceived wood as having *low initial cost*. Wood was an industry standard in marine/inland waterway structures therefore, they were commodity materials and had the lowest initial cost of construction materials. Wood was perceived to have the highest maintenance cost due to its high maintenance requirements in marine/inland waterway structures. Officials perceived wood to have the highest *life-cycle cost*. Interview participants said large wood products (piles and timbers) had high initial costs, high maintenance costs and that disposal of treated wood was becoming expensive. The officials had high perceived *life-cycle costs* for wood because of its high perceived initial, maintenance and disposal costs when used in marine/inland waterways. This suggests that wood products manufacturers need to reduce the initial costs of wood, especially in large wood products. Manufacturers may want to develop structure designs that require less maintenance and implement training programs to educate decision makers on the proper means to maintain wood structures in marine/inland waterway environments. Finally, wood products manufacturers may wish to develop inexpensive methods to dispose of treated wood products in order to decrease decision-makers disposal costs.

Perceptional Ratings of Durability Factors:

Marine/inland waterway 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 marine/inland waterway officials' mean durability factor importance ratings. Marine/inland waterway officials had the highest mean importance rating for *corrosion resistance* (5.94), which was significantly higher than *mechanical wear/abrasion resistance* (5.27), *fatigue resistance* (5.23), *biological decay resistance* (4.64) and *fire resistance* (4.60). Their mean importance rating for *weathering resistance* (5.61) was significantly higher than *biological decay resistance* and *fire resistance*. They had the lowest mean importance ratings for *fatigue resistance*, *biological decay resistance* and *fire resistance*, but each of these factors had above average importance ratings (Table 44).

Discussion of Durability Factors:

Durability was highly important in the marine/inland waterway market due to the harsh conditions in which structural materials were used. The mean importance ratings indicated that marine/inland waterway officials perceived *corrosion resistance* and *weathering resistance* to be the most important durability factors when making a material choice decision, while *biological decay resistance* and *fire resistance* were much lower in importance. *Corrosion resistance* was important because of the effects salt and water had on materials. *Weathering resistance* was highly important because of the water, sun/ultraviolet light and freeze/thaw elements marine/inland waterway structures had to endure. *Biological decay resistance* was less important because many structures in marine/inland waterway environments were constructed with materials that were not susceptible to biological decay. *Fire resistance* had less perceived importance because fires did not occur frequently. This indicates that wood products manufacturers may want to concentrate their marketing efforts on *corrosion resistance* and *weathering resistance* aspects when competing in the marine/inland waterway market. Also, they may need to concentrate a large part of strategic improvements on increasing the perception that wood is biological decay resistant.

Perceptional Ratings of Durability Attributes:

Marine/inland waterway officials were asked to rate the following materials for perceived possession of durability factors: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the marine/inland waterway officials' mean perceived ratings for materials with each durability attribute. They had the highest mean *fatigue*

resistance ratings for prestressed concrete (5.38), steel (5.28) and reinforced concrete (5.22). These mean ratings were significantly higher than their mean *fatigue resistance* ratings for wood (4.17), aluminum (4.17) and plastic (3.83). Marine/inland waterway officials' mean *fatigue resistance* ratings for wood were not significantly different from the other lowest rated materials (Table 45).

Marine/inland waterway officials had the highest *mechanical wear/abrasion* resistance ratings for steel (5.68), which was significantly higher than all other materials tested. They had the next highest mean ratings for reinforced concrete (5.16) and prestressed concrete (5.15), which were significantly higher than aluminum (4.22), plastic (3.42) and wood (3.34). Marine/inland waterway officials' mean rating for wood and plastic were significantly lower than all materials tested. Also, their mean *mechanical wear/abrasion resistance* rating for wood was below average, indicating that they perceived wood to be among the least *mechanical wear/abrasion resistant* materials (Table 45).

Marine/inland waterway officials had the highest mean perceived *fire resistance* ratings for reinforced concrete (6.22) and prestressed concrete (6.00). Their mean rating for reinforced concrete was significantly higher than steel (5.31) aluminum (4.21), wood (2.42) and plastic (2.22). Their mean *fire resistance* rating for prestressed concrete and steel were significantly higher than aluminum, wood and plastic. Marine/inland waterway officials' mean *fire resistance* rating for aluminum was significantly higher than wood and plastic. Their mean ratings for wood and plastic were significantly lower than all materials tested and were well below average. This indicates that marine/inland waterway officials perceive wood to be among the least *fire resistance* materials tested (Table 45).

Marine/inland waterway officials had statistically similar mean perceived *corrosion resistance* ratings for all materials except steel. Their mean perceived *corrosion resistance* rating for steel (3.74) was below average and was significantly lower than all materials tested. Their mean perceived *corrosion resistance* rating for wood (5.10) was statistically similar as their mean ratings for the other highest mean ratings for materials, including plastic (5.58), reinforced concrete (5.52), prestressed concrete (5.44) and aluminum (4.79). Marine inland waterway officials perceive wood to be among the most *corrosion resistant* materials (Table 45).

Marine/inland waterway officials' had the lowest mean perceived *weathering resistance* rating for wood (3.90), which was significantly lower than all materials tested. Their mean

perceived *weathering resistance* ratings for aluminum (5.83), prestressed concrete (5.46), steel (5.36), reinforced concrete (5.22) and plastic (4.83) were all above average, while their mean rating for wood was below average. This indicates that marine/inland waterway officials perceived wood to have little resistance to weathering, and was the least *weathering resistant* of the materials tested (Table 45).

Marine/inland waterway officials had the lowest mean perceived *biological decay resistance* rating for wood (3.22), which was significantly lower than their mean perceived ratings for all other materials tested. Their mean perceived *biological decay resistance* ratings for prestressed concrete (5.90), reinforced concrete (5.72), aluminum (5.58), steel (5.57) and plastic (5.29) were all above average, while their mean perceived rating for wood was below average. Marine/inland waterway officials perceived wood as not being *biological decay resistant* and less resistant to biological decay than all the materials tested (Table 45).

Discussion of Durability Attributes:

Wood products were not perceived to be durable in marine/inland waterway applications, which was shown in the durability attribute ratings. To know what adjustments to make to their strategy, manufacturers need details on the perceived durability of wood. Marine/inland waterway officials perceived wood to be comparable to other low *fatigue resistance* materials. This was due to wood products not being able to withstand the forces exerted upon them by commercial vessels and cargo. Wood was perceived to have low *mechanical wear/abrasion resistance* because it was easily abraded when compared to alternate materials. Wood was perceived to be least *fire resistant* because of the fact that wood, especially treated wood, was flammable. Wood was perceived by officials to be the least *weathering resistant* material because of the water, freeze/thaw and ultraviolet light damage it received in waterway structures. Officials perceived wood to be the least *biological decay resistant* of the materials tested. Participants in marine/inland waterway applications said that wood chemical treatments needed to be improved to make wood more *biological decay resistant*. Unlike alternate materials, officials perceived wood to be more corrosion resistant in marine/inland waterway applications. This indicates that wood products manufacturers may need to need promote the corrosion resistance of wood in marine/inland waterways structures. Also, it is suggested that manufacturers increase the weathering and mechanical wear/abrasion resistance of wood. To increase wood's *weathering* and

mechanical wear/abrasion resistance, manufacturers may want to promote protective wearing surfaces used in wood structures. Finally, manufacturers may need to develop preservative chemicals that are more protective in the marine/inland waterway environment.

Perceptional Ratings of Design Factors:

Marine/inland waterway officials were asked to rate the importance of the following design factors when making a material choice decision: *design standards available, material available, ease of construction, designer's experience with material* and *construction equipment available.* Marine/inland waterway officials had the highest mean importance ratings for *material available* (5.85), which was significantly higher than *design standards available* (5.19) and *construction equipment available* (5.11). No significant differences were found among the marine/inland waterway officials' mean importance ratings for any other design factors. Marine/inland waterway officials had above average mean importance ratings for each design factor, and their lowest mean importance rating was for *construction equipment available* (5.11) (Table 47).

Discussion of Design Factors:

Although design factors were rated less important, manufacturers will need to know which design factors are most important to marine/inland waterway officials to change the design aspects of their strategies. Marine/inland waterway officials had the highest importance for *material available* because this factor determined what materials were used and how a structure was designed. If a material was not available, then the official would have to completely change the design of the structure. This indicates that the manufacturer needs to be sure that materials are kept available to the officials. *Construction equipment available* had the lowest importance to officials because if the equipment was not readily available, a contractor would be hired who has the equipment. Therefore, manufacturers may want to use fewer marketing efforts to keep construction equipment available. All design factors were above average in importance to the marine/inland waterway officials therefore, each has importance as a design factor in the manufacturers market strategy.

Perceptional Ratings of Design Attributes:

Marine/inland waterway officials were asked to rate the following materials for perceived possession of design attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among marine/inland waterway officials' mean perceived design attribute ratings for materials. Marine/inland waterway officials had the highest mean perceived *design standards available* ratings for steel (6.34), reinforced concrete (6.18) and prestressed concrete (6.02). Their mean perceived *design standards available* ratings for these materials were significantly higher than wood (5.34), aluminum (5.00) and plastic (3.74). Their mean perceived *design standards available* ratings for wood and aluminum were significantly higher than plastic. Marine/inland waterway officials perceived wood to be above average in possessing the attribute *design standards available*. Their mean perceived *design standards available* ratings indicated that there were more *design standards available* for wood than for aluminum and plastic, but less when compared to steel, reinforced concrete and prestressed concrete (Table 48).

Marine/inland waterway officials had the highest mean perceived *material available* ratings for reinforced concrete (6.40), steel (6.23) and prestressed concrete (6.17). Their mean perceived *material available* ratings for these materials were significantly higher than wood (5.62), aluminum (5.04) and plastic (4.08). Officials perceived wood as more available than aluminum and plastic but less available than reinforced concrete, steel and prestressed concrete. They perceived wood as above average in availability for marine/inland waterway construction (Table 48).

Marine/inland waterway officials had the highest mean perceived *ease of construction* rating for steel (5.98), wood (5.55) and reinforced concrete (5.53). Their mean perceived *ease of construction* ratings for steel was significantly higher than prestressed concrete (5.26), aluminum (5.00) and plastic (4.24). Their mean perceived *ease of construction* ratings for wood, reinforced concrete, prestressed concrete and aluminum was significantly higher than plastic. Marine/inland waterway officials' perceived wood to be above average and among the highest rated materials in *ease of construction* (Table 48).

Marine/inland waterway officials' highest mean perceived *designer's experience with material* ratings were for reinforced concrete (6.27), steel (6.14) and prestressed concrete (5.64). Their mean perceived *designer's experience with material* ratings for these materials were

significantly higher than wood (5.17), aluminum (4.15) and plastic (3.13). Marine/inland waterway officials mean perceived *designer's experience with material* rating for wood grouped with their rating for prestressed concrete. Their mean perceived rating for wood was significantly higher than aluminum and plastic, but significantly lower than reinforced concrete and steel (Table 48).

Marine/inland waterway officials had highest mean perceived *construction equipment available* ratings for steel (6.12), reinforced concrete (5.89), wood (5.80) and prestressed concrete (5.38). Their mean perceived *construction equipment available* ratings for steel and reinforced concrete were significantly higher than aluminum (5.14) and plastic (4.63). Their mean perceived *construction equipment available* rating for wood was significantly higher than plastic. They perceived wood to be among the highest rated materials, including steel and reinforced concrete, for having *construction equipment available* (Table 48).

Discussion of Design Attributes:

Marine/inland waterway officials perceived wood to be low in possessing the attribute *design standards available*, which was supported by the interview participants. Wood was perceived to be high in availability because it is a standard material used in waterway construction throughout the US. Some interview participants said there was a supply problem with larger wood products, such as pile, but there was no supply problem with smaller wood products. Due to construction workers having knowledge and equipment necessary to work with wood, officials perceived wood to be among the easiest materials in construction. Officials' perceived structural designers to have less experience with wood than with alternate materials. Officials did feel that they had the equipment available for wood construction.

To improve competitive position, manufacturers may want to first make sure *wood products are available* in the required sizes as there is a demand for wood especially in waterway recreation structures. Manufacturers may want to use the perception of wood being *easy in construction* and the perception that *construction equipment is available* with wood to improve promotional efforts. It is suggested that manufacturers may want to improve the *design standards* for wood in waterway structures and make sure that they are available to decision-makers. Finally, wood products manufacturers may need to improve structural *designer's experience with material* through educational programs on proper wood use in marine/inland waterway structures.

Perceptional Ratings of Environmental Factors:

Marine/inland waterway officials were asked to rate the importance of the following environmental design factors when making a material choice decision: *chemically safe*, *aesthetically pleasing*, *disposable/biodegradable*, *low environmental effects of material production*, *recyclable/reusable* and *percent recycled content of material*. Significant differences were found among their mean importance ratings for these environmental factors. Marine/inland waterway officials had the highest mean importance ratings for *chemically safe* (5.66), which was significantly higher than their mean ratings for all other environmental factors. Their mean importance ratings for *aesthetically pleasing* (4.68) and *low environmental effects of material production* (4.22) were significantly higher than *recyclable/reusable* (3.33) and *percent recycled content of material* (2.67). Their mean importance rating for *disposable/biodegradable* (4.08) was significantly higher than their mean importance rating for *recyclable/reusable* (Table 50).

Discussion of Environmental Factors:

Wood products manufacturers may want to include environmental factors in their market strategy to compete more effectively in marine/inland waterways. Officials had the highest importance for the factor *chemically safe* due to regulations against using oil-borne chemicals in US waterways. Also, future environmental regulations on disposal of treated wood and concern for environmental safety around marine structures may have influenced officials' importance for the factor *chemically safe*. The factor *aesthetically pleasing* was important because aesthetics were important to recreational users of marine/inland waterways and considered part of the culture around these recreational structures. *Low environmental effects of material production*, *disposable/biodegradable*, *recyclable/reusable* and *percent recycled content of material* affect the performance of a structure to a smaller degree therefore, these factors were low in importance. This suggests that wood products manufacturers may want to improve their competitive strength in the marine/inland waterway market by including *chemical safety* and *aesthetics* of materials in their marketing strategy.

Perceptional Ratings for Environmental Attributes:

Marine/inland waterway officials were asked to rate the following materials for perceived possession of environmental attributes: reinforced concrete, prestressed concrete, steel, aluminum,

wood and plastic. Significant differences were found among the marine/inland waterway officials mean perceived environmental ratings for wood. They had the highest mean perceived *chemically safe* ratings for prestressed concrete (5.95), steel (5.82), reinforced concrete (5.81) and aluminum (5.64). Their mean perceived *chemically safe* ratings for these materials were significantly higher than wood (5.02) and plastic (5.01) (Table 51).

Marine/inland waterway officials' mean perceived *aesthetically pleasing* rating for wood (5.27) was not significantly different than other highest mean rated materials, including prestressed concrete (5.47), reinforced concrete (5.33), aluminum (5.12) and steel (5.10). Their mean perceived *aesthetically pleasing* rating for these materials was significantly higher than plastic (4.05) (Table 51).

Marine/inland waterway officials had the highest mean perceived *disposable/biodegradable* ratings for wood (4.92), aluminum (4.13) and steel (3.84). They had the lowest mean perceived *disposable/biodegradable* ratings for ratings for reinforced concrete (3.50), prestressed concrete (3.42) and plastic (2.66). Their mean perceived rating for wood was significantly higher than reinforced concrete, prestressed concrete and plastic (Table 51).

Marine/inland waterway officials had the highest mean perceived *recyclable/reusable* ratings for aluminum (5.31) and steel (5.22). Their mean perceived *recyclable/reusable* ratings for aluminum was significantly higher than plastic (4.25), reinforced concrete (3.79), prestressed concrete (3.62) and wood (3.28). Their mean perceived rating for steel was significantly higher than reinforced concrete, prestressed concrete and wood. Their mean perceived *recyclable/reusable* rating for wood was the lowest of mean ratings for materials and was not significantly different from plastic, reinforced concrete or prestressed concrete (Table 51).

Marine/inland waterway officials had the highest mean perceived *percent recycled content of material* rating for steel (4.18) and aluminum (4.14). Their mean perceived *percent recycled content of material* ratings for these materials was significantly higher than reinforced concrete (3.05), prestressed concrete (3.03) and wood (2.41). Also, their mean perceived *percent recycled content of material* rating for plastic (3.84) was significantly higher than for wood, which had the lowest mean perceived rating of all materials tested (Table 51).

Discussion of Environmental Attributes:

Marine/inland waterway officials perceived wood to be among the least *chemically safe* materials due to the fact that wood used in marine inland waterways generally was treated with chemical preservatives. *Chemically safe* was one of the most important factors to the officials, therefore, it is suggested that manufacturers use wood preservative chemicals that are more environmentally safe. Even though wood was perceived less chemically safe than other materials, officials still perceived it to be above average in chemical safety. Therefore, improvements to chemical treatments may not be vital to wood products survival in this market. Wood was perceived to be the most *aesthetically pleasing* material and because of this, interview participants said wood was a cultural requirement in marine/inland waterway recreation facilities. This suggests that manufacturers may want to use the perceptions of wood being *aesthetically pleasing* in promotional efforts.

Officials perceived wood to be low in *recyclability/reusability* and *percent recycled content* because it could be difficult to recycle solid wood products, especially if chemically treated. Also, most wood structural products would not be removed from service until they are broken or decayed. This indicates that a recycling/reuse program for solid wood products may need developing by manufacturers/associations. Finally, officials perceived wood to have high environmental effects when produced. It is suggested that wood products manufacturers/associations promote best management practices in timber harvesting and wood products manufacturing.

Perceptional Ratings of Maintenance Factors:

Marine/inland waterway officials were asked to rate the importance of the following maintenance factors in making a material choice decision: *standard structure designs available*, *field modification easy*, *ease of repair*, *experience in maintenance with material* and *inspection easy*. Significant differences were found among the marine/inland waterway officials' mean importance ratings for these factors. They had the highest mean importance ratings for *experience in maintenance with material* (5.59) and *ease of repair* (5.54). Marine/inland waterway officials' mean importance ratings for these factors were significantly higher than *field modification easy*

(5.09), *standards structures designs available* (4.88) and *inspection easy* (4.75). No significant differences were found among their mean importance ratings for *field modification easy, standard structure designs available* and *inspection easy* (Table 53).

Discussion of Maintenance Factors:

Although less important than durability or cost, maintenance was important to marine/inland waterway officials when making a material choice decision. Marine/inland waterway officials perceived the factors *experience in maintenance with material* and *ease of repair* to be the most important maintenance factors when deciding on a material. The greater experience a marine/inland waterway official had with maintaining a material, the more proficiently that person would be able to maintain the structure made with that material. *Ease of repair* was important because it would allow a decision-maker to reduce maintenance costs. This indicates that wood products manufacturers should center their maintenance improvements on *experience in maintenance with materials* and *ease of repair*. Even though these two factors were perceived to be more important than *field modification easy, standard structure designs available* and *inspection easy*, it should be noted that all these factor were above average in importance to marine/inland waterway officials. Therefore, manufacturers may need to consider each maintenance factor when improving their marketing efforts.

Perceptional Ratings of Maintenance Attributes:

Marine/inland waterway officials were asked to rate the following materials for possession of maintenance attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among the marine/inland waterway officials' mean perceived maintenance factor ratings for materials. They had the highest mean perceived *standard structure designs available* ratings for steel (5.63), reinforced concrete (5.57) and prestressed concrete (5.36), which were not significantly different from each other. Their mean perceived *standard structures designs available* rating for steel was significantly higher than wood (5.02), aluminum (4.51) and plastic (3.40). Their mean perceived *standard structure designs available rating* for wood was not significantly different from reinforced concrete and prestressed concrete, but was significantly higher than their mean perceived ratings for aluminum and plastic (Table 54).

Significant differences were found among the marine/inland waterway officials' mean perceived *field modification easy* ratings for materials. Marine/inland waterway officials had the highest mean perceived *field modification easy* ratings for wood (5.54) and steel (5.20), which were not significantly different from each other. Their mean perceived *field modification easy* rating for wood was significantly higher than aluminum (4.60), reinforced concrete (4.26), plastic (3.61) and prestressed concrete (3.15) (Table 54).

Significant differences were found among the marine/inland waterway officials' mean perceived *ease of repair* ratings for materials. They had the highest mean perceived *ease of repair* ratings for wood (5.38) and steel (5.27), which were not significantly different from each other. Their mean perceived *ease of repair* ratings for these materials were significantly higher than reinforced concrete (4.43), aluminum (4.34) plastic (3.41) and prestressed concrete (3.39) (Table 54).

Significant differences were found among the marine/inland waterway officials' mean perceived *experience in maintenance with material* ratings for materials. They had the highest mean perceived *experience in maintenance with material* ratings for reinforced concrete (5.70), steel (5.56), wood (5.48), and prestressed concrete (5.09). Their mean perceived *experience in maintenance with material* ratings for these materials were not significantly different from each other, but were significantly higher than aluminum (4.22) and plastic (2.89). They had the lowest mean perceived *experience in maintenance with material* ratings for aluminum and plastic (Table 54).

Significant differences were found among the marine/inland waterway officials' mean perceived *inspection easy* ratings for materials. They had the highest mean perceived ratings for steel (5.32), wood (4.77), reinforced concrete (4.77) and aluminum (4.69), which were not significantly different from each other. Their highest mean perceived *inspection easy* rating was for steel, which was significantly higher than prestressed concrete (4.24) and plastic (4.00) (Table 54).

Discussion of Maintenance Attributes:

Marine/inland waterway officials have high importance for maintenance attributes when making a material choice decision. In order to improve competitive strength in this market, manufacturers need to know decision-makers' perceptions of wood products possessing

maintenance attributes. Officials perceived standard structural designs in maintenance for wood to be less available than alternate materials. Wood products were perceived to be the easiest materials to modify in the field and the easiest to repair, which could reduce maintenance costs. Marine/inland waterway officials perceived maintenance personnel to have as much experience with wood as alternate materials. Finally, wood was perceived by officials to be among the easiest materials to inspect. These perceptions of wood should be carefully considered when developing a marine/inland waterway market strategy. To be more competitive in this market, it is suggested that manufacturers increase the availability of *standard designs in maintenance* for wood. Also, these standards should be made more current and easy to understand by decision-makers. Manufacturers may want to increase promotions that wood products are easy to *modify in the field, easy to inspect and easy to repair*.

Perceptional Ratings of Innovation Factors:

Marine/inland waterway 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 marine/inland waterway officials' mean importance ratings for these innovation factors. They had the highest mean importance ratings for *innovative in durability* (5.02), *innovative in maintenance* (4.72), and *innovative in performance* (4.58), which were not significantly different from each other. Their mean importance rating for innovative in durability was significantly higher than *innovative in design* (4.28) and *innovative in the environment* (4.19). No significant differences were found among the marine/inland waterway officials' mean importance ratings for *innovative in maintenance, innovative in performance, innovative in design* and *innovative in the environment* (Table 56).

Discussion of Innovation Factors:

Although innovativeness of material was least important to marine/inland waterway officials and was below average in importance, it still holds some importance in their material choice decision. Marine/inland waterway officials perceived *innovative in durability, innovative in maintenance* and *innovative in performance* to be the most important innovation attributes. Marine/inland waterway officials felt that it was important for a material to offer a new position or

change in durability or maintenance. This suggests that it would be more important for manufacturers to develop improvements in strategy to improve *maintenance* of materials (possibly through less maintenance requirements) and increase durability and performance of materials. *Innovative in design* and *innovative in the environment* were less important to the officials, but they were above average in importance and should be included in market strategy.

Perceptional Ratings of Innovation Attributes:

Marine/inland waterway officials were asked to rate the following materials for possession of innovation attributes: reinforced concrete, prestressed concrete, steel, aluminum, wood and plastic. Significant differences were found among their mean perceived innovation ratings for materials. They had the highest mean perceived *innovative in performance* rating for plastic (4.90) and prestressed concrete (4.34). Their mean perceived *innovative in performance* ratings for plastic was significantly higher than aluminum (4.25), steel (4.07), reinforced concrete (3.91) and wood (3.85). Officials had the lowest mean perceived *innovative in performance* ratings for wood, which was not significantly different from prestressed concrete, aluminum, steel, and reinforced concrete (Table 57).

Significant differences were found among the marine/inland waterway officials' mean perceived *innovative in design* ratings for materials. They had the highest mean perceived *innovative in design* ratings for plastic (4.85), prestressed concrete (4.52), aluminum (4.32) and steel (4.31). Officials' mean perceived *innovative in design* rating for plastic was significantly higher than reinforced concrete (4.09) and wood (3.93). Also, their mean *innovative in design* rating for prestressed concrete was significantly higher than wood. Officials had no significant differences between their lowest mean perceived *innovative in design* rating for wood, which was not significantly different from their mean perceived ratings for aluminum, steel and reinforced concrete (Table 57).

Marine/inland waterway officials had the highest mean perceived *innovative in maintenance* ratings for plastic (4.60), aluminum (4.25), prestressed concrete (4.22), reinforced concrete (4.05) and steel (4.01). One significant difference was found among the officials' mean perceived *innovative in maintenance* ratings for materials. Their mean perceived *innovative in maintenance* rating for plastic was significantly higher than wood (3.98). Officials' mean

perceived *innovative in maintenance* rating for wood was not significantly different from aluminum, prestressed concrete, reinforced concrete and steel (Table 57).

Significant differences were found among the marine/inland waterway officials' mean perceived *innovative in durability* ratings for materials. They had the highest mean perceived *innovative in durability* ratings for prestressed concrete (4.71), reinforced concrete (4.58), plastic (4.46), aluminum (4.32) and steel (4.04). Their mean perceived *innovative in durability* ratings for these materials were not significantly different from one another. Their mean perceived *innovative in durability* ratings for prestressed concrete and reinforced concrete were significantly higher than wood (3.61). Officials' mean perceived *innovative in durability* rating for wood was not significantly different from plastic, aluminum and steel (Table 57).

Significant differences were found among the marine/inland waterway officials mean *innovative in the environment* ratings for materials. They had the highest mean perceived *innovative in the environment* ratings for plastic (5.03) and aluminum (4.28). Their mean perceived *innovative in the environment* ratings for these materials were not significantly different from one another. Marine/inland waterway officials mean perceived *innovative in the environment* rating for plastic was significantly higher than their mean perceived ratings for prestressed concrete (4.16), steel (4.15), wood (4.08) and reinforced concrete (4.00). Their mean perceived *innovative in the environment* rating for wood was not significantly different from aluminum, prestressed concrete, steel, and reinforced concrete (Table 57).

Discussion of Innovation Attributes:

Marine/inland waterway officials perceived wood to be the least innovative of all materials tested. Their mean perceived ratings indicate that they felt wood was below average in possessing each innovation attribute. This indicates that they did not perceive wood to be new, an improvement or a change in any attribute. Although innovativeness is least important in a material choice decision, it is recommended that wood products manufacturers consider making changes to improve the innovativeness of wood. The most important areas to include innovations, or improvements, in wood products would be in durability and maintenance.

Case Study Interviews:

Interviews were conducted in four states, including Georgia, Indiana, Maine and Montana. The interview participants included officials from the US Army Corps of Engineers, port officials, private consulting engineers and State DOT intermodal engineers. In Georgia, one private consulting engineer and five officials from the US Army Corps of Engineers were interviewed. Interviews in Indiana consisted of five officials from the US Army Corps of Engineers. In Maine, two private consulting engineers, two officials from the US Army Corps of Engineers, one port official and one State DOT intermodal engineers were interviewed. Two officials from the US Army Corps of Engineers were interviewed in Montana. The results from these interviews are presented as case studies for each state.

Case Study 1: Georgia

Marine/inland waterway structures designed, maintained or constructed by Georgia interview participants were: wharves, navigational locks, dams, docks, bridges, bulkheads, signs systems and buoy markers. Georgia has guidelines for the use of wood products in marine/inland waterway construction which limited the use of creosote treated wood products in certain areas. The US Army Corps of Engineers has specifications for wood products, but the Corps is trying to replace internal specifications with those used in commercial applications.

In the past three years, Georgia participants have used wood products in design, construction and/or maintenance of fendering systems, piles, lock diaphragms, formwork/falsework, and recreation facilities including marinas, docks and pedestrian bridges. Within Georgia waterways, the highest current use of wood products is fendering systems, formwork/falsework, pilings, and marina structures. Participants said the greatest potential or future use of wood products would be in fendering systems, recreational use structures and in formwork/falsework. Participants said they have plans to use wood products in marine/inland waterway construction in the next three years for construction of recreation facilities including marinas, docks and pedestrian bridges.

Problems with the durability of wood used in Georgia marine/inland waterway construction were discussed in the interviews. The main concern is durability of wood in marine applications. Marine borers cause great damage to wood piles and wood construction in marine applications. Also, weathering is said to cause problems with wood products in Georgia waterway

applications, especially around metal/wood connections. One must use weather sealers to protect wood and there often is a problem with nails backing out in marine/inland structures. Finally, participants stated that wood in marine applications could not withstand much abrasion. Participants have seen durability benefits with the use of wood used in marine/inland waterway construction. They said pilings are somewhat abrasion and impact resistant.

Georgia participants saw maintenance benefits to using wood in marine/inland waterway construction. They said unlike many other construction materials, wood in marine and inland waterway structures is workable in the field. Also, maintenance personnel were comfortable with wood or have the knowledge to work with wood in marine/inland waterways and wood is considered easy to repair.

Maintenance problems are cited by Georgia officials in using wood products in marine/inland construction. Participants reported that when repairing wood waterway structures, they often have to completely replace the wood structures or wood parts as there was no way to repair the wood products in the structures. Wood rots very quickly in marine applications, therefore making it a high maintenance material in an industry that only wants to build complete structures and does not want to maintain them. Labor is expensive and decision-makers trying to minimize costs see high-maintenance wood structures as costly.

Participants have seen other problems with wood in marine/inland construction. Wood is not strong enough to use economically and there is a problem with wood having too much deflection under heavy loads. Wood treatments currently used are less toxic to wood decay organisms therefore, the durability of wood is not as great as when the more highly toxic wood treatments were used. They reported that not only has this shortened the working life of wood, but it increases the difficulty in storing wood products for long periods of time. Wood is not economical in heavy marine applications which require large timbers for construction. Finally, wood splintering and warping could be a problem with docks and marinas. The splinters are hazardous to people, and the warping weakened the structures.

Georgia participants cite benefits in using wood in marine/inland waterway construction. Wood works best in fendering systems because it is resilient and could withstand impact from ships while not scaring the ships. Wood is best used in aesthetic applications, for instance, in recreation areas. They reported wood is cheaper in light marine/inland waterway structures, such as for light boat docks, and was widely available in the sizes needed for recreation structures in marine/inland

waterways. Construction/maintenance labor generally have the knowledge to work with wood, and wood generally is easy to work with than concrete or steel. Finally, Georgia participants said wood can support heavy loads (for instance, some timber piles could support twenty tons or more).

Participants were asked what needs to occur to increase the use of wood products in waterway construction. Participants said there is a need to improve the durability of wood products. Decision-makers need technical know-how about wood products. There is a need for an organization to promote wood in industrial applications such as marine and inland waterway transportation. Specifically, Georgia interview participants said more promotional and educational efforts should be directed toward infrastructure decision-makers by the wood products industry.

Case Study 2: Indiana

Indiana marine/inland waterway participants said they have designed, maintained or constructed locks, dams, flood control facilities, and recreation structure such as boat docks/marinas. Indiana does not have guidelines for the use of wood products in marine/inland waterway construction. In the past threes years, participants have used wood products in design, construction and/or maintenance of lock gates, wearing surfaces along gates, piers and decks. Participants said the highest current use of wood products in marine/inland waterway applications in Indiana is wicket dams and recreation facilities such as boat docks/marinas. They reported the greatest potential or future use of wood products in marine/inland waterway construction is in wearing surfaces in locks, formwork/temporary structures, and recreation structures such as boat docks/marinas. In the next three years, Indiana participants said they plan on using wood products in marine/inland waterway construction in wickets in dams, wearing surfaces in locks, formwork/falsework and recreation structures such as boat docks/marinas.

Indiana participants cited problems and benefits with the durability of wood. They said biological decay and mechanical wear/abrasion of non-wearing surfaces (such as wood piles) are the two main problems. The benefits of wood in marine/inland waterway structures are that wood is fatigue resistant and is relatively more abrasion resistant as a rub-guard than concrete or steel, but maybe not as resistant as plastic.

Participants reported they have seen maintenance benefits and problems in using wood. Wood is easy to adjust or modify in the field and is less costly to replace than concrete or steel. Wood required lower technology to maintain and most marine/inland waterway maintenance

workers have the knowledge required to work with wood. Wood is light weight relative to concrete, making maintenance and repairs easier. One problem cited by interview participants is that certain wood species used in marine/inland waterway structures, such as white oak, are becoming harder to obtain in the required sizes. They have to take certain precautions to keep chemical wood treatments from affecting maintenance workers. Also, participants said wood structures require a great deal of costly and time-consuming maintenance that is not seen with other construction materials.

Participants cited problems with wood in marine/inland waterway structures. Overall, wood is not meeting adequate service life because of decay and impact damage. Participants said the cost to replace wood is high and there is a low availability of wood, especially white oak. Wood is not strong enough to use in many waterway applications. Finally, wood splinters and people contacting treated wood are concerned with wood products in marine/inland waterway applications.

Indiana participants said there are benefits in using wood for marine/inland waterway construction. Wood is easier to modify in construction, is easy to machine and requires low technology construction equipment. Wood is light weight relative to some materials such as concrete. Maintenance/construction workers have the knowledge and equipment necessary to work with wood. Wood used in recreation structures is readily available and that they are seeing adequate service life from some wood species such as white oak. Finally, wood is aesthetically pleasing and in recreation use wood is a culture material, which means that people expected wood to be used in recreation areas.

Participants were asked what needs to occur to increase the use of wood products in marine/inland waterway. Wood products should be made more available. Marine/inland waterway decision-makers need unification of suppliers or a list of suppliers of wood materials. There are supply problems with wood causing a switch to other materials in marine/inland waterway use. The cost of wood needs to be reduced to increase the use of wood in marine/inland waterway applications. Durability of wood needs to be improved in marine/inland waterway structures. There is a need to improve wood chemical treatments and make wood last longer. Finally, marine/inland waterway decision-makers need specifications for wood use in marine/inland waterway environments.

Case Study 3: Maine

Marine/inland waterway structures designed, constructed or maintained by Maine participants include: commercial and non-commercial harbor facilitates, floats for berthing, fendering, weirs (for catching herring) which use pilings, bridges, fish piers, cargo piers, ferry systems, port facilities and hurricane barriers. Maine does have guidelines for the use of wood products in marine/inland waterways. Oil-borne preservative treated wood is not allowed below the high-water mark; CCA is the only treatment allowed below the high water mark. Otherwise, American Standards in Testing Materials (ASTM) specifications are used.

Maine participants have used wood products in design, construction and/or maintenance of marine/inland waterway structures in the following wood structures in the past three years: piles, fish piers, ferry piers, small harbor projects, municipal piers, stringers, decking, retaining walls and locks. Participants said the highest current use of wood in marine/inland waterway is in fendering for concrete and steel piers, wharves, fish pens, small municipal/ferry piers and piling. They reported the greatest potential or future use of wood products in marine/inland waterway applications is in floating piers, new wharf construction, small municipal/ferry piers and short span timber bridges. In the next three years, the participants have very few plans to use wood products in marine/inland waterway construction and only plan to maintain the structures they have now.

Participants said there are problems with the durability of wood used in marine/inland waterway construction. They have a great deal of worm damage to wood piles, especially in the mud at tidal areas and wood is susceptible to rot and decay. Wood piles can not withstand the forces that steel can withstand and therefore, there is a switch to steel piles even in smaller ports. Wood chaffs easier when under mechanical abrasion forces and they have some connection design problems which cause splitting in the wood piles when forces are applied. Participants said durability of wood in construction have much to do with maintenance of the wood structures.

Participants reported benefits with the durability of wood used in marine/inland waterway. Wood is fatigue resistant and has repetitive impact resistance unlike some materials such as concrete. Participants stated that wood products will not corrode like steel in salt water applications and unlike steel, wood can withstand fire damage and still be salvaged.

Maine participants have maintenance benefits in using wood products in waterway construction. They said wood is easier to replace than steel because wood structures are easier to fabricate. Wood is light weight and easier to transport than some materials. Maintenance costs

with wood are lower relative to concrete and steel because there is a better supply of wood. Also, the equipment and labor needed to work with wood are not specialized and therefore are cheaper. Wood does not require paint to protect it from corrosion like steel, which reduces maintenance costs. Wood is flexible: one is able to easily modify and adapt wood to fit needs.

Participants have maintenance problems in using wood products in marine/inland waterway construction. Wood breaks under stress more easily than steel, so they have to replace wood construction more often than steel construction. The lower cost of replacing wood construction is the trade-off, therefore, wood is utilized more often than steel. With alternative materials such as concrete and steel, one can fix the individual break (patch concrete, weld parts onto steel, etc.), however, with wood, one has to replace the whole piece. The grades and species of wood needed often are not readily available, which can cause a supply problem in a maintenance situation. Engineered wood products are the possible solution to this availability problem.

Participants reported other problems with wood in marine/inland waterway construction. Wood is not able to support loads of larger boats and vehicles. It is difficult to anchor wood in thin soil and still handle the loads of today's marine transport systems. Vessels are too big and forces exerted by these vehicles are too great to be handled by certain wood products. Participants said wood piles can only reach a certain depth because of the limited size of the wood piles available. Therefore, wood piles are able to hold a limited amount of force often exceeded by today's vessel loads. Depending on the forces applied, there is often a problem with splitting of wood piles. One has to be careful when constructing with treated wood products because drilling holes and cutting treated wood products leave the heartwood exposed to decay organisms. Ice damage occurs to wood piles in cold climates and therefore, a fender or guard is needed to protect wood piles from damage. It is difficult to obtain high quality wood products and there are supply problems with the size of products needed. Participants reported it is difficult to design with wood, and a quality assurance program needs to be available to insure the proper designing with the wood products in marine/inland waterway applications.

Maine participants cited several benefits in using wood in marine/inland waterway construction. Wood is aesthetically pleasing. Wood is cheaper because labor does not need special skills to work with wood and the material itself is less expensive. Wood structures are easier to build, wood is lighter and can be fixed using local materials/labor. Participants said there is an

ample supply of local wood pilings and wood is a renewable resource. Finally, they are seeing adequate life of wood structures in many instances.

Several needs are cited by Maine interview participants for the increased use of wood products in marine/inland waterway construction. There is a need for better availability of quality wood products; they need good treated wood products and longer length wood products. Wood products manufacturers need to implement better promotional efforts and educational efforts about wood products for engineers. The engineers are the ones who determined what structural materials are being used. If wood products manufacturers educate engineers and use promotional resources to reach engineers with information about what wood products are available for marine use, then more wood products could be utilized in marine/inland waterway construction. There is a need for a quality control program. Much construction is being done with less supervision, so the best quality products are needed to achieve quality construction. There are comments that the quality of the wood products is at the bottom of the scale. There needs to be an improved grading system to assure quality wood products are available for use. Proper maintenance programs and education of decision-makers in marine/inland waterway systems need to be implemented. This will increase life expectancy of wood structures and more people will want to use wood products in construction. Finally, wood products needs to be made more durable with less susceptibility to attack from decay organisms. There is a need for research on wood treatment from an environmental and a structure longevity standpoint.

Case Study 4: Montana

In Montana, the primary marine/inland waterway structures are for recreation areas, including docks, pump houses and picnic areas. Montana does not have guidelines for the use of wood products in marine/inland waterway construction. Interview participants said in the past three years they have used wood products in design, construction and/or maintenance of recreation facilities around waterways and lakes, such as picnic tables. Interview participants said the greatest potential or future use of wood products in Montana's inland waterways is in retaining walls, dock construction and maintenance of current structures. In the next three years, interview participants have plans to build fishing piers and possibly expand recreation facilities.

Montana participants cite durability problems and benefits with using wood in marine/inland waterway construction. If wood stays dry, it has adequate service life. Also, wood warps and breaks easily, which decreases its durability.

Montana participants said there are maintenance benefits with using wood in marine/inland waterway structures. Wood is fairly inexpensive and readily available. Wood is easier to repair and easier to replace relative to concrete or steel. Participants are able to replace wood piece by piece in a structure, unlike concrete. No maintenance problems are noted with wood products used in Montana inland waterway structures.

Warping from improperly dried wood is a problem in wood products such as posts. Wood is flammable and people burned wood recreation facilities for firewood or as s form of vandalism. Treated wood, even CCA treated wood, is perceived to be hazardous to construction/maintenance workers and people in contact with the wood waterway structures.

Benefits are seen with wood in Montana inland waterway construction. Wood structures are considered aesthetically pleasing, especially in a recreation facility. Wood is equal in cost to other materials and wood is flexible in construction, unlike concrete. Once concrete is poured, the structure is in place and is not easily moved or modified.

Montana participants suggested to increase the use of wood products in marine/inland waterway construction several things need to occur. The price of wood needs to remain competitive with other materials. Decision-makers need wood to be available for construction. The environmental concerns with treated wood products need to be addressed. Water quality around treated wood products needs to be researched and the information disseminated to waterway construction decision-makers.

Conclusions

Marine/inland waterway officials rated the importance for durability and cost the highest. Durability is important because it extends the service life of structures and reduces the cost for maintenance/replacement of materials in these structures. Cost is important due to the fact that marine/inland waterway officials want to most economically operate marine facilities. Maintenance of materials is important due to the damage incurred by structures in the harsh marine/inland waterway environments. *Environmental impact* is important because officials are

responsible for the environmental effects of structures they design, construct or maintain. *Ease of design* and *innovativeness of materials* do not directly affect the efficient operation of marine/inland waterways, and therefore are perceived to be below average in importance.

Marine/inland waterway officials perceived wood to be below average in overall performance. They perceived prestressed concrete and reinforced concrete to be above average in overall performance of all materials evaluated. Concrete is perceived to have the best overall material performance in marine/inland waterway structures. These results indicate that wood products manufacturers need to improve the overall performance of wood in order to compete more effectively in marine/inland waterway markets. All these factors should be considered by wood products manufacturers in competition in the marine/inland waterway market, and they should be used in promotional and educational programs. Manufacturers should strive to produce wood with these qualities and attempt to improve these qualities to compete effectively in infrastructure markets.

Benefits of wood in marine/inland waterway structures can be utilized by manufacturers to compete effectively in the this market. Wood is perceived to be among the lowest initial cost materials. Wood is perceived to be highly *corrosion resistant.* Wood is perceived to be available, but improvements can be made on the availability of large wood products. Officials perceive wood to be among the most easy to construct, construction equipment is perceived available for wood, and structure design engineers are perceived to have experience with wood. Wood is perceived to be above average in disposability/biodegradability, but this may not be desirable if one wants the marine/inland waterway structure to last.

Wood products can be improved in several areas to compete more effectively in marine/inland waterway markets. Wood is perceived to be among materials with the highest *maintenance cost* and *life-cycle cost*. In durability attributes, officials perceive wood to have low *fatigue resistance, mechanical wear/abrasion resistance*, *fire resistance*, *weathering* and *biological decay resistance*. Officials perceive less design standards to be available for wood in marine/inland waterways than concrete and steel. Wood is perceived to be low in *recyclability/reusability* and *percent recycled content of material*. These were the areas manufacturers should try to improve upon in wood products, their prices and their promotions.

Wood products manufacturers have several strategic options to best compete in the marine/inland waterway market. The cost of wood should be competitive with alternative materials

to increase the use of wood in marine/inland waterway applications. Often it is less expensive to construct with concrete and steel than with wood, especially in many industrial marine/inland waterway applications which require large, expensive wood products for structures. Wood products should be made more available. These decision-makers would like a list of suppliers of wood materials. Supply problems with wood are causing decision-makers to switch to other materials. There is a need to improve the durability of wood products in this area. Chemical wood preservative treatments should be improved to increase wood service life while making treated wood safer in the environment. There is a need to make decision-makers more aware of quality control programs that are in place for wood products such as those provided by the Southern Forest Products Association. The wood products grading system should be improved to assure quality wood products are available for use in marine/inland waterway systems. This may increase life expectancy of wood structures and therefore, more decision-makers might use wood products in marine/inland waterway construction. Decision-makers need technical know-how about wood products and would like specifications for wood use in marine/inland waterway environments. More promotional efforts should be directed toward infrastructure decision-makers by the wood products industry. Decision-makers felt that further training was necessary in the proper use and maintenance of wood in marine/inland waterway systems.

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