A PERCEPTIONAL INVESTIGATION INTO THE ADOPTION OF TIMBER BRIDGES: A NATIONAL COMPARATIVE STUDY

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(Received July 1998)

ABSTRACT

This study follows a 1993 study by the authors that investigated the perceptions of rural bridge materials in twenty-eight states. This current research evaluates the perceptions in twenty continental states not included in the first study. These results are then compared directly with the 1993 research. Perceptions of major rural bridge materials by three distinct groups of decision-makers were investigated within four geographic regions of the United States. Timber, when compared to prestressed concrete, steel, and reinforced concrete was rated lowest in perceived performance within each group and region. Timber was also compared to prestressed concrete, steel, and reinforced concrete on eight preselected attributes. Timber was rated lowest on seven of the eight attributes including *low maintenance, pleasing aesthetics, environmentally safe, low cost, easy to design, long life,* and *high strength.* Only on the attribute of *Easy to construct* did timber rate above reinforced concrete, and timber never rated higher than prestressed concrete on any attribute.

Key words: Timber bridges, rural, perceptions, decision-makers, performance, geographic region.

INTRODUCTION

In 1993 a national study was conducted to measure the perceptions regarding materials used in rural bridge construction. Smith and Bush (1995) concluded that timber had the poorest perception of the four materials measured: steel, prestressed concrete, reinforced concrete, and timber. Attitudes about rural bridge materials were measured from three distinct groups of highway officials that included state department of transportation (DOT) engineers, private consulting engineers, and local highway officials. These three groups are the most important in the material selection process for bridge design and construction. The results of the 1993 study indicated that further educational training and niche marketing practices would be needed to increase the use of timber in bridge construction. To further evaluate the attitudes of highway officials, this research methodology was repeated in 1995 in those continental states that were not included in the first study.

OBJECTIVE

The objective of this study was to determine perceptions regarding timber as a rural bridge material. Specifically, to analyze this objective, the following propositions were investigated:

Wood and Fiber Science, 31(2), 1999, pp. 204–216

Proposition 1. Decision-makers perceive timber to be lower in overall performance than competing rural bridge materials (prestressed concrete, steel, reinforced concrete).

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type (state DOT, private consultant, or local highway official).

Proposition 3. Perceptions of the overall performance of timber as a rural bridge material differ by geographic region.

Proposition 4. Perceptions of the overall performance of timber differ based upon past usage in bridges and previous educational exposure to timber design.

METHODS

Sample and sampling procedure

A stratified sample of highway officials from four distinct geographic regions and three decision-making groups was used. These decision-makers were segmented into three groups: state DOT engineers, private consulting engineers, and local highway officials. These groups are most influential in the bridge material decision because of their involvement in the allocation of bridge replacement funds. In addition, state/local authorities are responsible for 90% of rural bridge maintenance and replacement decisions (USDOT 1989).

To determine if differences exist between geographic regions, four distinct geographic segments were identified. These regions were classified as: **Southwest** (Arizona, Colorado, Nevada, New Mexico, Utah, Wyoming); **Central** (Kansas, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota); **Northeast** (Connecticut, Delaware, Maryland, New Hampshire, New Jersey, Rhode Island); and the *Southeast* (South Carolina and Georgia), (Fig. 1).

These four areas accounted for 30% of bridges replaced since 1982 (FHWA 1992). To establish a representative sample of the various engineering groups, each region was sampled with approximately 230 decision-makers divided between the decision-making groups. Market segmentation is often used to identify distinct customer groups that have homogeneous needs (Wind 1978). This allows tailoring the marketing mix for particular segments and leads to better planning and use of marketing resources (Kotler 1988).

State DOT.—Highway departments in 20 states were contacted by letter requesting a list of engineers involved in rural bridge design, replacement, or maintenance decisions. A random sample consisting of 245 state bridge engineers was selected from this group. The population was stratified to allow each geographical region to be sampled with approximately 60 DOT engineers.

Private Consulting Engineers.—A list of private consultants was requested from the state DOT in the selected states. This was supplemented by firms listed in the American Consulting Engineers Council Directory (1992–1993). A stratified random sample of 379 private consultants was used for the study.

Local Highway Officials.—The emphasis of this study was on rural bridge replacement. Most states have an engineer or appointed official at a county/local level who is responsible for rural bridges. This official makes the routine decisions on maintenance and replacement of rural bridges. A stratified random sample of 304 officials was obtained from directories of local highway officials in the 20 states.

Data collection

A mail questionnaire was used for primary data collection. The questionnaire consisted of three primary areas. The first area used rating scales to collect data concerning overall bridge material performance and the engineers' past experiences with various bridge materials. This information identified exactly how timber is perceived by engineers and provides a basis for the development of marketing strategies.

The second area of the questionnaire used rating questions to collect data concerning how timber compares with prestressed con-

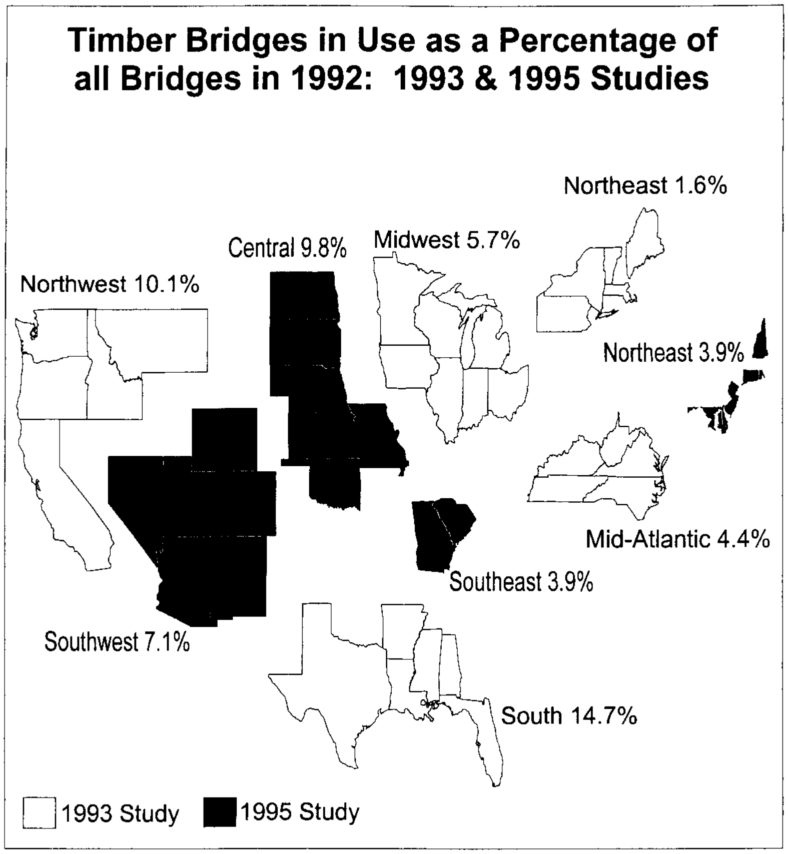

FIG. 1. Timber bridge use by region.

crete, steel, and reinforced concrete on eight preselected attributes. These data will assist in addressing where performance characteristics of timber should be improved. The third area consisted of multicotomous questions to gather information about the respondents.

The questionnaire was successfully pretested and used in the 1993 study. Given the success of the 1993 study, no changes were made to the questionnaire for the current study. In addition, deliberate duplication will facilitate further comparison between the two studies.

A disguised questionnaire with a cover letter explaining the purpose of the study was mailed to 928 engineers in October of 1995. No correspondence stated that the study was being conducted by the Department of Wood Science at Virginia Tech as it was felt that this would bias some respondents answers or have a negative affect on the response rate. In order to increase response rates, a reminder postcard was sent two weeks after the initial mailing. Four weeks following the initial mailing, a second questionnaire was mailed with a cover letter requesting participation from nonrespondents. A second reminder postcard was sent two weeks after the mailing of the second questionnaire.

RESULTS AND DISCUSSION

Analysis of data began with one-way tabulations to identify coding errors, and item nonresponse, to locate outliers, and to calculate summary statistics. Multivariate Analysis of Variance (MANOVA) was used to test significant differences between bridge materials, decision-maker groups, and geographic regions.

Overall response

A total of 491 surveys were returned, 380 of which were usable, resulting in an adjusted response rate of 41%. Nonusable responses were those indicating that the address was incorrect, that the decision-maker was not involved with bridges, or that the private consulting firm was no longer in business.

Nonresponse

Nonrespondents were measured indirectly through a comparison of early questionnaire respondents to late questionnaire respondents. The results of this comparison showed no difference in the perception of timber as a bridge material ($P = 0.78$). In other words, both early and late respondents rated timber the lowest as a bridge material. In addition, examination of the eight material attributes showed no difference between early and late respondents ($P = 0.53$). Other areas of interest showed that early and late respondents were identical in their formal training in timber bridge design and no difference was found in their level of education ($P = 0.60$). Awareness of advances in timber bridge design was the same ($P = 0.26$). In addition, there was no difference in scores for those attending timber bridge conferences ($P = 0.16$). Overall, these results suggest that nonresponse bias was not a problem and that respondents represented their respective populations. These results agreed with the 1993 study in which nonresponse bias was not significant.

Respondents

Thirty-one percent of the respondents were from state DOT offices, 40% were classified as private consultants, and 29% were local or county highway officials. Fifty-two percent classified themselves as design engineers, 12% reviewed design plans, 23% were responsible for maintenance of bridges, and 13% were involved in administration or other activities.

TABLE 1. *Summary of 1995 respondents.*

	Percentage
Decision-maker makeup	
Local officials (n = 163)	29
State DOT (n = 132)	31
Private consultants (n = 196)	40
Decision-maker duties	
Design engineers	52
Design plan reviewer	12
Bridge maintenance	23
Administration/other	13
Bridge plans	
Standardized bridge plans[1]	58
Timber standardized bridge plans[2]	11
Decision-maker training	
Formal timber design training	34
Awareness: new timber designs	45
Improved impressions of timber[3]	59
Material use: past 5 years[4]	
Prestressed concrete	82
Steel	73
Timber	32
Reinforced concrete	81

[1] Respondents in states with standardized bridge plans.
[2] Of the states with standardized bridge plans, those that included timber plans.
[3] Improved impressions of timber due to awareness of recent changes in design.
[4] Materials used by respondent in the past 5 years.

Almost 58% of highway officials said that their state had standard bridge plans, but only 11% of these said that the plans included designs for timber.

Highway officials were asked to state what materials they had used in the past five years in bridge design or replacement. Eighty-two percent of responding officials had used prestressed concrete, 81% had utilized reinforced concrete, 73% had employed steel in bridges, and 32% had experience with timber in bridges in the past five years. Approximately 34% of the respondents had a formal course in timber design, with 39% saying it was mandatory. Forty-five percent of the respondents indicated that they were aware of the recent changes in timber design, with 59% saying that these changes have improved their impression of timber as a bridge material (Table 1).

TABLE 2. *Mean material performance scores by decision-making group and geographic region: 1995 study.*

	Decision-making group (mean response)				
	Overall response[1] (n = 380)	Local officials (n = 110)	State DOT (n = 118)	Private consultant (n = 152)	P-Value univariate "F-test"
Prestressed concrete	5.80	5.85	5.60	5.91	0.06
Steel	5.03	5.10	5.05	4.96	0.45
Timber	3.67	3.71	3.46	3.80	0.14
Reinforced concrete	5.44	5.84	5.28	5.30	<0.01
Multivariate hotellings test: P-value = <0.01					

	Geographic region				
	Central (n = 152)	Northeast (n = 82)	Southeast (n = 31)	Southwest (n = 115)	P-Value univariate "F-test"
Prestressed concrete	5.84	5.65	6.20	5.73	0.01
Steel	5.00	4.99	4.79	5.17	0.39
Timber	3.43	4.20	2.68	3.78	<0.01
Reinforced concrete	5.68	5.01	5.67	5.37	<0.01
Multivariate hotellings test: P-value = <0.01					

MANOVA[2] analysis of decision-making level by geographic region

	P-Value multivariate "f-test"
Prestressed concrete	0.01
Steel	0.23
Timber	<0.01
Reinforced concrete	0.02
Multivariate hotellings test: P-value = <0.01	

[1] Scale 1 (below average) to 7 (above average), average = 4.
[2] Multivariate analysis of variance (MANOVA).

TABLE 3. *Mean material performance scores by decision-making group: 1993 and 1995 studies compared.*

	Overall response[1]	1993 response	1995 response	Independent sample t-test (P value)
Decision level: Local officials				
Prestressed concrete	5.81	5.78	5.85	0.61
Steel	4.94	4.83	5.10	0.07
Timber	3.89	3.99	3.71	0.13
Reinforced concrete	5.64	5.52	5.84	0.02
Decision level: State DOT				
Prestressed concrete	5.75	5.80	5.60	0.09
Steel	4.95	4.92	5.05	0.27
Timber	3.33	3.28	3.46	0.27
Reinforced concrete	5.40	5.44	5.28	0.19
Decision level: Private consultants				
Prestressed concrete	5.88	5.85	5.91	0.49
Steel	4.94	4.92	4.96	0.74
Timber	3.76	3.73	3.80	0.60
Reinforced concrete	5.33	5.35	5.30	0.68

[1] Scale 1 (below average) to 7 (above average), average = 4.

Overall material performance

To determine if differences existed in the perceived overall performance of different bridge materials, several propositions were posed for analysis. The following section describes each proposition and the result:

Proposition 1. Decision-makers perceive timber to be lower in overall performance than competing rural bridge materials (prestressed concrete, steel, and reinforced concrete).

Utilizing a MANOVA, perceptions of timber in 1995 were shown to differ by geographic region but not by decision group. However, timber was rated lowest by all groups and regions (Table 2). Prestressed concrete was rated highest, followed by reinforced concrete, steel, and timber. This was uniform by decision group and geographic region. This finding agrees with conclusions drawn by Dunker and Rabbat (1992) concerning the actual performance of bridges as reported in the National Bridge Inventory database.

In the 1993 study, prestressed concrete also rated the highest, followed by reinforced concrete, steel, and timber. This was uniform across all decision-making groups and all geographic regions. Independent sample t-tests were utilized to compare perceptions of timber by decision level between the two studies (Table 3). No significant difference between the two studies was noted by material across decision-making groups. One exception was a significant difference in the rating of reinforced concrete by local officials (Table 4).

TABLE 4. *Material performance scores by geographic region: 1993 and 1995 studies.*

Material performance scores by geographic region: 1993 & 1995 studies (mean response)

Geographic region	Bridge material: Prestressed concrete	Steel	Timber	Reinforced concrete
Northwest	6.00	4.72	3.80	5.35
South	6.06	4.99	3.32	5.89
Mid-Atlantic	5.86	5.04	3.17	5.38
Northeast (1993)	5.50	4.95	4.01	5.19
Midwest	5.56	4.77	3.99	5.26
Southwest	5.73	5.17	3.78	5.37
Northeast (1995)	5.65	4.99	4.20	5.01
Southeast	6.20	4.79	2.68	5.67
Mid-Central	5.84	5.00	3.43	5.68
P-Value univariate "*F*-Test"	0.00	0.03	0.00	0.00

Scale: 1 to 7

Multivariate hotellings test *P*-Value = 0.00

Overall, these findings agree with conclusions drawn by Dunker and Rabbat (1992) concerning the actual performance of bridges as reported in the National Bridge Inventory database.

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type (state DOT, private consultant, or local highway official).

In 1995, local, state, and private decision-makers rated timber 3.71, 3.46, and 3.80, respectively. Timber ranked last in performance by each level of decision-maker with no significant difference between the ratings (Table 2). These results are contrary to our original proposition.

Comparing the 1993 and 1995 studies, timber rated last in performance by each decision-making group. In 1993, significant differences did exist by decision-making group. Local highway officials, followed by private consultants rated timber the highest in overall performance. State DOT engineers rated timber as the poorest performing bridge material. In 1995, however, no significant differences in timber performance were found between decision-making groups. This may be a result of lower timber bridge use in these regions (Fig. 1), which resulted in limited and a uniform perception of timber. It also may indicate that the 1993 research findings could have slightly influenced this audience. Since 1990, there has been a strong educational effort in support of timber for bridge construction. This effort could have influenced a common perception by highway officials.

Proposition 3. Perceptions of the overall performance of timber as a rural bridge material differ by geographic region.

Significant differences in the perception of timber as a rural bridge material existed by region in 1995 (*P*-value = 0.05). The Northeast and Southwest regions' decision-makers rated timber higher as a bridge material with values of 4.20 and 3.78. The central and Southeast regions' decision-makers rated timber poorest in performance with values of 3.43 and 2.68 (Table 2).

Although the South had the highest number of timber bridges, decision-makers in this region perceived timber to be the poorest performing bridge material. Results from open-ended questions indicated that high decay rates and maintenance requirements were the primary reasons for this perception. This may have been one reason for poorer performance of timber bridges in the South.

As in the 1995 study, the 1993 study found that significant differences in the perception of timber as a rural bridge material existed across all geographic regions (*P*-value = 0.05). In addition, the Northeast and the Midwest regions' decision-makers rated timber higher as a bridge material than the other regions. The Mid-Atlantic region rated timber poorest in performance (Table 4). In the 1995 study, the Northeast and Southwest regions' decision-makers rated timber higher as a bridge material than the other regions. The Southeast region rated timber poorest in performance (Table 4).

Proposition 4. Perceptions of the overall performance of timber differ based upon past usage in bridges and previous educational exposure to timber design.

To analyze this proposition, engineers who have worked with timber in the past five years were compared with those who have not used timber in bridges or bridge design. In 1995, officials who have had a course on timber design during their professional training were compared with those who have not been exposed to timber. Respondents who have utilized timber in the past five years did not rate performance significantly different from those who have not used timber ($P = 0.10$). In addition, there was no difference ($P = 0.73$) in those individuals who have had a course in timber design during their professional career, to those who have not.

These results indicate that people who have tried timber recently do not feel better about timber's performance. Also, those individuals who have had at least one course in timber design feel no different than those who have had no course in timber design. This contradicts a current belief that negative perceptions exist because engineers are not trained in timber design. It may also indicate that more than one course in timber design is needed to improve the engineer's perception of timber. There was no significant difference with the education ($P = 0.32$) or age ($P = 0.18$) of highway officials in their perception of timber as a bridge material.

In the 1993 study, however, respondents who have utilized timber in the past five years felt significantly better ($P < 0.01$) about its overall performance versus those who have not used timber in bridges or bridge design. Timber bridge perceptions were significantly different between the 1993 and 1995 studies ($P < 0.01$). In contrast, there was no difference in either study in those individuals who have had a course in timber design during their professional career, to those who have not (1993: $P = 0.91$, 1995: $P = 0.73$).

From this, the two studies showed conflicting results between the perceptions of those people who have tried timber recently. Both studies agreed that those individuals who have had at least one course in timber design, felt no different than those who have had no course in timber design. There was no significant difference in the education ($P = 0.32$) or age ($P = 0.18$) of the highway officials between the two studies.

Material attributes

Every product can be viewed as possessing a collection of characteristics or attributes that impact its commercial success. These characteristics may be physical and measurable such as modulus of elasticity, market-related as in the case of price, or more nebulous such as quality or value (Trinka et al. 1992). A thorough understanding of these factors will better place timber in the bridge marketplace. By identifying how its product compares with competitive products on these attributes, a manufacturer can better address the requirements of their customers. Eight important attributes were identified in the bridge material choice decision by civil engineers across the United States. These attributes were: *low maintenance, pleasing aesthetics, environmentally safe, low cost, easy to design, easy to construct, long life, and high strength* (Table 5). These attributes were identified by secondary literature search, interviews with engineering faculty at Virginia Tech and personal interviews with highway officials in Virginia. A pretest of the questionnaire further defined the attributes.

On all attributes except *easy to construct,* timber was rated last. Under *easy to construct,* timber managed a second to last rating of 4.80 higher compared to steel at 4.63 (Table 5). Prestressed concrete was the top-rated material in almost every category, falling second to steel in the *high strength* category with ratings of 5.85 and 5.87. Reinforced concrete rated second in every category except *high strength* and *easy to construct.* Within *easy to construct,* reinforced concrete ranked last with a value of 4.63.

Timber was rated significantly higher in 1993 in the attributes of *low maintenance* and

TABLE 5. *Attribute ratings by decision-making group: 1995 study.*

Attribute	Decision-making group (mean response)				
	Overall response[1]	Local officials	State DOT	Private consul-tant	*P*-Value
Low maintenance					
Prestressed concrete	5.88	5.79	5.88	5.92	0.58
Steel	4.37	4.56	4.56	4.10	0.00
Timber	3.71	3.48	3.80	3.80	0.04
Reinforced concrete	5.39	5.65	5.37	5.23	0.01
Pleasing aesthetics					
Prestressed concrete	5.09	5.07	5.07	5.12	0.88
Steel	4.96	4.71	5.16	4.99	0.01
Timber	4.91	4.93	4.81	4.98	0.64
Reinforced concrete	5.05	4.97	4.95	5.17	0.12
Environmentally safe					
Prestressed concrete	5.62	5.54	5.56	5.71	0.44
Steel	4.73	4.85	4.71	4.67	0.68
Timber	4.68	4.55	4.48	4.91	0.03
Reinforced concrete	5.49	5.57	5.39	5.52	0.41
Low cost					
Prestressed concrete	5.23	4.92	5.23	5.44	0.03
Steel	4.35	4.39	4.35	4.32	0.98
Timber	4.31	4.57	4.02	4.33	0.05
Reinforced concrete	4.87	4.92	4.88	4.82	0.74
Easy to design					
Prestressed concrete	5.04	5.29	4.96	4.94	0.13
Steel	5.04	5.20	4.89	5.06	0.26
Timber	4.50	4.55	4.31	4.59	0.25
Reinforced concrete	5.25	5.35	5.28	5.16	0.44
Easy to construct					
Prestressed concrete	5.46	5.43	5.40	5.53	0.65
Steel	5.10	5.10	5.00	5.18	0.27
Timber	4.80	4.78	4.77	4.84	0.84
Reinforced concrete	4.63	4.69	4.73	4.51	0.60

TABLE 5. *Continued.*

Attribute	Decision-making group (mean response)				
	Overall response[1]	Local officials	State DOT	Private consul-tant	*P*-Value
Long life					
Prestressed concrete	5.82	5.89	5.82	5.76	0.67
Steel	5.13	5.25	5.22	4.97	0.09
Timber	3.83	3.88	3.77	3.85	0.89
Reinforced concrete	5.54	5.90	5.45	5.36	<0.01
High strength					
Prestressed concrete	5.85	5.94	5.76	5.85	0.44
Steel	5.87	5.69	5.95	5.06	0.02
Timber	3.63	3.88	3.60	5.92	0.11
Reinforced concrete	5.25	5.72	5.08	3.49	<0.01

[1] Scale 1 (below average) to 7 (above average), average = 4.

easy to construct by local highway officials. In both studies, prestressed concrete and reinforced concrete were the top-rated materials on all of the attributes except *easy to construct* and *high strength* (Table 6).

Criteria important in choosing a bridge material

Respondents were asked to rate the importance of certain factors in their choice of a bridge material. The number one factor was the opinions of other highway officials (peers). Opinion leaders will play a very important role in the transfer of timber bridge technology. Identification of these individuals will assist in continued adoption of modern timber bridges. This was followed by government research, journal articles about materials, and seminars sponsored by material suppliers. All of these can be classified as *educational activities.* Education may reduce the risk that highway officials perceive in trying this technology. Risk is an important factor in the design decision. Not only is safety of the material an issue, but the reputation and professional license of the engineer may be in question if a product fails. Every effort needs to be made

TABLE 6. *Material performance scores by decision-making group: 1993 and 1995 studies compared.*

Attribute ratings by decision-making group: 1993 & 1995 studies (mean response)											
			Local officials			State DOT			Private consultant		
Attribute	Overall response[1] 1993	Overall response[1] 1995	1993	1995	(*P* value)	1993	1995	(*P* value)	1993	1995	(*P* value)
Low maintenance											
Prestressed concrete	5.87	5.88	5.84	5.79	0.72	5.97	5.89	0.43	5.85	5.92	0.49
Steel	4.19*	4.37	4.40	4.56	0.29	4.21	4.56	0.01	4.05	4.10	0.68
Timber	3.71	3.71	3.89	3.48	0.02	3.55	3.80	0.09	3.65	3.80	0.24
Reinforced concrete	5.46	5.39	5.65	5.65	0.97	5.52	5.37	0.25	5.29	5.23	0.67
Pleasing aesthetics											
Prestressed concrete	5.10	5.09	5.14	5.07	0.64	5.14	5.07	0.52	5.12	5.12	0.96
Steel	4.87	4.96	4.55	4.71	0.29	5.04	5.16	0.33	5.00	4.99	0.90
Timber	4.92	4.91	5.16	4.92	0.17	4.68	4.81	0.37	4.91	4.98	0.60
Reinforced concrete	5.05	5.05	5.04	4.97	0.61	5.04	4.95	0.42	5.19	5.17	0.85
Environmentally safe											
Prestressed concrete	5.72	5.62	5.72	5.53	0.18	5.87	5.56	0.01	5.60	5.71	0.30
Steel	4.63	4.73	4.81	4.85	0.85	4.47	4.71	0.08	4.72	4.67	0.69
Timber	4.65	4.68	4.73	4.55	0.30	4.56	4.48	0.62	4.72	4.91	0.17
Reinforced concrete	5.52	5.49	5.55	5.57	0.87	5.62	5.39	0.05	5.46	5.52	0.58
Low cost											
Prestressed concrete	5.18	5.23	4.72	4.92	0.24	5.44	5.23	0.13	5.26	5.44	0.18
Steel	4.26	4.35	4.41	4.39	0.92	4.15	4.35	0.14	4.33	4.32	0.95
Timber	4.41	4.31	4.88	4.57	0.09	3.94	4.02	0.66	4.62	4.33	0.07
Reinforced concrete	4.89	4.87	4.69	4.92	0.13	5.11	4.88	0.07	4.79	4.82	0.81
Easy to design											
Prestressed concrete	5.19	5.04	5.06	5.29	0.17	5.44	4.96	0.00	5.06	4.94	0.39
Steel	4.89	5.04	4.91	5.20	0.06	4.87	4.89	0.89	5.05	5.06	0.94
Timber	4.64	4.50	4.87	4.55	0.06	4.34	4.31	0.84	4.81	4.59	0.11
Reinforced concrete	5.20	5.25	4.94	5.35	0.01	5.44	5.28	0.18	5.15	5.16	0.92

TABLE 6. *Continued.*

Attribute	Overall response[1] 1993	Overall response[1] 1995	Local officials 1993	Local officials (P value)	Local officials 1995	State DOT 1993	State DOT (P value)	State DOT 1995	Private consultant 1993	Private consultant (P value)	Private consultant 1995
Easy to construct											
Prestressed concrete	5.54	5.46	5.37	0.73	5.43	5.72	0.01	5.40	5.52	0.94	5.53
Steel	4.89*	5.10	4.80	0.03	5.10	4.89	0.31	5.00	5.10	0.46	5.18
Timber	5.01*	4.80	5.29	0.00	4.78	4.81	0.77	4.77	4.98	0.31	4.84
Reinforced concrete	4.70	4.63	4.61	0.65	4.69	4.91	0.21	4.73	4.53	0.86	4.51
Long life											
Prestressed concrete	5.86	5.82	5.95	0.70	5.89	5.99	0.11	5.82	5.70	0.56	5.76
Steel	5.02	5.13	4.92	0.02	5.25	5.14	0.50	5.22	5.03	0.56	4.97
Timber	3.80	3.83	4.04	0.36	3.88	3.55	0.10	3.77	3.78	0.61	3.85
Reinforced concrete	5.58	5.54	5.78	0.36	5.90	5.65	0.08	5.45	5.44	0.48	5.36
High strength											
Prestressed concrete	5.91	5.85	5.96	0.87	5.94	5.96	0.05	5.76	5.87	0.87	5.85
Steel	5.88	5.87	5.66	0.84	5.69	5.98	0.75	5.95	5.92	1.00	5.92
Timber	3.72	3.63	4.19	0.07	3.88	3.47	0.37	3.60	3.51	0.89	3.49
Reinforced concrete	5.34	5.25	5.71	0.93	5.72	5.31	0.04	5.08	5.13	0.56	5.06

Attribute ratings by decision-making group: 1993 & 1995 studies (mean response)

* Indicates significant differences in the 1993 and 1995 overall responses (alpha = 0.05).
[1] Scale 1 (below average) to 7 (above average), average = 4.

in reducing the risk the highway official perceives to exist when trying a modern timber bridge (Fig. 2).

Marketing practices reportedly had little influence on the choice of bridge materials. The lowest rated factors were advertisements in magazines, unsolicited sales literature, and trade shows or conventions. Although marketing practices were rated low, highway officials may have been reluctant to indicate that marketing played an important role in the source of information for their decisions. Officials were asked open-ended questions concerning the best locations for timber bridges. Repeatedly the response was *rural areas* and *park areas.*

CONCLUSIONS

This study sought to determine exactly how engineers and highway officials perceived timber on certain important attributes. It examined the twenty remaining continental states not included in the authors' 1993 study and then directly compared the results of the two independent studies. Timber was perceived to be the poorest performing material for bridge applications compared to prestressed concrete, steel, and reinforced concrete. The only attri-

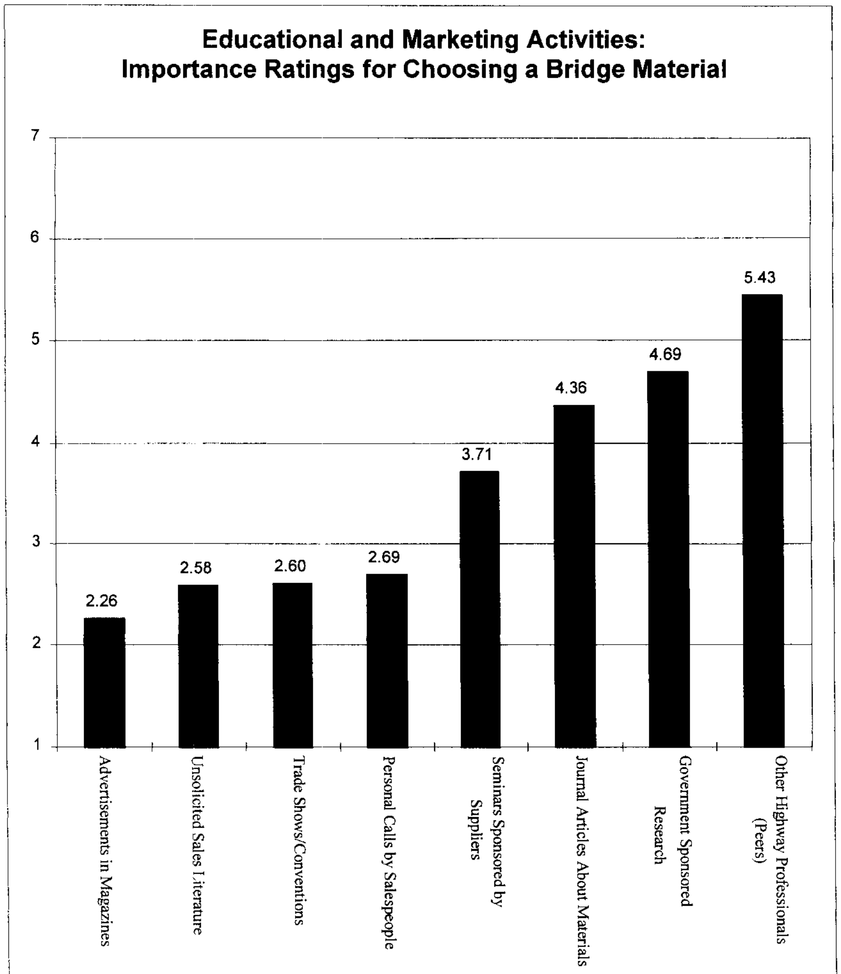

FIG. 2. Decision-makers 1995 ratings of educational and marketing activities.

bute it rated well on was *easy to construct.* Surprisingly, prestressed and reinforced concrete rated higher than timber on the attribute of *pleasing aesthetics.* Respondents did not perceive timber to be different by decision group. In the 1995 study, timber rated higher in the Northeastern U.S., while in the 1993 study, timber rated higher in the Midwest. The education, age, and training of the decision-makers had little effect on their perceptions of timber. Past usage of timber and formal coursework in timber bridge design also had little effect on timber bridge perception.

This research determined that the perceptions of timber as a bridge material between 1993 and 1995 did not change. This is in spite of a concerted effort by the USDA Forest Service, research universities, and private industry. There was no statistical significance between the material ratings by each decision group. This may be due to the short time frame between the two studies (2 years). These results may indicate that the current timber bridge effort will take a number of years before perceptions are changed. As the 1993 study reported, the poorest perceptions of timber are in the southern and southeastern U.S. This is the same area that reported poor actual performance of timber in bridges. The climate in the South favoring higher decay rates of wood may be a primary reason for timber's poor performance. Another reason is that numerous timber bridges have been built without proper design techniques that strongly influence performance. Where a timber bridge has been properly designed, such as in the state of Wisconsin, it has performed better and its perception is higher (Smith and Stanfill-McMillan 1998). Timber also rated similarly on each of the eight attributes measured between the two years. Only on the attribute *easy to construct* did it rate lower in 1995. This was primarily identified in the local highway officials group. Local officials also rated timber lower in 1995 on possessing the attribute of low maintenance. Since these regions built fewer timber bridges than the 1993 study, local officials may not be as familiar with timber that could have influenced this perception.

These results indicate that the perceptions of timber have not changed during the time between the two studies. This is during a time frame that saw increased promotion of timber as a bridge material. The results may indicate that until the performance of new timber bridge designs has a proven track record, perceptions may not change. Those promoting timber bridges need to recognize this in their efforts. Educational activities need to address the fact that new designs will perform better than timber bridges built at the turn of the century. New timber bridge performance must be closely monitored and shared with civil engineers and other highway officials. Supported factual information on initial cost, maintenance cost, and lifecycle cost must be distributed. Timber bridge manufacturers and those who design timber bridges need to address the requirements of reducing maintenance and increasing the lifespan of timber bridges to gain wider acceptance. Designs must also be aimed at reducing total bridge costs. Experts in wood treating must address why timber in bridge use is not lasting the expected 50 years. In addition, marketing activities must further address the *educational needs* of the decision-maker. The greatest opportunity for timber bridges appears to exist in the Northeast and Midwest, where timber is currently perceived higher in performance and attribute ratings, where there is a high level of local control of rural bridges, and where decay is slower than in other regions of the United States.

In conclusion, for increased use of timber for bridge construction, perceptions will be changed only when supporting information on the performance of new timber bridge designs is available. As soon as those promoting timber bridges can supply highway officials with this information, perceptions may change that could result in an increase use of timber for bridge construction.

ACKNOWLEDGMENTS

This research was funded by the USDA Forest Service Northeastern Area State and Private Forestry Wood in Transportation Program in Morgantown, West Virginia, the Cooperative State Research Service, U.S. Department of Agriculture Agreement No. 95-0290, and The Center for Forest Products Marketing and Management at Virginia Tech. The authors want to thank these agencies and all participants for their time and support of this project.

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