A PERCEPTIONAL INVESTIGATION INTO THE ADOPTION OF TIMBER BRIDGES

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ABSTRACT

Perceptions of major bridge materials by four distinct groups of decision-makers were investigated within five geographic regions of the United States. Timber was rated lowest in perceived performance within each group and region. Timber was compared to prestressed concrete, steel, and reinforced concrete on eight preselected attributes. Timber was rated lowest on the attributes of low maintenance, easy to design, long life, and high strength. Only on the attribute of easy to construct did the rating for wood exceed the rating for reinforced concrete. On no attribute did timber rate higher than prestressed concrete. Highway officials who have participated in the Timber Bridge Initiative program rated timber as a bridge material statistically higher in overall performance than those highway officials who have not participated in the program.

Keywords: Perceptions, timber bridges, factor analysis, highway officials.

INTRODUCTION

Traditional market research investigates the purchaser of a product as its consumer. However, many products require design decisions where engineers or other decision-makers are important in product specification. This has been demonstrated recently with the use of timber in modern bridges. Unless bridge engineers and highway officials are willing to utilize timber in their designs, no amount of promotion to the contractor (purchaser) will increase the use of timber for bridge construction.

The need for bridge replacement has been well documented (Brungraber et al. 1987; Cheney 1986; USDA 1989; USDOT 1989). Timber bridges currently represent less than 8% of all United States bridges (FHWA 1992). Other materials include prestressed concrete (15%), reinforced concrete (40%), and steel (37%). However, since 1982, prestressed concrete and reinforced concrete have been used in more than 70% of bridge replacements, while timber represents less than 6%. This suggests that negative perceptions of timber may exist, and it is necessary to understand how highway officials perceive timber on various factors if effective marketing strategies are to be developed. Day et al. (1979) indicate that judgmental data, in the form of perceptions or preferences, may provide insights into future patterns of competition and the reasons for present patterns. Therefore, this knowledge can serve as the basis for strategic planning.

All too often the evaluation of strengths and weaknesses of competing products is limited to tangible characteristics such as price or physical attributes, disregarding intangibles such as consumer perceptions and attitudes (Dickson 1974). However, it is these percep-

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tions that often determine a belief about a material, which results in an attitude that influences the design decision. Hiam and Schewe (1992) state that in marketing one must be concerned with perceptions as much as reality. It is not reality that drives our behavior, but our perception of reality.

Although the importance of perceptional variables in determining purchase behavior is established in marketing literature (Green and Carmone 1970; Johnson 1971; Lehmann and O'Shaughnessy 1974), little information is available concerning perceptions of, and attitudes toward, finished products made of wood. Stalling and Sinclair (1989) explored various materials, including wood, in the residential siding market. Cooper and Kalafatis (1984) investigated various species and end-use products. Blomgren (1965) studied the psychological image of wood. However, to date, little quantitative marketing research has been done involving design engineers' perceptions of various building products or how timber is perceived by various highway officials as a bridge material.

Clapp (1990) and Luppold (1990) conducted qualitative studies concerning perceptions of timber in the Northwest and South, respectively. Both concluded that timber was not perceived well as a bridge material. Dunker and Rabbat (1992) conducted an extensive analysis of the National Bridge Inventory to compare the performance of prestressed concrete and other major bridge materials since 1950. They concluded that prestressed concrete has outperformed all other materials in the past forty years, with timber being the poorest performing material.

Rosenberg et al. (1990) state that the development of many new wood products has been driven by resource availability, cost, and technology—not by customer needs. Yet this is in contrast with the marketing concept wherein the customer is the focal point of product development. In today's marketplace, understanding the needs of the customers and potential customers is becoming more essential to success (Cooper 1988; Porter 1980). This study seeks to improve understanding of highway officials as customers in bridge material decisions.

OBJECTIVE

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

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

The decline in the use of timber during the twentieth century suggests that highway officials do not consider timber to be of the same performance standards as other bridge materials (FHWA 1992). Qualitative investigations suggest that negative perceptions of timber currently exist (Clapp 1990; Luppold 1990).

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type [State Department of Transportation (DOT) engineer, private consulting engineer, or local highway official].

The greatest use of timber is by highway officials at the local unit of government. Over 80% of timber bridges are located on low-volume rural roads (Brungraber et al. 1987). Since these are locations where local highway officials have the greatest influence, this suggests that they perceive timber to be a better performing bridge material than do other decision-makers. Most states have design standards for concrete and steel, but not for timber. This suggests that state DOT engineers do not consider timber a viable option for their bridge needs.

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

Differences exist in the use of timber for bridges by geographic region (FHWA 1992). The South has the greatest number of timber bridges, while the Mid-Atlantic has the smallest number. The Midwest region is less vulnerable to timber decay than the other regions and uses more deicing chemicals. These factors play an important role in the varying uses of timber by region and may influence perceptions of timber as a bridge material.

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

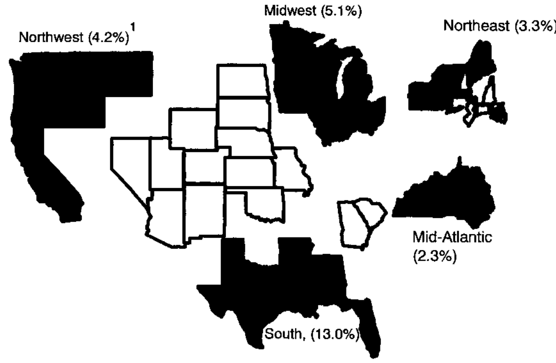

FIG. 1. Percentage of Timber Bridges Built between 1982 and 1992. (1. Number of timber highway bridges constructed divided by the total number of highway bridges built during this period.)

Many timber bridge supporters believe that the decline in timber's use in this century is due, in part, to the lack of training of professional engineers in timber design (Ritter 1990). It is believed that those highway officials who have had a timber engineering design course or have used timber in the past five years would perceive timber to perform better than those individuals who have not used timber or are not trained in designing with timber.

Proposition 5. Timber Bridge Initiative Program participants perceive the overall performance of timber to be higher than do individuals who have not participated in the program.

Efforts by the Timber Bridge Initiative and research institutions are aimed at educating the highway official in modern timber bridges. It is believed that by providing incentives to use timber and design assistance/education, highway officials will improve their perception of timber for bridges. These training efforts will reduce the risk the engineer perceives when adopting new bridge technology.

METHODS

Sample and sampling procedure

A stratified sample of highway officials across five geographic regions and four decision-making groups was used in this study. Highway officials were segmented into three decision-maker groups: State Department of Transportation (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 (USDA 1989).

Individuals who have recently participated in the Timber Bridge Initiative Program (TBIP 1989) were included in the study to allow the comparison of this group to other highway officials and to identify differences that may exist between adopters of new bridge designs and nonadopters.

To determine if differences existed between decision-makers based on geographic regions, five geographic segments were identified. These regions were: Northwest, South, Mid-Atlantic, Northeast, and Midwest (Fig. 1). These five areas accounted for more than 70% of the bridges replaced between 1982 and 1991 (FHWA 1992) and included 28 states. These regions were chosen because of different timber bridge usage, different bridge material selection protocols, and different timber resources. Market segmentation is often used to identify distinct customer groups that have homogeneous needs (Wind 1978). The segmentation used in this study will allow tailoring the marketing mix for particular segments and lead to better planning and use of marketing resources.

State Department of Transportation (DOT) engineers.—Departments of Transportation in twenty-eight states were contacted by letter requesting a list of engineers involved in rural bridge design, replacement, or maintenance decisions. A stratified random sample consisting of 401 state bridge engineers was selected from this group. The population was stratified to allow each geographical region to be sampled with approximately 80 Department of Transportation engineers.

Private consulting engineers.—A list of private consultants was requested from Departments of Transportation in the selected states. This was supplemented by firms listed in the American Consulting Engineers Council Directory (1992–1993). A stratified random sample of 419 private consultants was used for the study.

Local highway officials.—The emphasis of this study is 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 406 officials was obtained from directories of local highway officials in the 28 states (Example: Wisconsin County Commissioners Directory).

Timber Bridge Initiative Program (TBIP) participants.—In 1989 the U.S. Congress funded the National Timber Bridge Initiative to improve rural transportation and local economies by utilizing wood (timber) for bridge construction. More than 270 demonstration bridges in 48 states have been funded under this program as of 1993 (USDA 1993). To determine if differences exist between bridge decision-makers and those involved with innovative timber bridge design, an additional sample of 104 participants from the TBIP in the selected 28 states was included in the study.

Data collection

A mail survey was used for primary data collection as this method is an efficient and cost-effective way of securing data from a wide geographic base (Churchill 1991). The questionnaire consisted of three sections. The first section used rating scales to collect data concerning perceived overall bridge material performance and past experiences with various bridge materials. This information identified how timber is perceived by highway officials and provides a basis for the development of marketing strategies.

The second section of the questionnaire used rating questions to collect data concerning how timber compares with prestressed concrete, steel, and reinforced concrete on eight preselected attributes. These data assist in identifying the areas in which timber must improve its perceived performance characteristics. The third section consisted of multicotomous questions designed to gather information about the respondents. In particular, individuals were asked about past exposure to timber engineering.

The questionnaire was reviewed by knowledgeable civil engineers and university personnel to test its face validity, clarity, and to ensure that no important bridge material selection factor was overlooked. A pretest was then conducted with bridge highway officials in the various decision-making groups in Virginia, Wisconsin, and Minnesota. The responses from this pretest were used to clarify question wording and revise the set of material attributes and factors in the decision-making process.

A disguised questionnaire with a cover letter explaining the purpose of the study was mailed to 1,330 highway officials in April of 1993. 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 effect on the response rate. A total of 848 surveys were returned, 751 which were usable, resulting in an adjusted response rate of 61%. Nonusable responses indicated that the decision-maker was not involved with bridges or that the private consulting firm was no longer in business.

To test for nonresponse bias, 50 nonrespondents were contacted by telephone and asked to answer selected questions. These individuals represented the three primary decision-making groups. They were asked questions concerning material preference, ratings of important bridge material factors, timber design education, and job duties.

Multivariate Analysis of Variance (MANOVA) was utilized to determine if significant differences existed between respondents and nonrespondents on the selected parameters. In no case could the hypothesis of no difference between respondents and nonrespondents be rejected ($\alpha = 0.05$). Since this study is concerned with timber perceptions, Analysis of Variance (ANOVA) was used to determine if respondents and nonrespondents differed. Again, no significant difference at an $\alpha = 0.05$ could be shown. These results suggest that nonresponse bias was not a problem and that respondents represented their respective populations.

Data analysis

Analysis of data began with one-way tabulations to identify coding errors, item nonresponse, locate outliers, and calculate summary statistics. Multivariate Analysis of Variance (MANOVA) was used to test significant differences between bridge materials, decision-maker groups, and geographic regions. Factor analysis was utilized to group material attributes into smaller homogeneous groups for comparison purposes.

RESULTS AND DISCUSSION

Respondents

Forty percent of the respondents were from state DOT offices, 30% were classified as private consultants, and 30% were local or county highway officials. Forty-four percent classified themselves as design engineers, 17% reviewed design plans, 17% were responsible for maintenance of bridges, and 22% were involved in administration or other activities. Nearly 70% of highway officials said that their state had standard bridge plans, but only one-third of these respondents said 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-four percent of responding officials had used prestressed concrete, 79% had utilized reinforced concrete, 68% had employed steel in bridges, and 46% had experience with timber in bridges in the past five years. Approximately 40% of the respondents had had a formal course in timber design, with one-third saying it was mandatory. Fifty-four percent of the respondents indicated that they were aware of the recent changes in timber design, with one-half saying that these changes have improved their impression of timber as a bridge material.

Overall material performance

To determine if differences existed in the perceived overall performance of different bridge materials, the propositions detailed earlier in this paper were investigated. The following sections describe 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, reinforced concrete).

Utilizing Analysis of Variance (ANOVA), perceptions of materials were shown to differ in overall performance. Prestressed concrete was rated highest in overall performance, followed by reinforced concrete, steel, and timber. One-way Analysis of Variance indicated that timber's perceived performance rating of 3.70 was statistically different from the rest of the materials. In fact, all materials were rated statistically different from each other ($P < 0.01$). These findings agree with conclusions

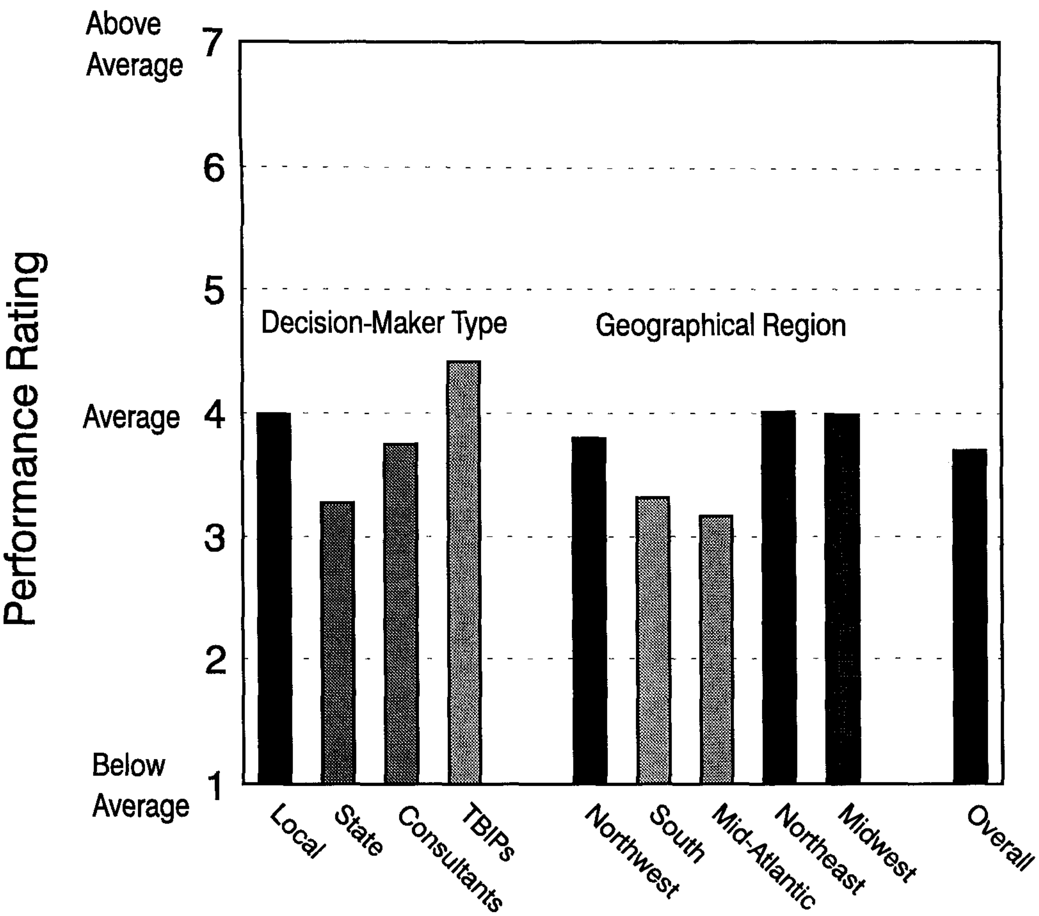

FIG. 2. Perceived Performance Ratings of Timber as a Bridge Material.

drawn by Dunker and Rabbat (1992) concerning the actual performance of bridges as reported in the National Bridge Inventory data base.

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type (State DOT engineers, private consulting engineers, local highway officials).

Timber was rated last in performance by each level of decision-maker (Table 1). Analysis of Variance was used to determine if these ratings differed by type of decision-maker. The results of the ANOVA suggest that significant differences did exist by decision group. Local highway officials rated timber the highest in overall performance (3.99), followed by private consultants (3.73). State DOT engineers rated timber (3.28) the poorest performing bridge material (Fig. 2).

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

Univariate Analysis of Variance indicated that significant differences in the perception of timber as a rural bridge material existed by region at a 0.05 significance level. The Northeast and 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 1).

TABLE 1. *Mean performance scores by material type, decision-making group and geographic region.*

	Decision-making group (mean rating[1])					
	All groups	Local officials	State DOT	Private consultant	TBIP[2]	P-value[3]
Prestressed concrete	5.8	5.8	5.8	5.8	5.5	0.68
Steel	4.9	4.8	4.9	4.9	4.5	0.44
Timber	3.7	4.0	3.3	3.7	4.4	<0.01
Reinforced concrete	5.4	5.5	5.4	5.4	5.1	0.63
	Multivariate Hotellings Test: P-value = 0.00					
	Geographic region					
	Northwest	South	Mid-Atlantic	Northeast	Midwest	P-value
Prestressed concrete	6.0	6.1	5.9	5.5	5.6	<0.01
Steel	4.7	5.0	5.0	5.0	4.8	0.09
Timber	3.8	3.3	3.2	4.0	4.0	<0.01
Reinforced concrete	5.4	5.9	5.4	5.2	5.3	<0.01
	Multivariate Hotellings Test: P-value < 0.01					

Multivariate analysis of variance (MANOVA) Decision-making level by geographic region	P-value multivariate "F-test"
Prestressed concrete	0.04
Steel	0.08
Timber	0.34
Reinforced concrete	0.01
Multivariate Hotellings Test: P-value < 0.01	

[1] Scale 1 (below average) to 7 (above average), average = 4.
[2] Timber Bridge Initiative Participants not included in MANOVA calculations.
[3] Univariate F-test.

Although the South has the highest number of timber bridges, decision-makers in this region perceived timber to be the poorest performing bridge material. The South and Mid-Atlantic states rated timber statistically lower than the other regions. Results from open-ended questions indicate that high decay rates and maintenance requirements are the primary reasons for this perception. Personal interviews in Mississippi indicated that numerous timber bridges are being built without engineering design. This may be one reason for poorer performance of timber bridges in the South.

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, highway officials who have worked with timber in the past five years were compared with those who have not used timber in bridges or bridge design. 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 rated timber significantly ($P < 0.01$) higher in overall performance (4.04) than did those who have not used timber (3.25). However, there was no difference in the ratings ($P = 0.91$) between those individuals who have had a course in timber design (3.69) during their professional career, and those who have not had a course (3.68).

These results indicate that people who have designed a timber bridge recently feel better about its performance and that negative perceptions may exist by those who have not tried timber in the past five years. It is not known, however, if those highway officials who have utilized timber in the past five years felt better about its performance before using timber or if using timber improved their perception.

Unfortunately, those individuals who have had at least one course in timber design rate timber no differently than do those who have had no course in timber design. This contradicts a current belief that negative perceptions exist because highway officials 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 between the education ($P = 0.10$) or age ($P = 0.22$) of highway officials and their perception of timber as a bridge material.

> *Proposition 5.* Timber Bridge Initiative Program participants' perceptions of the overall performance of timber are better than of those individuals who have not participated in the program.

One-way Analysis of Variance indicated that Timber Bridge Initiative Program participants perceived timber to be a better-performing material than did the other decision-making groups ($P < 0.01$). TBIP participants gave timber an overall rating of 4.41, while the mean rating of non-TBIP participants was 3.62. This may not be surprising since many of TBIPs were local officials who rated timber higher than did state or private engineers. It also supports the theory that individuals who have utilized timber in recent years do perceive it to be better than highway officials who have not used timber in design. It suggests that current training efforts by the Timber Bridge Initiative Program may be having some influence on highway officials' perception of timber as a bridge material. It may also suggest that people with higher perceptions of timber are more likely to use this program since some participants may not have built a timber bridge yet support the latter.

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 help to better place timber in the bridge marketplace. By identifying how its product compares with competitive products on selected attributes, a manufacturer can better address customer requirements.

Eight important attributes in bridge material decisions were identified 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 2). On all attributes, except easy to construct, timber was rated equal to or poorer than the other bridge materials.

Multivariate Analysis of Variance indicated that there existed statistical differences between material attribute ratings and decision-making groups. Depending upon the specific attribute, univariate tests indicated differences between some decision groups and the attribute (Table 2). However, prestressed concrete and reinforced concrete were the highest rated materials on all of the attributes except easy to construct and high strength. Figure 3 illustrates these comparisons with all attribute ratings normalized to timber having a value of 1.

Factor-analysis of material attributes

Hair et al. (1992) state that factor analysis can be utilized to examine the underlying patterns or relationships for a large number of variables and to determine whether or not the information can be condensed or summarized in a smaller set of factors or components. Principal component factor analysis is used when the objective is to summarize most of the original information (variance) in a minimum number of factors for prediction purposes.

TABLE 2. *Attribute ratings by decision-maker group.*

Attribute	Decision-maker group (mean rating[1])					P-value[2] univariate *F*-test
	Overall[1]	Local	State	Private	TBIP	
Low maintenance						
Prestressed concrete	5.9	5.8	6.0	5.9	5.5	0.14
Steel	4.2	4.4	4.2	4.0	3.9	0.03
Timber	3.7	3.9	3.6	3.7	4.2	0.03
Reinforced concrete	5.5	5.6	5.5	5.3	5.2	0.02
Pleasing aesthetics						
Prestressed concrete	5.1	5.1	5.1	5.1	4.4	0.98
Steel	4.9	4.6	5.0	5.0	4.4	<0.01
Timber	4.9	5.2	4.7	4.9	5.4	<0.01
Reinforced concrete	5.0	5.0	5.0	5.2	4.6	0.49
Environmentally safe						
Prestressed concrete	5.7	5.7	5.9	5.6	5.4	0.02
Steel	4.6	4.8	4.5	4.4	4.6	0.03
Timber	4.6	4.7	4.6	4.7	4.4	0.33
Reinforced concrete	5.5	5.5	5.6	5.5	5.2	0.23
Low cost						
Prestressed concrete	5.2	4.7	5.4	5.3	4.9	<0.01
Steel	4.3	4.4	4.2	4.3	4.1	0.08
Timber	4.4	4.9	3.9	4.6	4.5	<0.01
Reinforced concrete	4.9	4.7	5.1	4.8	4.7	<0.01
Easy to design						
Prestressed concrete	5.2	5.1	5.4	5.1	4.7	<0.01
Steel	4.9	4.9	4.9	5.1	4.4	0.45
Timber	4.6	4.9	4.3	4.8	4.5	<0.01
Reinforced concrete	5.2	4.9	5.4	5.2	4.9	<0.01
Easy to construct						
Prestressed concrete	5.5	5.4	5.7	5.5	5.1	0.01
Steel	4.9	4.8	4.9	5.1	4.4	0.09
Timber	5.0	5.3	4.8	5.0	5.2	<0.01
Reinforced concrete	4.7	4.6	4.9	4.5	4.4	0.02
Long life						
Prestressed concrete	5.9	6.0	6.0	5.7	5.5	0.01
Steel	5.0	4.9	5.1	5.0	4.7	0.13
Timber	3.8	4.0	3.6	3.8	4.4	<0.01
Reinforced concrete	5.6	5.8	5.6	5.4	5.2	0.01
High strength						
Prestressed concrete	5.9	6.0	6.0	5.9	5.7	0.26
Steel	5.9	5.7	6.0	5.9	5.7	<0.01
Timber	3.7	4.2	3.5	3.5	4.2	<0.01
Reinforced concrete	5.3	5.7	5.3	5.1	5.2	<0.01

[1] Scale 1 (below average) to 7 (above average), average = 4.
[2] Values do not include TBIPs in the MANOVA comparisons.

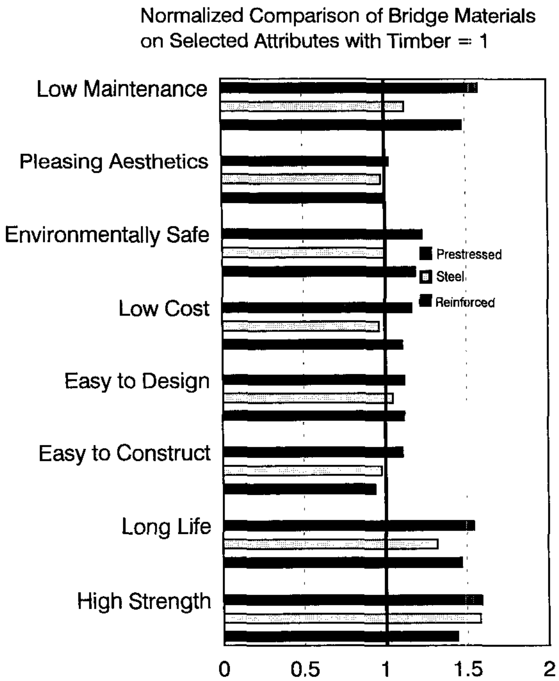

FIG. 3. Material Attribute Rating Normalized to Timber = 1.

Employing a principal components factor analysis to the eight attributes for each bridge material type, two factors with an eigen value greater than 1 resulted. This criterion, according to Stevens (1986), is probably the most widely used in determining the number of factors to be retained. Each attribute's loadings (correlations) on the respective factor exceeded 50%, which according to Dillon and Goldstein (1984) is the test for practical significance. With each of the four separate factor analyses, the same 5 variables loaded on factor 1, and the remaining 3 variables loaded on factor 2 (Table 3). A varimax rotation was employed to assist in the interpretation of variables as suggested by Hair et al. (1992). The first factor was labeled physical characteristics (long life, high strength, low maintenance, environmentally safe, and pleasing aesthetics), while the second factor was labeled decision criteria (easy to design, low cost, and easy to construct).

The reliability of the two factors was assessed using Cronbach's alpha. The cutoff point for internally consistent (reliable) was 0.60 (Bagozzi and Yi 1988; Peter 1979). For each material, the reliability exceeded this minimum, which indicates that the dimensions created by the factor analysis were internally consistent (Table 3).

Following the factor analysis, computation of factor scores is possible to obtain composite observations on each factor. Hair et al. (1992) state that factor scores have the advantage of

TABLE 3. *Factors and factor loadings for bridge materials on eight selected attributes.*

	Material							
	Prestressed concrete		Reinforced concrete		Timber		Steel	
	Factor loading		Factor loading		Factor loading		Factor loading	
Material attribute	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
"Physical characteristics"								
Long life	0.83	0.20	0.71	0.32	0.83	0.16	0.77	0.26
High strength	0.81	0.12	0.73	0.17	0.74	0.20	0.70	0.11
Low maintenance	0.70	0.19	0.67	0.29	0.77	0.13	0.69	0.20
Environmental safety	0.64	0.31	0.69	0.14	0.52	0.15	0.61	0.31
Pleasing aesthetics	0.51	0.32	0.66	0.11	0.65	−0.08	0.66	0.14
Cronbach's alpha	0.78		0.77		0.76		0.76	
"Design decision criteria"								
Easy to design	0.22	0.82	0.23	0.79	0.16	0.79	0.19	0.81
Low cost	0.15	0.81	0.17	0.81	0.12	0.70	0.16	0.73
Easy to construct	0.32	0.77	0.25	0.82	0.06	0.83	0.29	0.73
Cronbach's alpha		0.80		0.80		0.69		0.72

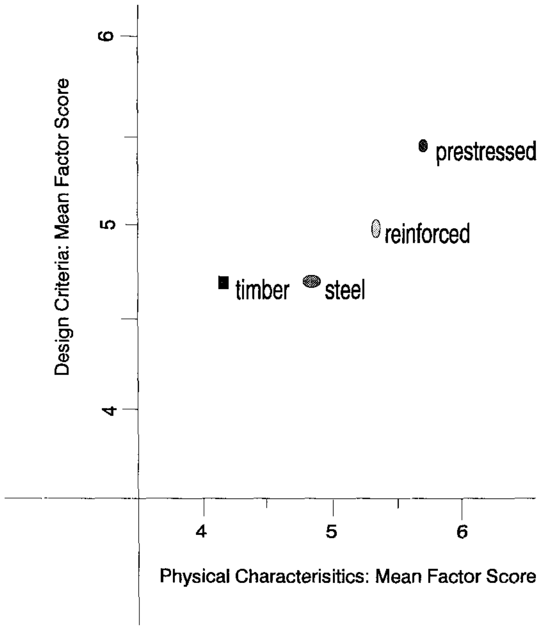

FIG. 4. Perceptions of Bridge Materials on Two Dimensions: Design Criteria on Y-Axis and Physical Characteristics on X-Axis.

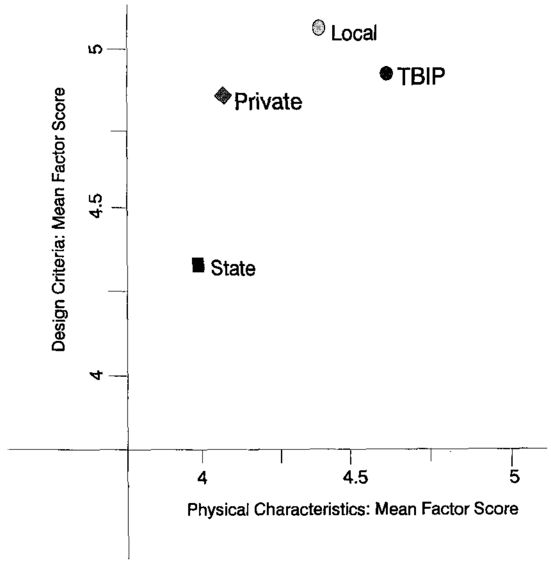

FIG. 5. Perceptions of Timber as a Bridge Material by Decision-Maker Type: Design Criteria on Y-Axis and Physical Characteristics on X-Axis.

representing a composite of all variables loading on the factor, whereas surrogate variables represent only a single variable. A simple method to compute factor scores is to add up the raw scores for any given individual's loading on a factor (Comrey and Lee 1992). Mean factor scores were calculated using this method for each material type: prestressed concrete, steel, timber, and reinforced concrete.

Timber was rated lowest on the physical characteristics dimension and rated only equal with steel on the design criteria dimension (Fig. 4). Timber was rated lowest by state DOT and private engineers on each dimension. Local highway officials rated timber higher on design criteria, while those who had participated in the recent Timber Bridge Initiative Program (TBIP) rated timber higher on physical characteristics (Fig. 5).

Geographically, timber was rated higher on design criteria in the South and lower in the Mid-Atlantic states. On physical characteristics, it was rated higher in the Midwest and lower in the South (Fig. 6). Since the South

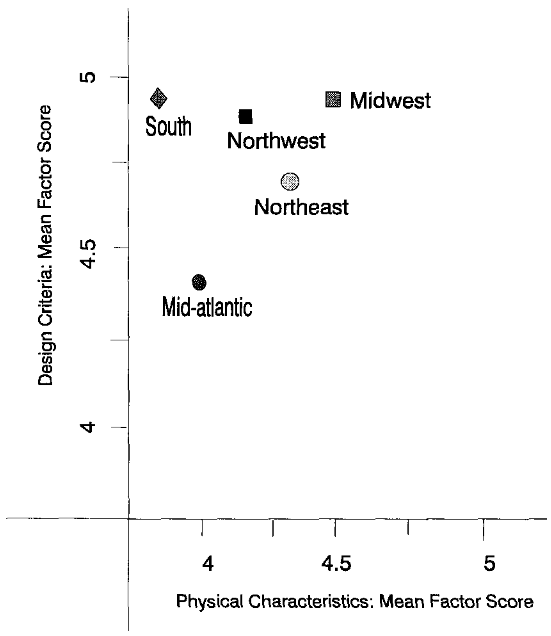

FIG. 6. Perceptions of Timber as a Bridge Material by Geographical Region: Design Criteria on Y-Axis and Physical Characteristics on X-Axis.

and Mid-Atlantic regions had the lowest overall perception of timber, this may indicate that the physical characteristics of the product dominate when a perception is developed. It would also indicate that it is the primary dimension to which manufacturers need to address their efforts to improve timber as a bridge material.

Highway officials who had utilized timber within the past five years rated timber statistically higher than those individuals who had not used timber on both dimensions ($P < 0.01$), while previous educational training in timber design had little effect on their overall ratings of the two dimensions ($P = 0.35$, $P = 0.42$). Those officials who had participated in the Timber Bridge Initiative Program rated physical characteristics higher ($P < 0.01$) than highway officials as a group. These results are supported by those individuals who said they were aware of the recent changes in timber bridge design ($P = 0.04$), have attended a timber bridge conference ($P < 0.01$), felt significantly better about the physical characteristics, than those who were not aware of changes. There was no significant difference between these groups and other officials on the dimension of design criteria. These improvements in perceptions on physical characteristics may be attributed to recent educational activities of the Timber Bridge Initiative Program.

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 other highway officials (peers). Consequently, opinion leaders are likely to 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.

Other factors important in the decision were government research, journal articles about materials, and seminars sponsored by material suppliers. These factors can be classified as educational activities. Education can reduce the risk that highway officials may perceive in trying this new 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 to reduce the actual and perceived risk to highway officials when trying a modern timber bridge.

Marketing practices reportedly had little influence on the choice of bridge materials. The lowest rated factors were advertisements in magazines, personal calls by sales representatives, 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.

CONCLUSIONS

This study sought to determine exactly how engineers and highway officials perceive timber as a highway material. Timber was perceived to be the poorest performing material for bridge applications when compared to prestressed concrete, steel, and reinforced concrete. The only attributes on which timber rated well were easy to construct and pleasing aesthetics. However, prestressed and reinforced concrete rated higher than timber on the attribute of pleasing aesthetics.

Respondents perceived timber differently, based on the decision group to which they belong. Local officials rated timber better than did private consultants and state DOT engineers. Timber rated higher in the Northeast and Midwest regions of the United States. The education, age, and training of decision-makers had little effect on their perceptions of timber. The major factor was past usage of timber, suggesting that perceptions of timber will improve with use of new designs and that people with good perceptions of timber are more likely to use timber. This was also supported by the Timber Bridge Initiative participants who rated timber higher in perceived performance and the dimension physical characteristics.

Timber design engineers 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. Marketing activities must address the educational needs of decision-makers.

The greatest opportunity for timber bridges appears to exist in the Midwest and Northeast, where timber is currently perceived to be higher in performance and attribute ratings, where there is a high level of local control of rural bridges, and where decay is slower than other regions of the United States.

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