4-3-PERCEPTION OF STRUCTURAL MATERIALS BY THE MODULAR HOUSING INDUSTRY

Understanding how the Mid-Atlantic modular housing industry evaluates and assesses its current structural materials is important when trying to determine critical performance needs. Performance needs are important in order to assess the potential substitution of structural materials for traditional sawn lumber and to promote the development of new materials. To determine performance needs of structural materials by the modular housing industry, this study addressed three areas. First, 1997 satisfaction levels of softwood lumber were compared to satisfaction levels in 1992. Second, softwood lumber was compared to engineered lumber products based on five characteristics. Finally, the performance needs of five building applications were compared to the perceived performance of eight structural materials.

Softwood Lumber Satisfaction

Two measures were used to obtain satisfaction discrepancy scores for softwood lumber. The first measure asked respondents to rate the importance of characteristics for product and service quality that might influence their purchase decisions. The second measure asked respondents to rate these same characteristics by how satisfied respondents were with currently available products and suppliers. These characteristics were then ranked by importance and satisfaction levels. A satisfaction discrepancy score was computed using procedures recommended by Borich (1980). These procedures were used to measure and then rank the differences between the importance and satisfaction for each characteristic. The satisfaction discrepancy score was then used to rank perceived market needs. Thirteen softwood lumber characteristics were comparable to Fuch's (1993), 1992 study. These characteristics are found in Table 4-3.1. Five additional characteristics were used for the 1997 study, (1) growth rate (rings/inch), (2) technical assistance, (3) overall product consistency (4) overall product quality, and (5) provide service. The ability of suppliers to provide rapid delivery characteristic used in the 1992 study was changed to the ability of suppliers to provide just-in-time delivery for the 1997 study. Unfortunately, changing this characteristic made it more difficult to compare it with the 1992 study.

Measure one – importance

Importance was measured using a 5-point likert scale with 1 = not important and 5 = very important. Mean importance ratings for each characteristic are presented in Table 4-3.1. In 1992, the top five most important characteristics were (1) competitive pricing, (2) accuracy of dimensions, (3) lumber straightness, (4) reliability of supply, and (5) consistency of grading. In 1997, competitive pricing and reliability of supply were equally the most important characteristic followed by (3) lumber straightness, (4) accuracy of dimension, and (5) consistency of grading. However, the most significant increases between 1992 and 1997 occurred for protective wrapping which increased 8.7 %, the ability of suppliers to arranged credit which increased 7.7 %, and supplier's ability to fill small orders which increased 5.2 %. Increases indicate that these services became more important to respondents over this five-year period. The greatest decreases in importance occurred for end coating (-12.0 %) and rapid/JIT delivery (-10.6 %), indicating that these services became less important to respondents between 1992 and 1997.

Table 4-3.1. Comparisons of mean importance ratings and ranks by respondents in 1992 and 1997

	1992[1] (n = 48)			**1997**[2] (n = 29)			**1992-1997**
	Mean[3]	Standard Deviation	Rank	Mean[3]	Standard Deviation	Rank	% Change
Competitive Pricing	4.81	0.45	1	4.86	0.44	1	1.0
Accuracy Dimension	4.81	0.50	2	4.69	0.66	4	-2.5
Lumber Straightness	4.77	0.47	3	4.83	0.60	3	1.2
Reliability of Supply	4.75	0.48	4	4.86	0.44	1	2.2
Consistent of Grading	4.67	0.56	5	4.55	0.78	5	-2.6
Rapid / JIT Delivery	4.58	0.61	6	4.14	1.16	8	-10.6
Consistent Moisture	4.33	0.86	7	4.38	1.01	7	1.1
Fill Large Orders	4.38	0.79	8	4.34	0.77	9	0.9
Protective Wrapping	4.06	1.12	9	4.45	0.69	6	8.7
Fill Small Orders	3.66	1.18	10	3.86	1.22	10	5.2
Arrange Credit	3.50	1.34	11	3.79	1.32	11	7.7
Trademark	3.00	1.27	12	2.93	1.51	12	-2.4
End Coating	2.98	1.08	13	2.66	1.17	13	-12.0

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers
[3] Five point Likert Scale: 1 = not important to 5 = very important

The five characteristics that were added for the 1997 study were excluded from Table 4-3.1 so that results would be easier to compare with 1992 data. Table 4-3.2 presents the results of the 1997 study to demonstrate how the order of importance changed when these new characteristics were included. While competitive pricing, reliability of supply and lumber straightness remained the top three characteristics, overall product quality moved into the fourth position, followed by accuracy of dimensions and overall product consistency.

Table 4-3.2. Mean importance ratings of product and supplier characteristics by respondents for 1997, (n = 29)

	Mean[1]	Standard Deviation	Rank	Range
Competitive Pricing	4.86	0.44	1	4 – 5
Reliability of Supply	4.86	0.44	1	4 – 5
Lumber Straightness	4.83	0.60	3	3 – 5
Overall Product Quality *	4.76	0.44	4	4 – 5
Accuracy of Dimensions	4.69	0.66	5	3 – 5
Overall Product Consistency *	4.66	0.48	6	4 – 5
Consistent Grading	4.55	0.78	7	2 – 5
Protective Wrapping	4.45	0.69	8	3 – 5
Supplier Provide Service *	4.45	0.78	8	2 – 5
Consistent Moisture Content	4.38	1.01	10	1 – 5
Supplier Fill Large Orders	4.34	0.77	11	3 – 5
Just-In-Time Delivery *	4.14	1.16	12	1 – 5
Supplier Technical Assistance *	3.97	1.30	14	1 – 5
Supplier Fill Small Orders	3.86	1.22	13	1 – 5
Supplier Arrange Credit	3.79	1.32	15	1 – 5
Supplier’s Trademark	2.93	1.51	16	1 – 5
Growth Rate (rings/inch) *	2.72	1.10	17	1 – 5
End Coating	2.66	1.17	18	1 – 5

* New for 1997 study
[1] Five point Likert Scale: 1 = not important to 5 = very important

In addition to mean score, frequency of 5 = very important, was compared for characteristics of the 1992 and 1997 studies. These finding are found in Table 4-3.3. The frequency of very important responses for each characteristic provides an understanding of the difficulties of suppliers to differentiate their product. For each characteristic in 1997, at least one respondent greatly valued this feature. However, it is clear that most respondents found accuracy of dimension, competitive pricing, lumber straightness and reliability of supply very important in both 1992 and 1997. However, the number of respondents who felt accuracy of dimension was very important decreased 16.1 percentage points from 85.1 % in 1992 to 69.0 % in 1997. The number of respondents who felt competitive pricing was very important also decreased 3.7 percentage points from 83.0 % in 1992 to 79.3 % by 1997. This decrease in the importance of competitive pricing might be an indication of a tradeoff between price and quality. Increases were found for lumber straightness, which rose 3.6 percentage points from 79.2 % in 1992 to 82.8 % in 1997 and reliability of supply which decreased from 77.1 % in 1992 to 79.3 % in 1997, a 2.2 percentage point increase. The most significant increases in very important responses between 1992 and 1997 occurred for supplier's trademark which increased 39.6 %, the ability of suppliers to fill small orders which increased 26.9 %, and protective wrapping which increased 17.0 %. The greatest decreases in very important responses between 1992 and 1997 occurred for the presence of end coating (-144.1 %), rapid/JIT delivery (-44.2 %), and accuracy of dimensions (-23.3 %).

Table 4-3.3. Comparison of the frequency of very important responses for products and supplier characteristics by respondents, 1992 and 1997

1992[1]				**1997**[2] (n =29)		**1992-1997**
Characteristic	n	Frequency[3]	% Total	Frequency[3]	% Total	% Change
Accuracy of Dimension	47	40	85.1	20	69.0	-23.3
Competitive Pricing	47	39	83.0	23	79.3	-4.7
Lumber Straightness	48	38	79.2	24	82.8	4.3
Reliability of Supply	48	37	77.1	23	79.3	2.8
Consistent Grade	48	34	70.8	17	58.6	-20.8
Rapid/JIT Delivery	48	31	64.6	13	44.8	-44.2
Fill Large Orders	48	27	56.3	15	51.7	-8.9
Consistent MC	48	26	54.2	16	55.2	1.8
Protective Wrapping	48	22	45.8	16	55.2	17.0
Arrange Credit	48	15	31.3	10	35.7	12.3
Fill Small Orders	47	13	27.7	11	37.9	26.9
Supplier's Trademark	48	6	12.5	6	20.7	39.6
End Coating	48	4	8.3	1	3.4	-144.1

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers
[3] Five point Likert Scale: 1 = not important to 5 = very important

Measure two - satisfaction

Satisfaction was measured using a 5-point likert scale, with 1 = not satisfied and 5 = very satisfied. Comparisons of mean satisfaction ratings between the 1992 and 1997 studies are presented in Table 4-3.4. In 1992, respondents were least satisfied with lumber straightness, consistency of grading and competitive pricing. They were most satisfied with the suppliers' ability to fill large orders, arrange credit, and having the supplier's trademark present. In 1997, respondents were the most dissatisfied with lumber straightness, accuracy of dimension, and consistency of moisture content and most satisfied with the ability of suppliers to fill large orders, reliability of supply, and the presence of protective wrapping. The greatest increases in satisfaction from 1992 to 1997 occurred in protective wrapping that rose 8.1 % and consistency of grade, which increased 7.3 %. The greatest decreases in satisfaction levels between 1992 and 1997 occurred for accuracy of dimensions that fell 12.4 %, lumber straightness, which decreased 10.9 %, and the presence of supplier's trademark, which decreased 6.1 %.

Table 4-3.4. Comparisons of mean satisfaction ratings of product and supplier characteristics by respondents in 1992 and 1997

	1992[1]				**1997**[2] (n = 29)			**1992-1997**
	n	Mean[3]	Standard Deviation	Rank	Mean[3]	Standard Deviation	Rank	% Change
Fill Large Orders	47	4.15	0.81	1	4.14	0.64	1	-0.2
Arrange Credit	45	4.09	1.00	2	3.79	1.05	5	-0.3
Trademark	43	3.98	0.91	3	3.75	0.89	6	-6.1
Accuracy Dimension	46	3.89	0.90	4	3.46	0.96	12	-12.4
Reliability of Supply	47	3.81	0.85	5	4.00	0.93	2	4.8
Fill Small Orders	46	3.74	1.06	6	3.69	0.85	8	-1.4
End Coating	44	3.70	0.88	7	3.69	0.97	8	-0.3
Protective Wrapping	46	3.65	0.87	8	3.97	0.87	3	8.1
Consistent Moisture	47	3.60	0.68	9	3.48	1.09	11	-3.4
Rapid / JIT Delivery	46	3.69	0.96	10	3.86	0.93	4	4.4
Competitive Pricing	47	3.49	0.91	11	3.66	0.90	10	4.6
Consistent Grading	47	3.45	0.77	12	3.72	1.00	7	7.3
Lumber Straightness	47	3.36	0.79	13	3.03	0.87	13	-10.9

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers
[3] Five point Likert Scale: 1 = not important to 5 = very important

Table 4-3.5 presents the mean satisfaction ratings of all characteristics used for the 1997 study. This includes the five characteristics excluded from Table 28. These new characteristics changed the ranking of satisfaction levels. While lumber straightness was still the characteristic respondents were most dissatisfied with; growth rate was second followed by overall product consistency and overall product quality. These last three are all new characteristics.

Table 4-3.5. Mean satisfaction ratings of product and supplier characteristics and rankings, by respondents for 1997 (n = 29)

	Mean[1]	Standard Deviation	Rank	Range
Suppliers Fill Large Orders	4.14	0.64	1	3 – 5
Reliability of Supply	4.00	0.93	2	2 – 5
Protective Wrapping	3.97	0.87	3	2 – 5
Just-In-Time Delivery *	3.86	0.93	4	2 – 5
Suppliers Arrange Credit	3.79	1.05	5	1 – 5
Supplier’s Trademark	3.75	0.89	6	3 – 5
Consistent Grading	3.72	1.00	7	1 – 5
Suppliers Fill Small Orders	3.69	0.85	8	1 – 5
End Coating	3.69	0.97	8	1 – 5
Suppliers Provide Service *	3.66	1.14	10	1 – 5
Competitive Pricing	3.66	0.90	10	1 – 5
Suppliers Technical Assistance *	3.62	0.98	12	1 – 5
Consistent Moisture Content	3.48	1.09	13	2 – 5
Accuracy of Dimensions	3.46	0.96	14	2 – 5
Overall Product Quality *	3.41	0.95	15	1 – 5
Overall Product Consistency *	3.38	0.98	16	1 – 5
Growth Rate (rings/inch) *	3.24	0.58	17	2 – 5
Lumber Straightness	3.03	0.87	18	1 – 5

* New for 1997 study

[1] Five point Likert Scale: 1 = not satisfied to 5 = very satisfied

Satisfaction discrepancy scores

For the 1992 study, satisfaction discrepancy scores were used to assess market needs (Fuchs 1993). Satisfaction discrepancy scores were calculated to identify discrepancies between the importance of product/service characteristics and satisfaction levels of respondents. This procedure was repeated for the 1997 study. A discrepancy or gap between “what is” and what “should be” is a measure of a market need (Borich 1980). Satisfaction discrepancy scores were calculated by subtracting respondents’ satisfaction level (S_{ij}) from the importance level (I_{ij}) of each characteristic. In order to rank perceived market needs through discrepancy scores, each characteristic was multiplied by the mean importance rating (I_I) for that characteristic.

$$DS_{ij} = (I_{ij} - S_{ij})\ I_I$$

This procedure allowed scores to be weighted to distinguish between two or more characteristics with equal discrepancy scores but different market needs (Braktovich and Miller 1983). Table 4-3.6 ranks shared characteristics from the 1992 and 1997 studies, as perceived market needs. Positive mean scores indicate a gap between the importance of a characteristic and the satisfaction level of respondents. A negative mean score indicates the satisfaction level of respondents was greater than the importance of the characteristic. This is the procedure indicated by (Borich) 1980 and used by Fuchs (1993). Any change in scores greater than 0.5 were considered significant.

Table 4-3.6. Comparison of descriptive statistics, based on satisfaction discrepancy scores, by respondents, 1992 and 1997

Variable	**1992**[1]				**1997**[2] (n = 29)			**'92-'97**
	n	Satisfaction Discrepancy	Standard Deviation	Rank	Satisfaction Discrepancy	Standard Deviation	Rank	% Change
Straightness	47	6.90	4.08	1	8.62	4.90	1	20.0
Price	47	6.27	5.16	2	5.79	5.04	3	-8.3
Grade	47	5.66	4.12	3	5.24	5.57	4	-8.0
Rapid/JIT	46	4.48	5.06	4	1.97	4.45	8	-127.4
Supply	47	4.44	4.79	5	4.31	4.73	5	-3.0
Dimension	46	4.39	4.03	6	5.83	6.23	2	24.7
Moist. Content	47	3.22	4.47	7	4.21	5.36	6	23.5
Wrapping	46	2.03	5.12	8	2.48	4.57	7	18.1
Large Orders	47	1.12	3.82	9	0.66	3.39	11	-69.7
Small Orders	46	-0.24	6.24	10	1.93	5.74	9	112.4
Arrange Credit	45	-1.48	5.76	11	0.48	5.83	10	408.3
End Coating	44	-1.90	3.81	12	-1.62	2.16	13	17.3
Trademark	43	-2.51	4.24	13	-0.45	2.86	12	457.8

[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers

In 1992, lumber straightness had the highest discrepancy between importance and satisfaction (Fuchs 1993). Satisfaction discrepancy was also high for competitive pricing, consistency of grade, and the suppliers' ability to provide rapid delivery. In 1997, lumber straightness was found to have the highest discrepancy with the mean score increasing by 1.72 points over 1992 figures. The satisfaction discrepancy score for accuracy of dimension increased from 4.39 in 1992 to 5.83 by 1997. The satisfaction discrepancy score for competitive pricing decreased from 6.27 in 1992 to 5.79 in 1997. There was a slight decrease in the satisfaction discrepancy score for consistent grading from 5.66 in 1992 to 5.24 in 1997. The satisfaction discrepancy score for suppliers' ability to providing rapid delivery decreased from 4.48 in 1997 to 1.97 for 1997 study. The comparison of satisfaction discrepancy scores for the supplier's ability to provide rapid delivery is not very reliable since the wording was changed from providing rapid delivery to just-in-time delivery. In retrospect had the type of delivery been kept the same, interpretation may have been better correlated. In both the 1992 and 1997 studies, differentiation based on the suppliers ability to fill large and end-coat lumber received low ranks. This is an indication that these supplier services either have little perceived market need or that these services are well served in the market.

Lumber straightness had the greatest satisfaction discrepancy score. However, the most significant increases in satisfaction discrepancy between 1992 and 1997 occurred for the presence of supplier's trademark (+ 457.8 %), the ability of suppliers to arrange credit (+ 408.3 %) and the ability of suppliers to fill small orders (+112.4). The most significant decreases in dissatisfaction were found for rapid/JIT delivery, which fell 127.4 % and the ability of suppliers to fill large orders, which decreased 69.7 % (Figure 4-3.1).

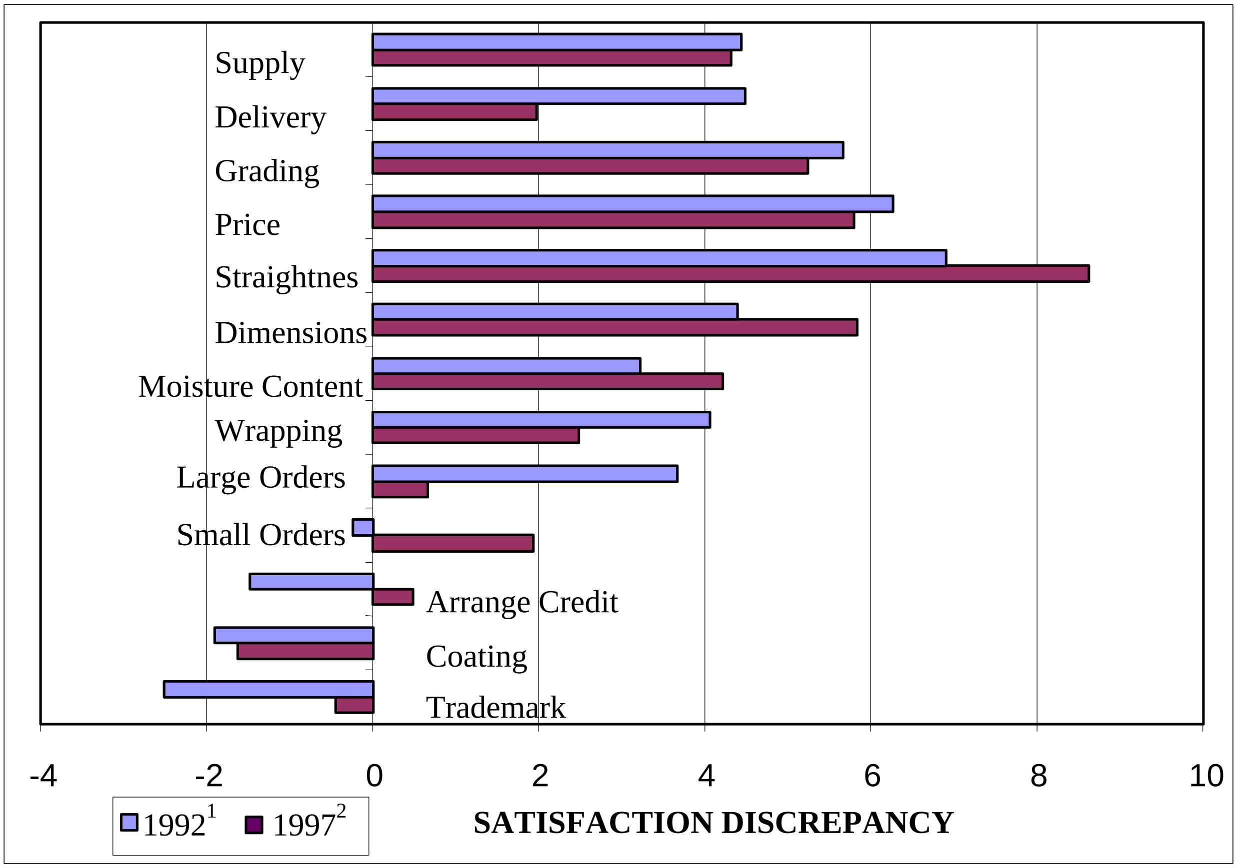


Figure 4-3.1. Changes in satisfaction discrepancy scores, by respondents, 1992 and 1997
[1] Fuchs (1993), study included 30 modular, 16 panelized and 2 pre-cut manufacturers
[2] 1997 study included 29 modular manufacturers

Table 4-3.7 presents the descriptive statistics and ranks for all characteristics used for the 1997 study. Lumber straightness remained the characteristic with the highest level of satisfaction discrepancy. However, the discrepancy score for overall product consistency and overall product quality ranked two and three respectively. These high ranks indicate a high level of discrepancy between importance and satisfaction, indicating that these characteristics might have a high market need that is not well served by the market.

Table 4-3.7. Descriptive statistics for perceived market needs ranked by satisfaction discrepancy scores, 1997 (n = 29)

	Mean[1]	Standard Deviation	Rank
Lumber Straightness	8.62	4.90	1
Overall Product Quality *	6.55	4.93	2
Overall Product Consistency *	6.17	5.40	3
Accuracy of Dimensions	5.83	6.23	4
Competitive Pricing	5.79	5.04	5
Consistency of Grading	5.24	5.57	6
Reliability of Supply	4.31	4.73	7
Moisture Content	4.21	5.36	8
Provide Service *	3.97	5.48	9
Technical Assistance *	2.83	5.61	10
Protective Wrapping	2.48	4.57	11
Just-In-Time Delivery *	1.97	4.45	12
Fill Small Orders	1.93	5.74	13
Fill Large Orders	0.66	3.39	14
Arrange Credit	0.48	5.83	15
Growth Rate	-0.14	3.18	16
Supplier's Trademark	-0.45	2.86	17
End Coating	-1.62	2.16	18

* New for 1997, study

[1] Satisfaction Discrepancy scores

Comparison of Structural Lumber to Engineered Lumber

Respondents were asked to compare engineered lumber products to structural lumber based on: (1) price, (2) knowledge, (3) willingness to use engineered lumber, (4) risk, and (5) quality. Results are presented in Table 4-3.8. Answers were measured on a seven point likert scale, with engineered lumber being 1 = much lower to 7 = much higher than structural lumber, with 4 = same. Respondents viewed engineered lumber products higher in both quality and price than structural lumber. Willingness to use engineered lumber was slightly higher than using structural lumber. Knowledge of engineered lumber products was considered about the same as structural lumber. Using engineered lumber products was viewed as slightly less risky than using structural lumber.

Table 4-3.8. Comparison of engineered lumber products to structural lumber by modular manufacturers, 1997 (n = 29)

	Mean [1]	Standard Deviation	Frequency of 6 & 7	Percent of Total
Price	5.21	1.35	16	55.1
Knowledge	4.10	0.90	3	10.3
Willingness to Use	4.66	1.04	6	20.7
Risk	3.93	1.22	3	10.3
Quality	5.72	0.70	17	58.6

[1] Seven point likert scale: 1 = much lower, 4 = same, and 7 = much higher

Performance Needs of Structural Building Applications

During follow-up interviews, a second questionnaire was administrated to interviewees. This questionnaire had two parts. Part one asked the respondents to evaluate characteristics for five building applications. Importance was measured on a seven point scale, with 1 = not important and 7 = very important. Part two asked respondents to evaluate the performance of eight structural building materials for the same characteristics. Performance was measured on a seven point scale, with 1 = very poor and 7 = excellent. These attributes were selected based on attributes shown to be important in past studies (Fuchs 1993; Hansen 1994; and Reddy 1994), material performance, and other more general characteristics that might be important to the modular housing industry when selecting a structural material for a selected application. These characteristics are found in Table 4-3.9.

Performance Dimensions

For each of the 22 respondents, the five building applications were combined to make 110 observations. These observations were analysis using a factor analysis in order to reduce the number of variables into factors that represented the original characteristics. Initially, the raw data was computed in a non-rotated state in order to obtain a preliminary indication of the number of factors. Examination of a scree plot suggested a three-factor solution. Three factors accounted for 59.942 % of the variance. Increasing the amount of factors beyond three would have only slightly increased variance explained and decreased interpretability. After the number of factors was determined, the raw data was re-analyzed using a varimax rotation. Rotation improves the interpretation by reducing some of the ambiguities that accompany the preliminary analysis (Hair et al. 1987). Varimax rotation was chosen as the rotation method because it maintains factors in an orthogonal position and it is easier to interpret than other methods.

Table 4-3.9, presents the factor loadings for characteristics used to determine important considerations when choosing different building applications (i.e. marriage headers, other headers, wall framing, roof framing, and floor framing). Factor loadings are given for each factor. A factor loading is the correlation between the original characteristics and the factors (Hair et al. 1987). Loadings were considered significant if greater than +/- 0.30. Loadings greater than +/- 0.40 were considered more significant and loadings greater than +/- 0.50 were considered very significant (Hair et al. 1987). In order to place some meaning to a factor, factor loadings were used to assign a name or label to each factor. The greater the significance the more emphasis that characteristic will have on the chosen name.

In Table 4-3.9, characteristics with the highest loadings on each factor are presented in bold print. Characteristics found most significant (0.5 and greater) for factor one were: bending strength, modulus of elasticity (MOE), absence of end splits, straightness, overall consistency, fastener retention, accuracy of dimensions, consistency of grade, and technical assistance. This factor appears to represent product performance. Variables for factor two found greater than 0.50 were warranty, weight, overall quality, hardness, and service. Factor two appears to represent supplier service. Availability, long lengths, appearance, overall consistency, service, and price were the characteristics that were considered very significant for factor 3. Factor 3 appears to represent some measure of product availability and assurance.

Table 4-3.9. Perceived importance factors for structural building applications using varimax rotation, 1998 (n = 22)

VARIABLE	FACTORS		
	1	2	3
Bending Strength	**0.820**	0.171	0.003
MOE	**0.800**	0.204	-0.003
End Split	**0.769**	-0.086	0.158
Straightness	**0.630**	-0.069	0.408
Fastener Retention	**0.561**	0.245	0.147
Dimensions	**0.521**	0.195	0.448
Grade	**0.512**	0.148	0.465
Technical	**0.503**	0.438	0.106
Warranty	0.040	**0.861**	0.010
Weight	0.152	**0.820**	0.003
Quality	0.242	**0.817**	0.260
Hardness	0.063	**0.797**	0.089
Service	0.068	**0.636**	0.581
Availability	0.142	-0.118	**0.802**
Long Lengths	0.399	0.217	**0.700**
Appearance	0.185	0.329	**0.627**
Consistency	0.566	-0.110	**0.626**
Price	-0.218	0.210	**0.539**
Moisture Content	0.315	0.195	**0.403**
Sum of Squares	4.175	3.779	3.435
Percent of Variance	21.975	19.889	18.078

Perceptual Maps

Perceptual mapping displays in two dimensions the location of products in the minds of consumers (Berkowitz et al. 1994). Perceptual maps can be used to change a product's offering or image by identifying areas of product need. The three factors (i.e. product performance, supplier performance, and product availability and assurance) determined using factor analysis, were used as the dimensions for the perceptual maps. These terms come from the variables that make up each factor. These dimensions were displayed in Figure 4-3.2a and 4-3.2b.

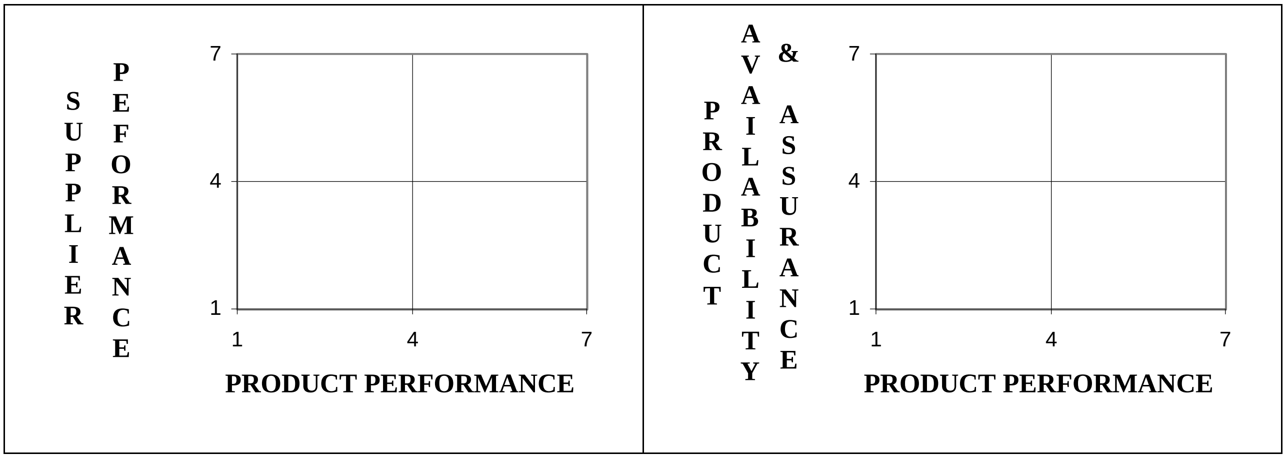


Figure 4-3.2a and 4-3.2b. Dimensions used for perceptual maps based on a 1 to 7 point likert scale, where 1 = very poor and 7 = very good

Ideal points represent the optimal combination of preferences for an object by respondents. Ideal points for building applications were identified using data from the factor analysis. Raw scores for each respondent were summed by those variables that loaded on each factor (F_{Vn}); this number was then divided by the total number of variables that loaded on the factor (V_n). This value became a composite score for each respondent (C_i) (Table 4-3.10). The mean of the composite scores ($\overline{x}_{Ci}$) became the ideal point (I_p) for that factor.

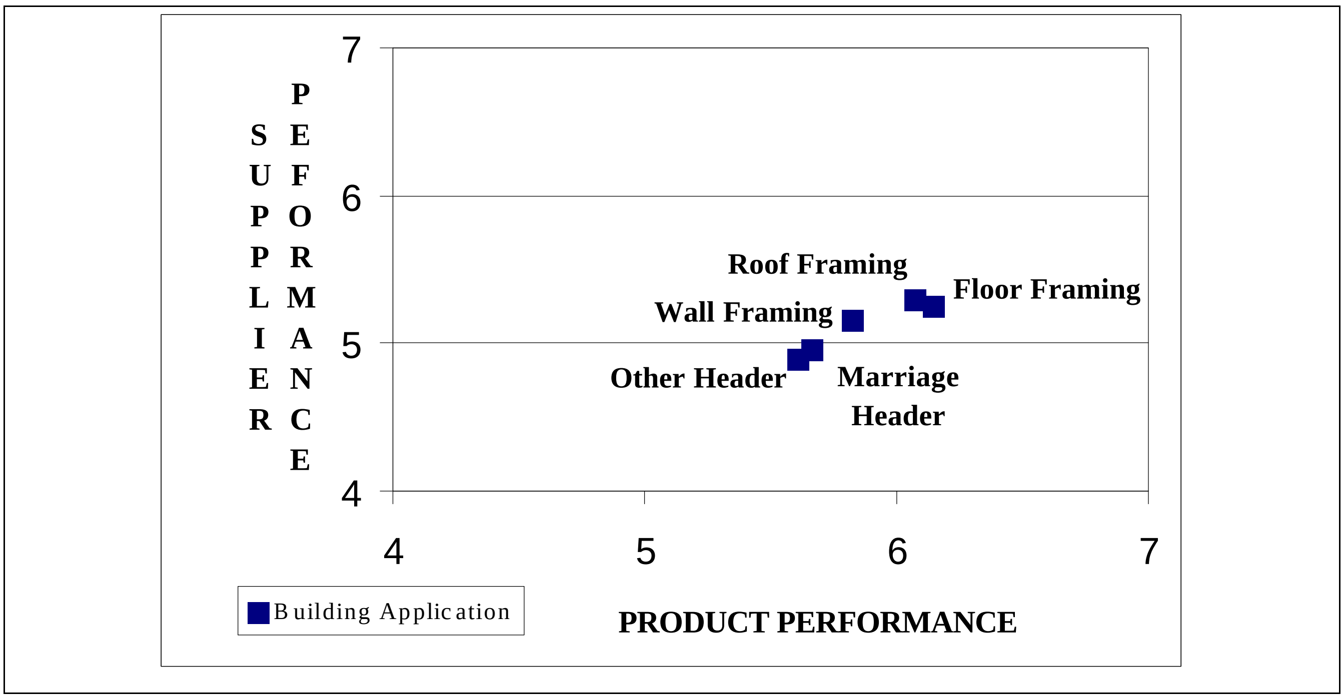
$$C_i = (F_{V1} + F_{V2} + F_{V3} + \ldots + F_{Vn})/V_n$$

$$I_p = \overline{x}_{Ci}$$

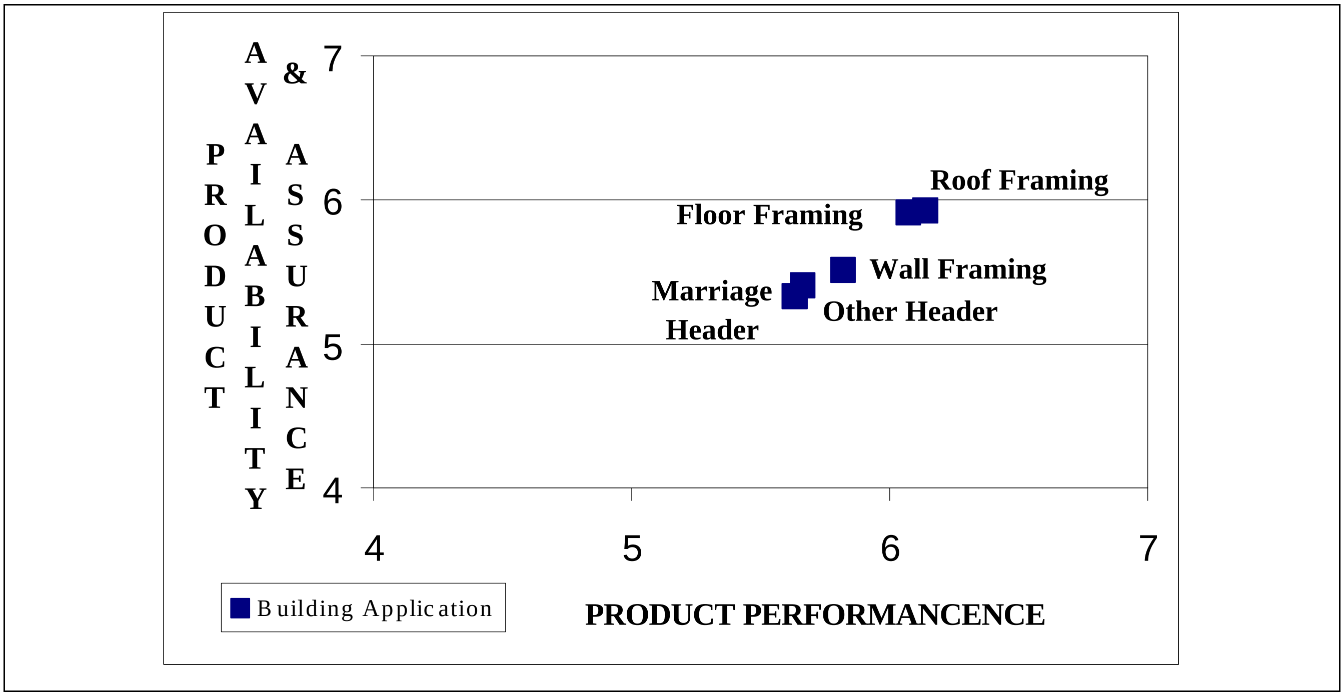
Table 4-3.10. Composite scores of respondents, by building application, 1998

BUILDING APPLICATION	n			Ideal Point			Standard Deviation		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Marriage Header	19	19	18	5.66	4.96	5.41	0.81	1.19	0.84
Other Header	19	19	17	5.63	4.95	5.33	0.81	1.20	0.89
Wall Framing	19	19	17	5.82	5.16	5.52	0.63	1.18	0.81
Floor Framing	20	20	20	6.07	5.3	5.92	0.66	1.26	0.71
Roof Framing	20	20	20	6.14	5.29	5.93	0.56	1.29	0.72

The ideal points were positioned on each of the three dimensions (i.e. product performance, supplier performance, and product availability and assurance). The locations of these points are found in Figures 4-3.3a and 4-3.3b. Roof framing and floor framing applications were perceived to have the highest product performance, supplier performance, and product availability and assurance needs. Wall framing had average product performance, supplier performance, and product availability and assurance needs. Marriage headers had lower product performance and supplier performance needs, but average product availability and assurance needs. Other headers had the lowest product performance, supplier performance, and product availability and assurance needs.



Figures 4-3.3a. Ideal points for building applications based on a 1 to 7 point likert scale, where 1 = very poor and 7 = very good, for product performance and supplier performance



Figures 4-3.3b. Ideal points for building applications based on a 1 to 7 point likert scale, where 1 = very poor and 7 = very good, for product performance and product availability and assurance

Table 4-3.11, provides the position of perceived performance for structural materials compared to the ideal points of building applications based upon the three dimensions identified in the factor analysis. Perceived performance for materials were positioned by summing the raw scores for each respondent those variables that loaded on each factor (F_{Vn}); this number was then divided by the number of variables for that factor (V_n) to become a composite score for each respondent (C_i). The mean of the composite scores ($\overline{x}_{Ci}$) became the perceived performance score (P_p) for that factor.

$$C_i = (F_{V1} + F_{V2} + F_{V3} + \ldots + F_{Vn})/V_n$$

$$P_p = \overline{x}_{Ci}$$

Table 4-3.11. Perceived performance scores for respondents, by structural material type, 1998

STRUCTURAL MATERIAL	n			Performance Score			Standard Deviation		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Spruce-Pine-Fir	18	18	19	4.69	4.76	4.82	1.13	0.98	0.90
Southern Pine	15	15	16	4.83	4.33	4.61	1.23	1.38	1.06
Wooden I-beam	16	16	16	5.81	5.45	5.47	0.77	1.05	0.84
LVL	17	18	19	6.36	5.59	5.89	0.44	0.92	0.65
Glulam	10	10	10	6.03	5.42	5.67	0.40	0.69	0.42
SCL	14	14	14	6.07	5.63	5.73	0.59	0.83	0.79
Prefab. Truss	16	16	16	5.62	5.48	5.33	0.77	0.97	0.91
Steel	7	7	7	6.38	4.63	5.86	0.33	1.43	0.67

Figures 4-3.4a and 4-3.4b show the perceived location of the eight structural building products based on their perceived performance compared to the ideal locations for the five building applications. These maps can be interpreted as follows: the ideal points for product performance were highest for floor framing and lowest for other headers. Respondents perceived product performance to be greatest for LVL and steel and lowest for SPF. The ideal points for supplier performance were highest for roof framing and lowest for other headers. Respondents perceived supplier performance to be greatest for SCL and LVL and lowest for Southern yellow pine. The ideal points were highest for roof framing and lowest for other headers for product availability and assurance. Product availability and assurance was perceived to be highest for LVL and lowest for Southern yellow pine.

Roof framing and floor framing had the highest supplier service needs across all dimensions. Of the structural materials studied in this project, only LVL rated high enough to meet the needs for product performance, supplier performance, and product availability and assurance. Steel exceeded product performance needs but failed to provide adequate supplier performance and product availability and assurance needs. Structural composite lumber (SCL) and glulam beams met product performance and supplier performance needs, but did not meet product availability and assurance needs. Prefabricated trusses and wooden I-beams only meet supplier performance needs. Neither SPF nor Southern yellow pine met the requirements necessary for roof or floor framing.

Since wall framing had only average product performance, supplier performance, and product availability and assurance needs, materials that met the requirements for roof and floor framing also met wall framing needs, in this case LVL. But due to lower material requirements, other materials also met product performance, supplier performance, and product availability and assurance needs. These materials were SCL, glulam beams, and wooden I-beams. Steel met product performance needs and product availability and assurance needs but did not meet supplier performance needs. Prefabricated trusses met supplier performance needs but did not meet the other two requirements. Neither SPF nor Southern yellow pine met the needs for wall framing.

All engineered lumber materials were perceived to meet product performance, supplier performance and product availability and assurance needs for marriage header and other header applications. Steel met supplier performance and product availability and assurance needs but failed to meet product performance needs. Spruce-pine-fir (SPF) came close to meeting supplier performance needs but did not meet the needs for product performance or product availability and assurance. Southern yellow pine did not meet any of these needs for marriage headers and other headers.

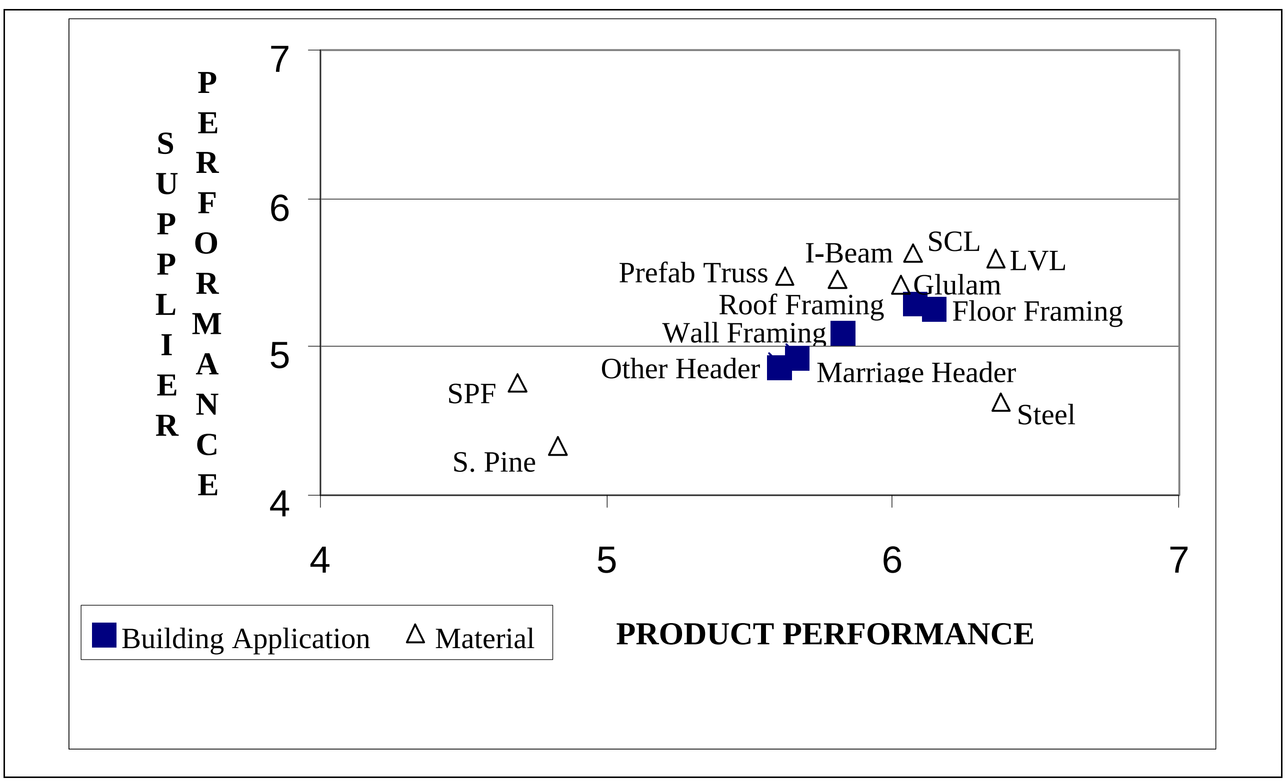


Figure 4-3.4a. Perceived structural material positioning based on a 1 to 7 likert scale for product performance and supplier performance

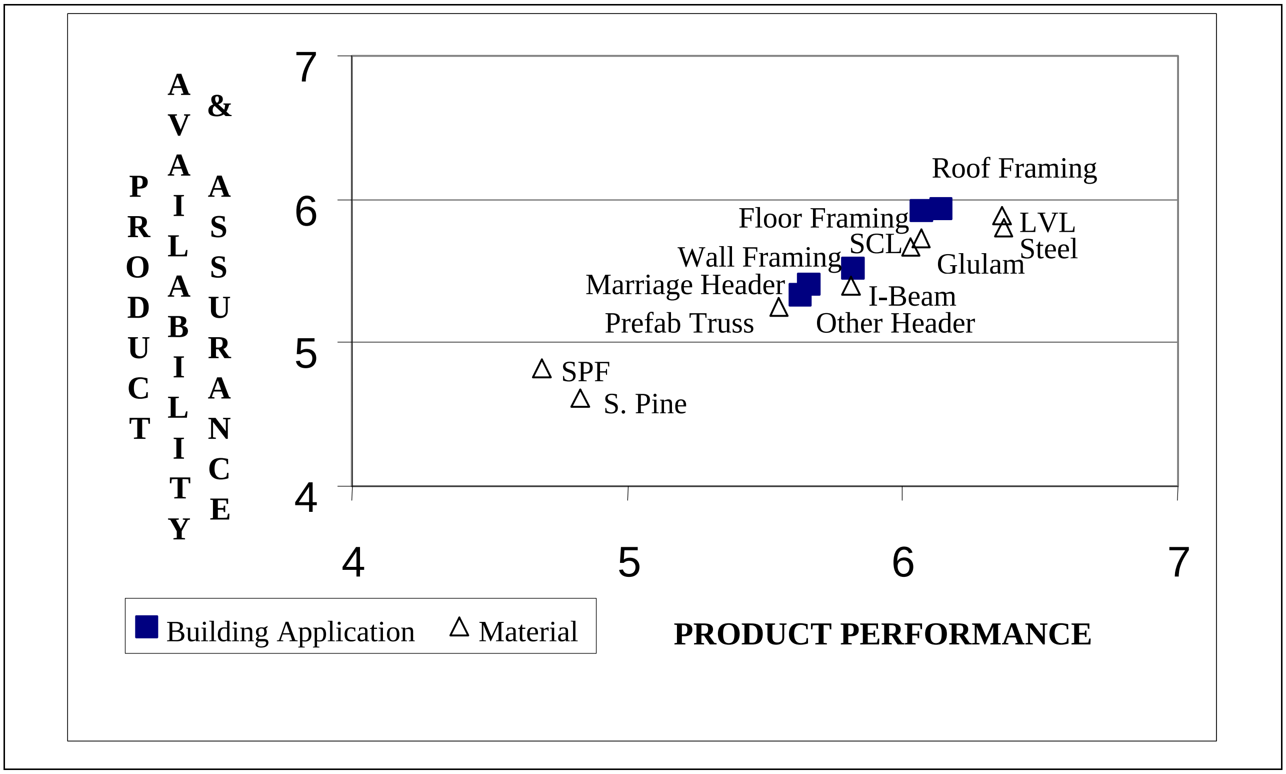


Figure 4-3.4b. Perceived structural material positioning based on a 1 to 7 likert scale for product performance and product availability and assurance

4-4 – FUTURE MATERIAL NEEDS ASSESSMENT

Factors Prompting Material Change

Respondents were asked how important availability, price, quality, and design were in prompting change from solid lumber to an engineered lumber product. Responses were measured on a seven point Likert scale with 1 = not important and 7 = very important. Respondents rated availability, price and design above average in prompting change and quality as very important (Table 4-4.1). Respondents were also asked if there were other factors prompting changes in structural materials used. Respondents gave the following open ended responses most frequently: (1) the material must be flexible, offering optional design features, such as trimming and hole punch outs, without losing structural integrity, (2) the materials needs to be accepted by the customer, and (3) have licensed engineering approval.

Table 4-4.1. Importance of availability, price, quality, and design to modular manufacturers in order to prompt change from solid lumber to engineered lumber, by respondents, 1997 (n = 29)

	Mean[1]	Standard Deviation	Frequency of 7	% of Total
Availability	6.14	1.13	15	51.7
Price	6.21	1.18	16	55.2
Quality	6.69	0.54	21	72.4
Design	6.34	0.94	17	58.6

[1]Five point likert scale, 1 = not very important, 7 = very important

Respondents were also asked to rank the order of importance for eight characteristics when choosing a structural building material. These characteristics were: (1) consistent moisture content, (2) consistent grade, (3) straightness, (4) stiffness (MOE), (5) bending strength (f), (6) cost savings, (7) availability of long lengths, and (8) accuracy of dimension. Straightness ranked the most important item to consider when choosing a building material (Table 4-4.2). The mean rank score for straightness was 1.69 points greater than the next most important item, accuracy of dimension. Five respondents found that all items were equal in importance. Respondents were also given the opportunity to provide other items they felt were important when choosing a structural material. Two respondents stated that customer acceptance and flexibility in use were very important. The other items mentioned were consistency in cost, efficiency of material use, other types of savings (i.e. time, labor, etc.), industry approval, and weatherability.

Table 4-2.2. Mean importance ratings and rank of structural properties considered by modular manufacturers when choosing a structural building material, by respondents, 1997 (n = 29)

	Mean[1]	Standard Deviation	Rank
Straightness	2.52	1.27	1
Accuracy of Dimension	4.21	2.37	2
Stiffness (MOE)	4.28	2.25	3
Consistent Grade	4.34	2.00	4
Bending Strength (f)	4.52	2.08	5
Cost Savings	4.76	2.46	6
Consistent Moisture Content	5.07	2.31	7
Availability of Long Length (16ft +)	6.31	1.85	8

[1] Seven point likert scale, 1 = not very important, 7 = very important

Limitations to material change

During interviews nine companies (47.4 %) stated that the most limiting factor to material change was cost. Eight companies (42.1 %) stated that they also felt industry acceptance/tradition was a barrier to change. Six companies (31.6%) felt materials were limited by current production facilities, the need for employees to have special training, user friendly installation, new equipment requirements, and/or additional inventory space. Four companies (21.1 %) felt availability might limit new materials and only one company felt it was risky to try new products.

Evaluation of new materials

Companies evaluated new structural materials in different ways. Some companies used committees (31.6 %), others worked though third party licensed engineering firms (21.1 %), and some companies only used a new product after it was an industry norm (26.3 %). Some of the things that companies evaluated when assessing a new product was whether or not it offered a cost, time or labor savings, if it was accepted by the industry, if it was versatile, if it fit current production facilities, and/or if it improved the strength or performance of the unit. Only five of the nineteen companies interviewed (26.3 %) had licensed engineers on staff, although most had individuals with some engineering training.

New products were often evaluated to see if they would meet a specific need that had been identified. An example of this is a new truss that was developed in order to meet a design challenge. The challenge was that a 12/12 roof pitch could not be put on a house with a nine foot ceiling and still meet height limitations for transport. The company worked with their third party licensed engineering firm to design a new truss that would offer a 12/12 roof pitch, but still would be able to collapse low enough for transport.

Structural material benefits

An alternative structural materials for housing construction offered companies many benefits over traditional solid softwood lumber. Alternative structural materials were broken into two categories, (1) engineered lumber and (2) steel. These benefits varied by product type. Engineered lumber products currently being used by the respondents were laminated veneer lumber (LVL), wooden I-beams, trusses (roof, floor and wall), finger-jointed studs, and structural composite lumber (SCL). Steel products currently being used by the respondents were studs and engineered wooden I-beams.

<u>Laminated veneer lumber</u>

Laminated veneer lumber (LVL) was considered by respondents to add design flexibility by offering long lengths, up to eighty feet, and by having higher span ratings than traditional lumber of equal dimension. Benefits of LVL stated by respondents were that LVL was straight, with no checking or splitting, had minimal shrinkage, did not delaminate when wet, was considered very high in quality and was therefore less risky than tradition softwood lumber. LVL was offered in a variety of dimensions and increased the load bearing capacity of roof systems. Other benefits of LVL given by respondents were that LVL was accepted by the industry and readily available. All nineteen companies interviewed currently used LVL for marriage headers.

<u>Wooden I-beams</u>

Four of the nineteen companies interviewed (21.1 %) used wooden I-beams in their floor systems. Companies using wooden I-beams stated that I-beams were lighter weight and straighter than softwood lumber. These companies also felt that I-beams were cost competitive compared to softwood lumber since prices were more stable, beams had no cull, and offered a time-savings. Timesaving occurred in two ways. First, since I-beams have no crowns, the sub-floor was more level and less time was spent leveling out the floor. Secondly, the availability of long lengths increased decking spans and therefore decreased the number of connecting plates. Other benefits of I-beams given by respondents were I-beams allowed plumbing and electrical work to be run through the beam and that I-beams were readily accepted by the industry. By the year 2000, two more interviewed companies planned on using I-beams in their floor systems.

Prefabricated trusses

Companies used trusses in their roof, floor and wall systems. Roof trusses can be either bought pre-assembled from truss dealers or manufactured within the plant. About half of builders constructed their roof trusses on site. Eighteen companies (94.7 %) were currently using trusses in their roof systems and only one company was still using a rafter system. This company was planning on changing over to a prefabricated truss system in 1999. This company stated trusses were faster to install than their current system. The benefits of roof trusses, stated by respondents were that trusses increased flexibility, were easy to install and were easy to build from patterns, decreasing errors in construction. One of the greatest benefits of floor trusses stated by respondents was that plumbing and electrical systems could be easily run through the open webs of the trusses, decreasing labor cost. Other benefits included availability of long lengths, industry acceptance, and an increased on center spacing for second floors, decreasing material use and total unit weight. Eight companies (42.1 %) currently used some form of open web-floor truss. Four additional companies were planning to use open web floor trusses over the next three years. One company was using a wall truss, which ran the length of the unit. This company stated the wall truss added rigidity of the structure during lifting and transporting and offered increased design flexibility. Three companies (15.8 %) were using prefabricated metal plate studs, however three more companies were planning to use them within three years. Companies using prefabricated metal plated studs stated that they prefer them to regular stud because they were straighter, had no cull, and offered labor savings when installing electrical wiring.

Finger-jointed studs

Four companies (21.1 %) were currently using 2x4 and 2x6 finger-jointed studs. These companies claimed that finger-jointed studs gave them cost savings over solid softwood studs because finger-jointed studs were straighter and had no cull. Another company planned to use finger-jointed studs within three years. One company, which had previously used this product, complained that they stopped using the product due to warping problems.

Structural composite lumber

Only one company was currently using structural composite lumber (SCL). This company used SCL in applications requiring long spans with height restrictions. They stated that SCL was stronger than the same dimension of LVL. SCL also expands in both height and width so long lengths can be used without increasing in height as fast as LVL. This becomes important when designs specify for long lengths, but height restrictions limit the use of LVL. Only one additional company was considering using SCL within the next three years.

Steel

Although several companies have occasionally used steel, only one of the interviewed companies consistently uses steel. Currently they only used steel studs but planned to expand their use of steel into other applications such as a whole wall truss system. Before expansion can take place they stated that more research and development was needed to develop better fasteners and make it more user friendly. This company felt that steel studs built straighter walls, was more cost effective, was readily available and had less moisture problems than wood. Also steel joists allowed for increased design flexibility by increasing span length without increasing span height. Two other companies planned to incorporate steel studs within next three years.

Past structural materials

Interviewed companies were asked if they had ever used an engineered lumber product and then decided not to used it. Thirteen companies had tried an engineered product and had a problem with it and discontinued using it. Six companies had problems with wooden I-beams. Complaints stated by at least two companies included: deflection problems, dimensional differences (i.e. 9 ½ inch I-beam vs. 9 ¼ inch 2x10), difficulty installing plumbing and electrical systems correctly, and availability problems. Complaints concerning new fastener types, higher costs, and increased inventory were each noted by only one company. Three companies had problems with Sim-stud ™ wall trusses. Two companies felt that Sim-studs ™ were not cost competitive and the other company did not feel Sim-studs ™ were straighter than solid studs and therefore not worth the extra cost. Two companies felt Open Joist 2000 ™ open web trusses were too expensive and restricted cutting options. Two companies had tried SCL beams, but felt they were currently too expensive. One company would like to use SCL studs, and was waiting for building code approval for all their market areas. One company tried to use finger-jointed 2x4s, but complained that the studs warped even more than softwood studs.

Structural Material Performance Requirements

The most critical structural material performance characteristics noted by all companies were bending strength and the ability to carry structural load. The chosen material must be able to carry snow loads, live loads, and dead loads without deflecting past allowable design limits. Third party licensed engineering firms were used by all companies to ensure structural integrity. Design and stress factors also affected the performance requirements of materials as described below.

Design factors

As the design of units change so do the performance requirements of the structural members. During interviews, company representatives were asked how design changes affected the performance needs of structural members. All respondents explained that as the size of a clear span increased, the length of headers must also increase. In order to support the structure one of two things must occur, (1) the size of the beam and/or (2) the material type used must change. Companies varied in the length of clear span when they stopped using solid softwood beams and changed to a LVL beam. One company continued to use solid softwood lumber for any beam under ten feet before changing material types. Another company used LVL for clear spans as small as four feet. Fifteen companies (78.9%) stated that they compensated for design changes that caused a change to structural loads by using engineered lumber. Some of the designs that affected structural loads included long clear spans, complex roof systems, and bump-outs. Three companies (15.8 %) stated they compensated for design changes by using alternative materials such as steel or plastic. Only one company felt that changes to design did not affect their choice of material.

Sometimes the environment can cause a change to design, such as, areas where building codes call for heavy snow loads requiring roof elements to be spaced closer together, LVL was sometimes used to increase rigidity and strength of the roof. This in turn increased the load the structure must carry, which increased the performance requirements of all load-bearing elements. Snow loads affected the designs of seven companies (36.8 %). All other companies built homes to meet the most rigid building codes in their market area.

Customization can alter designs and change materials. Twelve companies stated that increased customization increased the amount of engineered lumber products used within a home. The following examples demonstrated how custom features could change structural materials within a home. Increasing clear spans in large rooms changes the length and dimension of the support beam. This will often require a LVL beam to substitute for a softwood beam. Complicated roof systems use more engineered products in order to support the roof by transferring loads over to load bearing areas. The floor system will often use LVL if plans call for clear spans in the basement.

Design changes affect the way stress and environmental factors interact with the type of material selected. Respondents stated that material choice was decided by choosing among those materials, which could support the load on the structure. Third party licensed engineers were needed for any major change to a currently approved design. Third party licensed engineers calculated load paths, stresses and performance needs of each element within the structure and approved material performance criteria.

Limitations of design change

The most limiting factor to design change reported by companies (52.6 %) was transportation restrictions. In addition, seven companies (36.8 %) felt that their current production facilities limited design change. Five companies (26.3 %) felt that there were no limits to design with the use of a little imagination. Two companies (10.5 %) felt tradition limited design. Other limits mentioned were set time on site, building in sections, cost effectiveness, skill of employees, and inventory space.

Companies were asked what sort of design limits they currently had. The most commonly given response by companies (63.2 %) was that they could build almost anything, but that they had to decide if it was cost effective. Designs which were not considered cost effective were those that slowed the production line. These designs tended to have one or more of the following problems: complicated roof designs, high ceilings, and openings that exceed modular section dimension limitations (no support walls), complex floor patterns, and split levels. Two companies had their own established set crews and stated that time consuming on-site set up times increased total cost by increasing labor cost and lowering production. At some point complex designs become more cost effective to build on site. Six companies did not know what their design limits were. Only one company felt that they had no limitations since they have the capacity to build in panelized sections.

Stress factors

Companies were asked which part of the manufacturing process placed the greatest stress on the unit. Nine companies felt that the outside walls received the greatest stress when a unit was lifted. Six companies felt that the greatest stress occurred during transportation as stress was placed on the center of the unit. Eight companies' felt that units were equally stressed during both lifting and transportation. Failures that occurred at these times were drywall cracks, racking around windows and doors, slippage of wall/floor joist connections, and framing cracks when the unit was improperly lifted.

Critical stress points were found within a structure's load paths. A load path is how the structure transfers the weight from the roof, through the load bearing walls, and into the foundation. In a modular home the load bearing walls were usually the exterior walls and marriage walls. Respondents stated that the critical stress points occurred at the ends of trusses, the center of clear spans, ceiling to wall connections, and the corners of headers, usually above windows and doors. These stress points can cause structural failures such as cracks and racking if not properly built and engineered. All nineteen companies used third party licensed engineering firms to properly engineer their products. These companies also used several methods to reinforce the critical areas ensuring structural integrity.

The most common form of reinforcement used by respondents was an oriented strand board (OSB) wrap. All nineteen companies used OSB to enclose all exposed interior sections during shipping. The wrap helped to support open spans by tying together floors, walls and ceilings, and helped to prevent racking of the unit. Five companies (26.3 %) used metal bracing at the corners of headers to help prevent movement during times of high stress. Some companies used temporary walls to add bracing during lifting and transporting and kept drywall rounded at the corners of openings until the unit was set on site. By rounding drywall, stresses at the corners of headers were more evenly distributed, helping to prevent stress cracks. One company constructed the walls around their windows, to ensure that they were flush and square. The company felt that this made the walls stronger and more resistant to stress. Another company built a longitudinal wall truss that ran the entire length of each section, adding stability and strength. Companies used rigid trailers with adjustable outriggers to minimize flex during shipping.

Long Term Performance Concerns for Engineered Lumber

Interviewees were asked if they had any concerns about the long-term performance of engineered lumber products. Fifteen of company representatives (78.9 %) had no concerns and four representatives (21.1 %) had concerns. Those concerns were over de-lamination of the products and other types of adhesive failures. Those who had no concerns stated that they felt confident in the engineering involved to design engineered lumber and if any failures were to occur, the liability would fall on the manufacturer of the engineered lumber product.

CHAPTER 5-DISCUSSION AND CONCLUSIONS

This study provides an in depth look into the modular housing industry of the Mid-Atlantic region. Previously there has been little or no information available about this industry. This study documented the current and future state of the industry, their markets and products, their structural material usage and preferences, and their structural material performance requirements. Material use was compared to 1992 data in order to track material use trends over an eight year period, by utilizing data from Fuchs 1992 study (1993). The 1992 study focused on the industrialized housing industry, which included material use data from thirty modular manufacturers. The perceptions of respondents were used to learn what barriers exist to the adoption of new structural materials. To learn how structural materials were evaluated. To explore concerns for the future state of the timber resource and what effects this could have on their industry and choice of structural material. Perceptions were also used to discover what factors cause structural material usage to change. This study learned what opportunities exist for the substitution of current structural materials and for the development of new structural materials.

Current and Future State of Modular Housing Industry

The modular housing industry is an important and growing segment of the housing industry. In 1992, responding manufacturers produced 8250 units. By 1997, twenty-nine companies produced approximately 18,000 units, 15,000 of those being units for single-family homes. The average production per week was 21.4 units. By 2000, these twenty-nine companies all planned to increase production. The average increase in production by the year 2000 was expected to be 15 %.

Along with increased production, increased sales are also expected. Sales in 1997 averaged approximately 22.3 million dollars per company. This figure is expected to increase approximately 35 % by the year 2000. The increase in sales dollars will come from increased sales volume as production and demand for customization raise the average price of homes.

This study found that the majority of respondents felt that all categories of homes would increase in price. Some small change will be in the base price of homes due to inflation.

However, the most significant increases will be in the average price of homes, which will come from increases in the amount of customization per unit. In 1997, an average of 71.6% of units built by responding manufacturers were customized. By 2000, approximately 70% of respondents planned on increasing the amount of customization.

Since 1975, the average square footage of homes has continued to increase. Modular producers also seem to be following this national trend. Modular homes in all categories were expected to increase in size by the year 2000. For example in 1997, the square footage of the most popular modular home averaged 1659 square feet. Over half of respondents felt that the square footage of their most popular home would increase by 2000. An increase in house size seems to correspond to a decrease in interest rates.

The greatest barrier to market expansion is transportation distance. The further a unit must be shipped the less cost effective it becomes. Market expansion was expected to occur in the South and Midwest regions of the country. Expansion is possible by building new production facilities to decrease shipping distances. Expansion would take advantage of two opportunities: the market potential in the South due to rising housing starts which rose 5% in 1997 over 1996 figures and to take advantage of the lack of modular competition in both regions.

Competition for the industry varies in its intensity. However, based on this research there are clearly two competitive threats. First, manufacturers of mid-sized to large-sized homes compete directly with site builders. Site-built homes have an advantage over modular homes since there are no design limitations. Modular homes, while they can be very customized, are limited in size to sections that meet transportation restrictions. Any feature/design that does not conform to this size restriction can not be built in a factory and instead must be completed on site. An example of this is room size restriction, which becomes a problem if the design dimensions of the room are so large that there is no way to span the length and still remain within allowable size limits of the unit. This type of room could not be built by modular construction since it would not have enough support walls to maintain structural stability. However, the advantages of modular homes over site-built homes include that they can be built much faster and have less labor costs. The challenge modular homes must overcome to stay competitive is to find ways to offer the same customized designs as site homes without increasing labor cost, slowing production or increasing the cost of modular homes over the cost of site built homes. This is an opportunity for the use of engineered lumber products since they overcome many structural design limitations like vaulted ceilings and custom roof pitches while providing accurate dimensions and high quality.

The second competitive threat is to manufacturers of smaller modular homes from manufacturers of manufactured homes. Manufactured homes are becoming increasingly customized and popular. Manufactured homes are built even faster than modular homes. Because of less stringent building codes, they can be built less expensively. Modular manufacturers of small homes plan on staying competitive by taking one of two approaches: first, increase the size of their homes, so that they no longer directly compete with manufactured builders; or second, find a market niche, such as building homes for assisted living communities. Builders of all sizes of modular homes are challenged to overcome a negative image problem and lack of consumer understanding of the differences between manufactured homes and modular homes.

Material Use Trends and Future Predictions: 1992-2000

When assessing the potential for material substitution, it is important to determine current and future material use. One of the descriptors of material consumption is size in board feet. Figure 4-2.1 indicated a significant decrease in the percentage of 2x4 used by respondents in 1997 from 1992 figures. Reasons for this decrease might be differences in the statistical populations or the substitution of alternative materials. These alternatives might include the use of 2x3 in non-load bearing walls, use of 2x6s to increase wall stability or use of engineered materials such as wall trusses or finger-jointed studs. The national U.S. consumption figures reported in 1983 (Marcin) showed that the national housing industry used 10 % more 2x8s and 2x10s than respondents of the 1992 and 1997 studies. This decrease could be caused by the substitution of engineered lumber for larger dimension lumber needed to meet design and transportation requirements.

In 1992, the average responding manufacturer purchased approximately 3.3 million board feet of dimensional lumber. By 1997, this figure had increased to 3.8 million board feet. This was consistent to the increase in production from 1992 to 1997. However, for the same period the amount of lumber used per unit decreased from 9710 board feet in 1992 to 6161 board feet in

1997. Two possible explanations for this decrease in board feet per unit are: a trend to lower the weight of units in order to decrease shipping costs or differences between the two statistical populations. The source of the statistical difference might be that the 1992 study included all factory built housing excluding manufactured homes whereas the 1997 study included only modular housing.

The most commonly used grade of lumber in 1997 was No. 2 and better Northern spruce-pine-fir. Companies felt this material provided the best quality for the price and that the material met structural needs with minimal cull. Some companies did buy lower grades of Western spruce-pine-fir. These companies felt that the quality of Western spruce-pine-fir was higher than Northern spruce-pine-fir and they could therefore buy less expensive lumber without increasing cull.

Respondents felt that the availability of lumber had remained the same over the last five years, and felt that the supply of lumber would not be in jeopardy over the next three to five years. However, most respondents did feel that the quality of lumber had decreased over the last five years and would continue to decrease over the next three to five years. This decrease in quality has already been reflected in some building codes, which were revised in 1995 to lower the allowable load carrying capacity of a structural member. To compensate for lower strength values and increased waste, companies have increased the grade of lumber they purchase. However, if quality continues to decrease the cost effectiveness of lumber will decrease, making engineered lumber products more attractive.

Substitution Opportunities for Engineered Lumber

Approximately one third of responding manufacturers felt that the amount of dimensional lumber used by 2000 would decrease. This decrease in solid lumber will correspond to increases in the amount of engineered lumber and steel purchased. The change will occur as the quality of lumber decreases or as engineered lumber becomes more cost competitive. The largest increases will be found in the use of laminated veneer lumber, engineered wooden I-beams and prefabricated trusses. These changes will occur for three reasons: increased consumer knowledge; industry acceptance; and cost effectiveness. As knowledge about engineered lumber becomes more readily available, the product will be tried by the most innovative of companies and will begin to be adopted and accepted by the industry, but only if the product is found to be cost effective. In order to be cost effective a material must be equal to or better in quality and offer a labor, price, or some other alternative incentive.

Some engineered products are better suited to certain applications than other applications. Respondents felt that the greatest increases in engineered products will occur for wooden I-beams, laminated veneer, and prefabricated trusses. Respondents anticipated an increased use of wooden I-beams for floor framing applications. An increased use of laminated veneer lumber was expected for marriage headers, other headers, floor framing, and roof framing. Increased use of prefabricated trusses used in floor framing, roof framing, and wall framing applications was also expected.

Currently engineered lumber use has increased dramatically over the last five years. Respondents stated that these increases have occurred to meet structural requirements of customized designs and not for quality reasons. However, many respondents expressed such concerns as the lack of quality of softwood lumber and the need to start investigating alternative materials to softwood lumber.

Perception of Structural Materials

Respondents perceived engineered lumber to be higher in price, but also higher in quality than solid dimensional lumber. If given a choice without including price, most respondents would prefer to use engineered lumber to solid lumber and even considered it less risky. However, the reason more engineered lumber is not being used relates back to the price increase associated with using engineered lumber. Some respondents apparently felt that engineered lumber is not currently as cost effective as solid lumber.

Dimensional lumber was perceived to have large gaps between importance and satisfaction levels for the following characteristics: straightness, overall product quality, overall product consistency, accurate dimensions, and competitive pricing. Discrepancy scores for straightness and accuracy of dimensions have continued to increase since 1992 and will continue to increase if quality of softwood lumber decreases. These gaps between importance and satisfaction level indicate a market need and create substitution opportunities and generate new product ideas. One possible opportunity for suppliers to differentiate their product may occurr through small orders, protective wrapping and arranging credit since these characteristics had the most significant increases in satisfaction discrepancy scores from 1992 to 1997.

Respondents perceived current engineered products to be high in quality with little risk compared to dimensional lumber. They are very willing to use engineered lumber and feel that their knowledge concerning engineered lumber is very good. However, respondents feel that dimensional lumber is lower in price than engineered lumber and is, therefore, the preferred product.

Through factor analysis it was determined that respondents had three underlying criteria when assessing which structural materials to use when choosing a building application: product performance, supplier performance, and product availability and assurance. Through the use of perceptual mapping, roof and floor framing were found to have the greatest product performance, supplier performance and product availability, and assurance needs, followed by wall framing, marriage headers and other headers. A probable reason for these strict requirements is the high volume of material used in these applications and that these applications also provide much of the structural support for the building. It is important that the industry has these materials readily available and feels confident in their performance and use. Of all the materials studied for this project only LVL met the perceived needs of these two applications. However, the primary material used for flooring and roof framing was dimensional lumber, which rated lowest on product performance, supplier performance and product availability, and assurance. Prefabricated trusses are also often used for these applications. Prefabricated trusses are engineered from small pieces of dimensional lumber, which improves their performance over traditional dimensional lumber, but still it does not fully satisfy the needs of these applications and was only perceived to meet supplier performance. This is an indication of a product opportunity for LVL. An increased use of LVL should be able to take place as a substitution for dimensional lumber and prefabricated trusses. However, respondents felt LVL had several disadvantages that should be considered. (1) It is much heavier than dimensional lumber and prefabricated trusses, (2) it is more expensive, and (3) it makes plumping and electrical installation difficult. Therefore, need for a new product might be indicated. The new product would need to perform as well as LVL and meet supplier availability and assurance needs without the disadvantages of LVL. Steel is the closest material other than LVL to meet the needs of these applications. Before steel can become a viable substitute, supplier performance will need to be improved.

Currently, a wide variety of engineered lumber materials exist that would better meet the needs of wall framing applications. Wall framing is almost exclusively made from SPF. Substitution opportunities are indicated for wooden I-beams, SCL and Glulam beams since these materials meet all the needs for wall framing applications. Wooden I-beams also meet supplier performance needs and could become a better substitute if increases in product performance and product availability and assurance occur.

Marriage headers and other headers had the lowest needs for product performance, supplier performance and product availability and assurance. All engineered lumber products were sufficient to meet the needs of these applications. However, dimensional lumber did not meet any of these application needs. Therefore many substitution opportunities currently exist for engineered lumber. This concurs with Table 4-2.8, which indicates significant decreases in dimensional lumber and significant increases in LVL with smaller increases in wooden I-beams, glue laminated beams, SCL, and prefabricated trusses.

Opportunities for New Product Development

Respondents felt the most important factor prompting a change in material is quality. If a material does not meet the quality needs of an application then that material must be substituted and new material chosen. Design is the second most important factor determining which type of material was chosen. A material must meet the engineering performance criteria of the design. The third most important factor prompting material type is price. Once quality and design needs are met, a company chooses which material they feel is most cost effective. The last factor used to determine material is availability. Most companies probably did not feel this factor was as high in importance since most materials that are currently being used are readily available. Obviously, if a material is not readily available, another will be chosen which meets quality, design and price needs.

In 1997, straightness ranked as the most important consideration when choosing a building material followed by accuracy of dimension. However, in 1992, the modular housing industry ranked lumber straightness as the characteristic with the largest discrepancy between importance and satisfaction. This discrepancy has continued to grow since the 1992 study.   The discrepancy for the accuracy of dimension has also grown since 1992. These two factors are an indication of an important gap between current dimensional lumber performance and the industry's material needs. In both the 1992 and 1997 studies, a large discrepancy was also found for competitive pricing indicating another important gap. This gap indicates an opportunity for suppliers to see if they can find a way to be more cost effective to their customers. Clearly, a new material is needed which will met the need for straightness and accuracy of dimension, but at the same time be cost competitive.

Within a company, the adoption of a new material can be faced with several challenges. The management style for a company can be a constraint to adoption. For example, a company might not have program in place to explore new products, or a company many not have considered what materials may be needed to overcome a design or quality issue until they are faced with a particular challenge. The adoption of a new material must also overcome the tradition of softwood lumber construction and resistance to change, this includes manufacturers, builders and the individual home buyer. These people will not buy a home if they do not approve of the components that go into construction it. New materials will be challenged to overcome many other limitations. Any new material must be cost effective and equal to or better in performance than the material it is replacing. The material needs to be easy to install and not require a large capital investment in equipment or training. It must also be quickly accepted by the building industry in order to gain market share.

Currently increased use of LVL is being seen for all types of headers and in some roof and floor framing applications. LVL is the mostly commonly used engineered product and is the most accepted by the industry, both by builders and manufacturers. Increased use occurred in wooden I-beams for floor framing. These increases have occurred in order to decrease the weight of units, increase straightness, and save labor costs by increasing the ease of utility installation. The greatest increase in LVL use has been in the South where producers typically have used Southern yellow pine for floor joists.

Use of prefabricated trusses for roof, floor and wall systems are increasing. Prefabricated trusses are more expensive than dimensional lumber but have less waste, are easy to install, and offer labor savings for installing utilities and electrical wiring. Most companies would like to increase the amount of trusses that they use to speed production, but buying prefabricated trusses limits customization options. Most companies felt floor and roof trusses are cost effective for standard designs but are not cost effective for less used designs since they take up valuable inventory space. Most companies have not tried wall trusses or are just starting to use them. They are unsure if wall trusses are cost effective.

Finger-jointed studs are an engineered material that have future potential but were not included in most of this study. Companies who currently use this product seem to feel that it has filled the gap between the low price of dimensional lumber and the high quality and low waste of engineered lumber for wall framing applications. Companies using finger-jointed studs stated that they were willing to pay more for each stud, since there was almost no waste and stated that they did not have a problem with warping, even though one company had stopped using finger-jointed studs due to warping problems. Companies stated that the money they saved by not having cull easily paid for increases in price. Although no data was collected on future use of finger-jointed studs, expect use of this product to increase over the next three years.

Although only one company is currently using structural composite lumber, this company stated that it allowed them to increase design options. However, respondents stated that this material was too expensive to use except when other materials were excluded because of design restrictions. Increased use of this product will likely be minimal to provide for design flexibility, unless the price becomes more in line with competing products.

Steel does not appear to have a significant future in the modular housing industry. There is a lack of knowledge about the product and an unwillingness to use it. Steel also involves a large investment in equipment, installation, and the retraining of employees.

Designs of modular homes will become more complex as more customized features are added to meet market needs and to stay competitive with site-built homes. With increased customization, load paths become more complex and longer. This affects which structural materials can be used to meet code restrictions. The chosen material must be able to carry snow loads, live loads, and dead loads without deflecting past allowable design limits. Materials must also be able to withstand extra stress during transport and lifting of the unit.

The most critical stress points for a unit are along the structure's load path. Failures are more likely to occur at the ends of trusses, the center of clear spans, ceiling to wall connections, and the corner of headers. Structural failures that can occur at these locations include cracking and racking. Third party licensed engineering and added reinforcement during times of high stress help to ensure structural integrity and minimize structural failures.

Future Research Needs

This study found many substitution opportunities for current engineered lumber products and has identified gaps where new products are needed. Further research is needed to explore how engineered lumber manufacturers can modify or enhance their products to better suit the needs of the modular housing market. Making substitution opportunities more viable will increase their use. Enhancement could come if engineered lumber manufacturers offer price incentives and/or more technical service to demonstrate how their products can be used. Manufacturers of engineered lumber products will be challenged to find ways to demonstrate how their products can be cost effective. This is attainable since these products have no waste, are available in almost any dimension, and are offered in many grades so that modular producers need only purchase the material that meets the minimum structural requirements for the unit.

The rapid growth of the modular housing industry, the improved attributes of engineered lumber products, the decreasing quality of softwood lumber as well as the increasing demand for cost-effective building materials points toward a promising future for the use of engineered lumber products by the modular housing industry in the mid-Atlantic and Appalachian regions. Consumer demand and the ability of the engineered lumber industry to create and promote new engineered products will continue to spur the modular housing industry into the twenty-first century. The Appalachian region has the resource and opportunity to supply engineered lumber producers with the raw materials they need to develop and manufacture engineered lumber products. This process will add value to the abundant but under utilized, low quality, soft hardwood species in the region and ensure that quality building materials will be available to the modular housing industry.

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Appendix A-Survey Instrument A

Study of Structural Material Use in the Modular Housing Industry

Center for Forest Products Marketing & Management
Department of Wood Science and Forest Products
1650 Ramble RD., Blacksburg Virginia 24061-0503

If you have any questions, please contact Sara J. Gurney Phone: (301) 762-7933

Part I: This section assesses your needs and satisfaction with structural building materials. Your answers will help us to develop future structural wood products that better meet the needs of the modular housing manufacturers.

1. An engineered lumber product is lumber which is formed by gluing together veneers, wood wafers, or smaller pieces of solid dimension lumber. The following 3 items concern your experiences with engineered lumber.

A. Is your company currently using engineered lumber? Yes ______ No ______

B. If Yes, please rate how favorable your experiences with engineered lumber products have been:
(Please circle most appropriate number)

1	2	3	4	5	6	7
very poor			indifferent			excellent

C. Do you predict your company will use more engineered lumber in the future? Yes ______ No ______

2. Indicate how engineered lumber products compare with solid structural lumber.
(Please circle most appropriate number)

A. In price, engineered lumber products are __________ compared to solid structural lumber:

1	2	3	4	5	6	7
much lower			same			much higher

B. Your knowledge about engineered lumber products is ___________ compared to structural lumber:

1	2	3	4	5	6	7
much lower			same			much higher

C. Your willingness to use engineered lumber products is ___________ compared to structural lumber:

1	2	3	4	5	6	7
much lower			same			much higher

D. The risk of using a new engineered lumber product is ___________ compared to structural lumber:

1	2	3	4	5	6	7
much lower			same			much higher

E. The quality of engineered lumber products is ___________ compared to structural lumber:

1	2	3	4	5	6	7
much lower			same			much higher

3. Please rank the order of importance for each of the following items when choosing a structural building material: (Number 1 to 8 with 1 being *most important* to 8 being *least important*, use each number only once)

Consistent Moisture Content	__________
Consistent Grade	__________
Straightness	__________
Stiffness (MOE)	__________
Bending Strength (f)	__________
Cost Savings	__________
Availability of long Lengths (16ft +)	__________
Accuracy of Dimension	__________

4. Please list any other factors you feel are important when choosing a structural building material:

5. Listed below are a series of characteristics related to SOFTWOOD LUMBER and the suppliers who distribute it. Please circle the number which best describes your rating of the *Importance* of each characteristic and how *Satisfied* you are with current suppliers in the industry.

	Importance to Company					Satisfaction with Suppliers				
	Not Important				**Very Important**	**Not Satisfied**				**Very Satisfied**
Lumber Straightness	1	2	3	4	5	1	2	3	4	5
Growth Rate (rings/inch)	1	2	3	4	5	1	2	3	4	5
Accuracy of Dimension	1	2	3	4	5	1	2	3	4	5
Reliability of Supply	1	2	3	4	5	1	2	3	4	5
Competitive Pricing	1	2	3	4	5	1	2	3	4	5
Consistency of:										
Moisture Content	1	2	3	4	5	1	2	3	4	5
Grading	1	2	3	4	5	1	2	3	4	5
Suppliers Ability to:										
Fill Small Orders	1	2	3	4	5	1	2	3	4	5
Fill Large Orders	1	2	3	4	5	1	2	3	4	5
Arrange Credit	1	2	3	4	5	1	2	3	4	5
Just-In-Time Delivery	1	2	3	4	5	1	2	3	4	5
Provide Service	1	2	3	4	5	1	2	3	4	5
Technical Assistance	1	2	3	4	5	1	2	3	4	5
Presence of:										
Supplier's Trademark	1	2	3	4	5	1	2	3	4	5
End coating	1	2	3	4	5	1	2	3	4	5
Protective Wrapping	1	2	3	4	5	1	2	3	4	5
Overall Prod Consistency	1	2	3	4	5	1	2	3	4	5
Overall Product Quality	1	2	3	4	5	1	2	3	4	5

Part II: The following questions ask about your company's product line. This information will help us to better understand your product needs.

1. How many UNITS did your company produce in each of the following categories?

In the last 12 months		Anticipated % change in 3 years (Please circle (+) increase or (-) decrease and indicate the percent change)	
Single-family	_______	Single-family	+ / - ________ %
Multi-family	_______	Multi-family	+ / - ________ %
Commercial	_______	Commercial	+ / - ________ %
Other _______________ (please specify)	_______	Other	+ / - ________ %

2. What is the square footage of the:

Largest single-family home that your company manufactures _____________
Smallest single-family home that your company manufactures _____________
Best Selling single-family home that your company manufactures _____________

3. How do you expect the square footage of these homes to change in 3 years: (Mark your best estimate)

Largest single-family home:	decrease	no change	increase
Smallest single-family home:	decrease	no change	increase
Best Selling single-family home:	decrease	no change	increase

4. What percent of total single family homes produced includes a great room ______ **%**

5. How do you expect this percent to change in 3 years:
(Please circle (+) increase or (-) decrease and indicate the percent change) + / - ______ %.

6. What is the price of your company's:

Largest single-family home	Base Price ________	Average Price ___________
Smallest single-family home	Base Price ________	Average Price ___________
Best Selling single-family home	Base Price ________	Average Price ___________

7. How do you expect the average price of these homes to change in 3 years: (Mark your best estimate)

Largest single-family home:	decrease	no change	increase
Smallest single-family home:	decrease	no change	increase
Best Selling single-family home:	decrease	no change	increase

8. **What percentage of the single family units produced by your company were custom-built as opposed to built from standard plans with only minor alterations?**

__________ % custom-built homes

9. **How do you expect the percentage of custom single family units to change in 3 years:**
(Mark your best estimate)

decrease   no change   increase

Part III: Please provide us a look into your company's material usage and future needs. This information will help us to better understand your structural material needs.

---

1. **What quantity of framing material did your company purchase over the last 12 months?**

Spruce-Pine-Fir/Hem-fir __________ MBF (Thousand Board Feet)
Southern Pine/Douglas-fir __________ MBF (Thousand Board Feet)

2. **What percent of structural construction materials by DOLLAR VALUE was purchased in the last 12 months and is expected to be purchased 3 years from now?**

	Last 12 months	Expected in 3 years
Spruce-Pine-Fir/Hem-fir	______ %	______ %
Southern Pine/Doug-Fir	______ %	______ %
Engineered Wooden I-beams	______ %	______ %
Laminated Veneer Lumber (1)	______ %	______ %
Glulam (2)	______ %	______ %
Structural Composite Lumber (3)	______ %	______ %
Prefabricated Trusses	______ %	______ %
Steel	______ %	______ %
Other ________________ (please specify)	______ %	______ %

(1) Lumber constructed from laminated veneers, all veneers are aligned in a parallel direction.
(2) Lumber constructed of individual pieces of lumber laminated together to make a single piece, all pieces are aligned in a parallel direction.
(3) Lumber constructed by gluing together long strands of wood from veneer.

3. **What percent of softwood lumber by QUANTITY was purchased and is expected to be purchased in each of the following sizes:**

In the last 12 months		Expected in 3 years	
2x4	_____ %	2x4	_____ %
2x6	_____ %	2x6	_____ %
2x8	_____ %	2x8	_____ %
2x10	_____ %	2x10	_____ %
2x12	_____ %	2x12	_____ %
Other	_____ %	Other	_____ %

4. What structural building materials is your company currently using in the following building component applications? (Please estimate the % of materials used in each of the building components)

MATERIAL TYPE	BUILDING COMPONENT				
	Marriage Header	**Other Header**	**Wall Framing**	**Floor Framing**	**Roof Framing**
Spruce-Pine-Fir/Hem-fir					
Southern Pine/Doug-Fir					
Wooden I-beams					
Laminated Veneer Lumber					
Glulam					
Structural Composite Lumber					
Prefabricated Trusses					
Steel					
Other					
TOTAL	100 %	100 %	100 %	100 %	100 %

5. Do you expect this distribution to change in 3 years. You do not have to estimate the amount of change. (Please indicate if (+) increase, (∅) no change or (-) decrease)

MATERIAL TYPE	BUILDING COMPONENT				
	Marriage Header	**Other Header**	**Wall Framing**	**Floor Framing**	**Roof Framing**
Spruce-Pine-Fir/Hem-fir					
Southern Pine/Doug-Fir					
Wooden I-beams					
Laminated Veneer Lumber					
Glulam					
Structural Composite Lumber					
Prefabricated Trusses					
Steel					
Other					

6. **How important are the following factors in prompting change from solid lumber to an engineered lumber product?** (Please circle most appropriate number)

A. Availability

1---------2----------3---------4---------5---------6----------7
Not Important — Very Important

B. Price

1---------2----------3---------4---------5---------6----------7
Not Important — Very Important

C. Quality

1---------2----------3---------4---------5---------6----------7
Not Important — Very Important

D. Design

1---------2----------3---------4---------5---------6----------7
Not Important — Very Important

E. Please list any other factors you feel are important:

Part IV: The following questions ask some basic demographic information about you and your company. This information will help us understand the relative size of the industry.

---

1. **Your job title:__________________________________**

2. **In what states do you currently sell your products? __________________________________**

3. **In 3 years, which states does your company expect to sell their products?**

   ____

4. **What was your company's sales volume in DOLLARS over the last 12 months:**

   $________________

5. **What is the company's predicted change in sales volume over the next 3 years:**
   (Please indicate (+) increase or (-) decrease and indicate the percent change)

   +/ **-** _______________ %,

Thank you very much for your help

Appendix B-Survey Instrument B

Listed below is a set characteristics related to structural lumber. Please circle the number which best describes the importance of each characteristic for each application.

Importance Ratings for Structural Material Applications

	Application		
Attribute	**Marriage Headers**	**Other Headers**	**Wall Framing**
	Not Important … Very Important	Not Important … Very Important	Not Important … Very Important
Straightness	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Moisture Content	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Grading	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Hardness (ease of nailing)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Stiffness (MOE)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Bending Strength (f)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy of Dimensions	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Price	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability of Long Length (16+ ft)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Consistency	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Quality	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Warranty	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Technical Assistance	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Appearance	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Weight	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Absence of End Splits	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Fastener Retention	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Service	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Importance Ratings for Structural Material Applications

	Application	
Attribute	**Floor Framing**	**Roof Framing**
	Not Important ... **Very Important**	**Not Important** ... **Very Important**
Straightness	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Moisture Content	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Grading	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Hardness (ease of nailing)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Stiffness (MOE)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Bending Strength (f)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy of Dimensions	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Price	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability of Long Length (16+ ft)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Consistency	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Quality	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Warranty	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Technical Assistance	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Appearance	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Weight	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Absence of End Splits	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Fastener Retention	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Service	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Listed below is a set characteristics related to structural lumber. Please circle the number which best describes the performance of each characteristic by structural lumber type.

Perceived Performance Ratings for Structural Material Types

	Material Type		
Attribute	**S. Pine/Doug.**	**S-P-F/Hem-**	**Laminated Veneer**
	Very Poor ... Very Good	Very Poor ... Very Good	Very Poor ... Very Good
Straightness	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Moisture	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy & Consistency of Grading	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Hardness (ease of nailing)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Stiffness (MOE)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Bending Strength (f)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Accuracy of Dimensions	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Price	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Availability of Long Length (16+ ft)	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Consistency	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Product Quality	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Warranty	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Technical Assistance	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Overall Appearance	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Weight	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Absence of End Splits	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Fastener Retention	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Service	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Perceived Performance Ratings for Structural Material Types

Attribute	Structural Composite Lbr.							Wooden I-Beams							Prefabricated Trusses						
	Very Poor						Very Good	Very Poor						Very Good	Very Poor						Very Good
Straightness	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy & Consistency of Moisture	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy & Consistency of Grading	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Availability	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Hardness (ease of nailing)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Stiffness (MOE)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Bending Strength (f)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy of Dimensions	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Price	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Availability of Long Length (16+ ft)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Product Consistency	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Product Quality	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Warranty	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Technical Assistance	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Appearance	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Weight	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Absence of End Splits	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Fastener Retention	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Service	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7

Material Type

Perceived Performance Ratings for Structural Material Types

	Material Type													
Attribute	**Glulam**							**Steel**						
	Very Poor						Very Good	Very Poor						Very Good
Straightness	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy & Consistency of Moisture Content	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy & Consistency of Grading	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Availability	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Hardness (ease of nailing)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Stiffness (MOE)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Bending Strength (f)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy of Dimensions	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Price	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Availability of Long Length (16+ ft)	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Product Consistency	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Product Quality	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Warranty	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Technical Assistance	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Overall Appearance	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Weight	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Absence of End Splits	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Fastener Retention	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Service	1	2	3	4	5	6	7	1	2	3	4	5	6	7

Appendix C-Cover Letter

Date

«First_Name» «Last_Name»
«Company»
«Address»
«City», «State» «Zip_Code»

Dear «Form_of_addr» «Last_Name»

As I explained during our recent telephone conversation, I am a graduate student at Virginia Tech, conducting a survey of modular housing manufacturers. This information will be used to determine your needs and requirements for structural material products. In response to increasing uncertainties and concerns regarding traditional sources of supply and quality of many softwood lumber products, research has been initiated to evaluate possible alternatives.

One product alternative that is being evaluated as a possible substitute for traditional structural materials is engineered lumber. An engineered lumber product is lumber which is formed by gluing together veneers, wood wafers, or smaller pieces of solid dimension lumber. By learning about your requirements for structural wood products and opinions towards current structural materials we can assist manufacturers and suppliers to develop products which better meet your needs and utilize our timber resources most efficiently in the future.

Your reply is very important for the accuracy and usefulness of our research and will be greatly appreciated. It will take about 15 minutes to answer the questions on the enclosed questionnaire and then simply return it in the stamped reply envelope provided. All responses are confidential and will not in anyway be associated with your name or company. The code number which appears in the upper right hand corner of the questionnaire will be used only to identify those companies who have responded and allow for future contact to be made with those who have not responded. All respondents will be provided with a complimentary report summarizing our findings.

Please return the completed questionnaire at your earliest convenience. Thank you for your help!

Sincerely,

Sara J. Gurney
Graduate research assistant

Appendix D-Follow-up Letters

Date

«First_Name» «Last_Name»
«Company»
«Address»
«City», «State» «Zip_Code»

Dear «Form_of_addr» «Last_Name»:

Recently I contacted or attempted to contact you on the telephone to request your participation in a survey of factory-built housing manufacturers. The purpose of this survey is to determine your needs and requirements for structural wood products and to evaluate the potential for substituting engineered lumber products for traditional solid structural lumber.

You should have already received the questionnaire in the mail. As of today, however, I have not yet received your response. If you have already mailed in the completed questionnaire, consider this a thank you note for your valuable help. Your participation is extremely important so as to provide an accurate representation of structural wood product requirements and use in the industry. In the case that the original was misplaced or lost in the mail, I have enclosed another questionnaire form so you may still respond. It will take only a short time to answer the questions on the enclosed questionnaire and then simply return it in the stamped reply envelope. All responses are confidential and will not in any way be associated with your name or company. The code number which appears in the upper right hand corner of the questionnaire will be used only to identify those companies who have responded and allow for future contacts to be made with those who have not responded.

Please return the completed questionnaire at your earliest convenience. Thank you for your help!

Sincerely,

Sara J. Gurney
Graduate Research Assistant

Date

«First_Name» «Last_Name»
«Company»
«Address»
«City», «State» «Zip_Code»

Dear «Form_of_addr» «Last_Name»:

A few weeks ago I sent you a questionnaire that will be used to determine your needs and requirements for structural materials for you company. This project is a 100% census of the region and while I have gotten a great response from most companies I am still missing your information. Please take a moment to answer as many of the questions that you can on the enclosed questionnaire or track down what happened to the pervious questionnaire. Please mail the completed questionnaire by August 10th in the stamped reply envelope provided.

Your reply is very important for the accuracy and usefulness of my research and will be greatly appreciated. I am waiting for your reply in order to complete the data collection process of my graduate research thesis. All responses are confidential and will not in anyway be associated with your name or company. The code number which appears in the upper right hand corner of the questionnaire will be used only to identify those companies who have responded and allow for future contact to be made with those who have not responded. All respondents will be provided with a complimentary report summarizing my findings.

Thank you for your help!

Sincerely,

Sara J. Gurney
Graduate Research Assistant

VITA

Sara J. Gurney

Sara J. Gurney has been an extension associate with the Ohio State University since January 1999. Her interests are in value added marketing of Eastern Appalachian Hardwoods. Sara received her B. S. degree in Forest Resource Management from Virginia Tech and plans on finishing her M. S. degree in Forest Products Marketing also from Virginia Tech in May 1999.