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Properties of 12-Year Low Thinning Teak Wood for Furniture Production of Communities in Thailand

Sirisyos Kijmongkolvanich, Somchai Sevisat, Songwut Egwutvongsa*

Department of Architectural Education and Design, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

Corresponding Author Email: Songwut.ae@kmitl.ac.th

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ABSTRACT

The objectives of this research were to study the physical properties of 12-year-old split teak wood and to determine the structural equation model of the utilization of 12-year-old teak by testing the mechanical properties of the wood with techniques from Thai folk wisdom as follows: 1) raw wood, 2) baked wood, and 3) wood soaked in water and dried in the sun, in order to measure the modulus of rupture (MOR) and modulus of elasticity (MOE) values for all three techniques. Moreover, the strength of the wood can be enhanced in order to support the weight by using the technique of soaking the teak wood in water and drying it in the sun. Thus, it can help to effectively reduce production costs as a method that is suitable for the climate of northern Thailand based on four factors: 1) Product Knowledge, 2) Policy and Social Requirements, 3) Material, and 4) Production Procedure by promoting the use of teak in the community in order to demonstrate good environmental friendliness.

1. INTRODUCTION

Teak (Tectona grandis Linn. f.) is recognized for its beauty and is one of the world's most valuable hardwoods [1-3]. Moreover, teak is a hardwood that has the properties of strength and durability. Consequently, it is commonly used to produce furniture and construct houses in Southeast Asia as teak is a natural wood that is abundant in India, Myanmar, Laos, Thailand, and other countries.

In 1941, the Thai government enacted the Forest Act B.E. 2484 (1941) by repealing the law in Section 7, which set out the terms about tree restriction on non-forested land by allowing people to plant restricted trees on their own land and to be able to cut down trees. This resulted in the people growing teak plants for commercial purposes, especially in Northern Thailand ("Announcement by the Prime Minister's Office of the Master Plan Announcement under the National Strategy [4].

For the strategy and work plan with Thailand's Comprehensive Teak Promotion Program, this utilized the strategic framework by focusing on formulating a plan to support the promotion. Moreover, this involved the participation of agriculturists, entrepreneurs, developers, and promoters by opening opportunities to develop wood products for selling on their own. Thus, this became a mechanism that could drive the green economy to create opportunities for income production for agriculturists by stimulating in paying attention on planting teak trees. In the same way, this also assisted in eliminating the poverty or debt of rural agriculturists in Thailand by creating career stability and income security. As a consequence, this could encourage them to plant teak trees in good environments and helped create a better quality of life. In addition, this could focus on creating a good quality production process that would be acceptable to the teak market both within Thailand and abroad, as well as increase the competitiveness and income of the people in Thailand to escape from the middle-income trap and be a high-income society [5-7].

Nowadays, the government of Thailand is operating a project to encourage agriculturists to plant teak, which has become a channel for creating occupations. Moreover, this has made a good quality of life with stable and sustainable income, which has also helped to recover the soil in the planting area. Consequently, the soil has abundant fertility to become an economic forest that has generated income and helped to maintain a sustainable environment [5, 6, 8]. The government has supported the cost of various kinds of wood, such as teak, Burma padauk, Yangna, Rosewood, Takhian, and others with a cutting cycle of more than 10 years. The Forest Industry Organization has also supplied plant species for the people to plant. Thus, the government has allocated a budget to promote planting of at least 100 trees per 1 rai of planting area before receiving the government subsidy. In the first year, the amount of 3,900 Thai Baht per rai is provided, and in the second year, the amount of 1,020 Thai Baht per rai is given, which is also according to the policy of the Sustainable Development Goals (SDGs) of the United Nations.

The Thai government's promotion policy has resulted in a large number of agriculturists planting teak products until gaining teak yields obtained from the cuttings and planting each year. This used the young teak of 7-12 years with fine wood properties that had light brown to dark brown heartwood with a beautiful dark wood pattern.

Therefore, the wood was often used to produce furniture or to decorate buildings because it was distinguished: 1) Beautiful patterns and 2) resistant to climate. Moreover, teak is suitable for planting on sandy loam, especially in the Northern region of Thailand [9]. However, teak plantation by

agriculturists in the 7–12-year-old teak period was cut, carded, and extended to stimulate the growth of teak in the planting area [10]. During the extension of the planting period, the agriculturists also often used it to burn charcoal or as fuel for cooking in their daily life. Thus, it lost the value from young teak by damaging the environment in the community [9], especially by not being developed sustainably for the ecosystem.

According to Kollert and Cherubini [11], young teak is a fast-growing wood that can be cut and used with problems: 1) Sapwood, 2) short fibers, 3) thin walls, 4) large microfiber corners, 5) low density of wood, and 6) less strength properties compared to mature teak [12-16]. As a result, the young teak was not popular and required by the Thai furniture industry [17].

Furthermore, Rizanti et al. [18] tested the properties of young teak with the modulus of elasticity (MOE) and modulus of rupture (MOR) values of short rotation teak and long rotation teak. Moreover, it was found that the properties of the two types of wood did not differ in the MOE and MOR values, including the strength. This was consistent with the research by Darmawan et al. [19] that found the teak planted in a rotational age of 7 - 12 years had MOE and MOR shrinkage that had not differed with old teak aged 40 - 50 years. Therefore, attention should be given to the use of short rotation teak or the useful wood processing [20].

For the research, young teak was dried [21, 22] to increase the strength properties by utilizing suitable chemicals or preservatives for modifying the value of the wood. Then, it could preserve the wood from natural fungi and insects, including the decreasing of warping and cracks after the wood had been used. Additionally, this was consistent with the study of by Bond and Espinoza [23] who presented a drying method from young teak by realizing about the thickness of the wood, the moisture and mechanical properties as the main method. The wood also had to be baked for preventing the warping of the wood and maintaining its quality.

Currently, the Thai government encourages teak farmers to plant teak in northern Thailand for reforestation in degraded forest areas. This has brought forth a large number of teak planting areas, especially during the rainy season of every year. After that, the farmers will cut the spaces between the teak planting rows to reduce the density of the canopy and help the teak trunks grow upright. As a result, in each year, a large number of teak trees are cut from the planting line during this pruning process. However, it has been shown that the teak wood that is produced from the cutting period has the properties of soft wood, and it is not sufficiently durable for use. Thus, when the farmers sell the teak from the cutting of rows, they receive low economic returns. Therefore, this research aims to develop a technique for preserving teak wood in order to provide suitable properties for use. Lühr et al. [24] presented a method for drying wood naturally under suitable weather conditions during April of every year with high temperatures and low humidity. In this case, this method is highly environmentally friendly and has a low cost of preserving the wood while increasing the efficiency of the process for teak by soaking it in water. This results in the decomposition of the starches and sugars in the teak pulp, which helps prevent insect infestation [25]. As a result, it is a way to maintain the quality of the wood that is highly environmentally friendly.

Based on this concept, this method was selected as the focus of this research. Moreover, the physical properties of 12-year-old teak from the cutting of the planting rows were tested, including the strength properties in the base of the tree, in the middle of the tree and at the end of the tree. Then, the process of baking, drying and soaking in water was applied in order to increase the strength properties of the teak before being tested with the Standard Test Methods for Small Clear Specimens of Timber D 143–94 (Reapproved 2000) [26] by the Royal Forest Department of Thailand. Later, the mechanical properties testing was also conducted to study the effect of stress that acts on wood in two ways: 1) the Static Bending Test and 2) the Hardness Test. Therefore, the goals of the research process were to study the strength of the 12-year-old teak and to identify the factors that affect the use of split teak wood involved with the community development products based on information from farmers, entrepreneurs and consumers. Subsequently, the results of the research will help create knowledge of the techniques for the preservation of 12-year-old teak and knowledge in using this teak wood to create green products that meet the needs of consumers. As the result, it will also help to increase the economic value of the teak, which is abundant in local areas.

2. MATERIALS AND METHODS

2.1 Research objectives

1) To study the physical properties of teak that had an extended age of 12 years.

2) To determine the structural equation model (SEM) factor in the use of teak cutting, carding, and extending the lifespan of 12 years.

2.2 Conceptual framework

1. The conceptual framework techniques for increasing the quality of carding the trees by extending the age of 12 years was divided into three periods that were the base, the middle, and the tip of the tree. This used the techniques to increase the properties of the wood with community wisdom: 1) baking, 2) soaking, and drying.

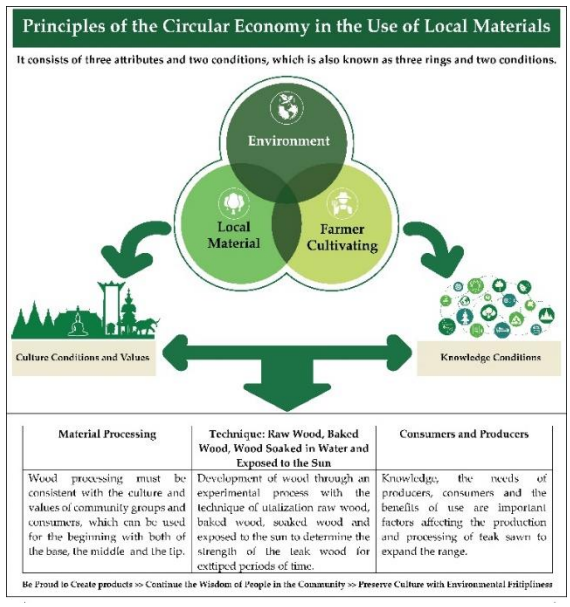

Figure 1. Principles of the circular economy in the use of local materials

2. The conceptual framework was established for determining the SEM factors, the utilization of sawn teak with the exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) brought into manufacturing of furniture products. Research manuscripts reporting large data sets that were deposited in a publicly available database specified where the data had been deposited and provided the relevant accession numbers. If the accession numbers had not yet been obtained at the time of submission, they should be provided during the review. As such, they would need to be provided prior to publication (Figure 1).

In Figure 1, the material processing must rely on two factors, both in terms of culture and the manufacturer values consumers to be based on knowledge-based conditions and the wisdom of the people in the community from the past to present as follows:

1) Culture Conditions and Values: Promote to use the local materials for producing the products by transferring the cultural wisdom of the people in the community from the past and apply to create a new and modern pattern to the requirements of today's consumers.

2) Knowledge Conditions: Producers should have the knowledge in producing quality products and processing wood by applying techniques with the needs of consumers, and the consumers should have the knowledge to choose the quality and effective products to gain the most benefit mostly as the needs of consumers with the concept of His Majesty King Bhumibol Adulyadej The Great.

2.3 Research scope

1. The study of the physical properties of teak wood extended to 12 years of age.

a) Method of study: 1) Testing of flexural strength was conducted that was from the base, the trunk, and the tip of the teak wood with the test size of 50 x 50 x 760 mm with 27 pieces. 2) The wood hardness test of low thinning teak was conducted, such as the base, the middle, and the tip with the test size of 50 x 50 x 150 mm with 27 pieces. There was a total amount of 54 pieces.

b) Testing process: The cuttings extended the root, the middle, and the tip of the tree that consisted of raw wood, baked wood, wood soaked in water, and wood exposed to sunlight. Three pieces of each were used to test the bending strength of the wood for three times.

c) Research Tools: Mechanical Properties Tester according to the Standard Test Methods for Small Clear Specimens of Wood D 143–94 Reapproved 2000.

d) Data analysis was conducted to compare the bending force and the pressure of the wood.

2. Determination of the structural equation model factors for the use of low thinning teak.

a) Population group: Trade associations of furniture and wood product entrepreneurs in the Northern region of Thailand and consumers of teak products attending the event of the creative economy culture promotion activities called the Patochai Night Market" of Phrae Province.

b) Sample group: A total of 194 people were divided into two groups: 1) A group of 49 furniture and wood product entrepreneurs in Phrae Province, and 2) 145 consumers applying teak wood products who were participating in supporting the activities of the creative economic culture called the Gate Triumph Night Market. The participants were selected by simple random sampling with a 10% discrepancy as stated by Yamane [27].

c) Research tool: A structured questionnaire was produced about the data on the application of low thinning teak by utilizing a five-point Likert scale of 33 variables. The alpha coefficient or Cronbach 's Alpha = 0.969, which was considered to be at a very good level. Thus, the questionnaire was considered to be reliable for use with the population.

d) Data Analysis: This used EFA and CFA.

e) Procedures for Constructing the Questionnaire and Collecting Data.

- The data collection occurred during field visits and the confidence was checked with Cronbach's alpha from the specified criteria (Nunnally, 1978 and Robert A. Peterson) [28]. Then, all 194 sets of the questionnaire underwent Normality Testing and passed the criteria for considering the skewness and Kurtosis values that were less than +/-1, followed by a complete analysis with parametric statistics [29, 30].

- The questionnaire was created to be used to inquire about consumer needs and was certified by the Ethical Standards for Human Research (EC-KMITL_65_118) from King Mongkut's Institute of Technology Ladkrabang.

3. RESULTS

3.1 Results of the study

1) Tree and wood samples: A 12-year-old teak tree was cut in the community forest park of Soem Klang Subdistrict, Soem Ngam District, Lampang Province, Northern Thailand at a latitude of 18.0369028256353,99.1896201854. Moreover, the topography is a flat area surrounded by mountains, and the area is a large basin that has hot weather all year. However, in summer, it is very hot, but in winter it is very cold with the highest temperature of 42.30°C and the lowest temperature of 13°C, respectively. The climate has three seasons: Summer for four months, rainy season for four months, and winter for four months.

2) Soil test results: The soil properties at the abovementioned latitude had the following values: 1) Humidity of 13.39% by weight, 2) nitrogen of 0.24% by weight, 3) available phosphorus of 18.48 milligrams per kilogram, and 4) available potassium of 256.91 milligrams per kilogram.

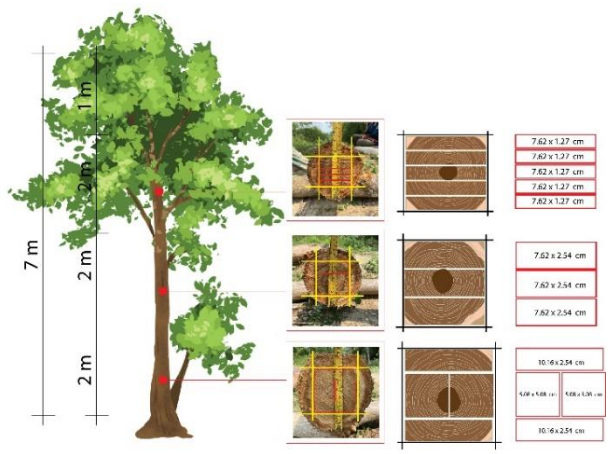

Figure 2. The sectioning of the trunk with the produced products

3) Preparation of the teak pieces for testing: The characteristics of the cutting intervals were conducted as shown in Figure 1 for reducing the warpage of the wood, and allowing for the flexibility of the wood with easiness so to process it. Then, this could be applied to the production of furniture by processing. Similarly, the teak processing was consistent with the lifestyles of the agricultural community and the Thai Lanna culture that had been inherited from the past. Hence, the wood was divided into three sections from the beginning, the middle, and the tip. However, the wood had different sizes that were the base of the tree was 20 centimeters wide, the middle part was 15 centimeters wide, and the tip of the tree was 10 centimeters wide (Figure 2).

4) Experimental Plan to Improve Wood Properties by Local Farmers who use three testing techniques.

1) Technique 1 of raw wood: Cut and processed the wood and dried it indoors before use (Figure 3).

Figure 3. Cutting and processing of raw wood that is dried indoors before use

2) Technique 2 of baked wood: The processed teak was baked at a temperature of 50 - 80°C for 336 hours and 14 days (Figure 4).

Figure 4. The transforming process of the low thinning teakwood before being tested using the technique of baked wood

3) Technique 3 of soaked and dried wood: The low thinning teak was soaked in water for three days and 72 hours and exposed to the sun for 140 hours within 14 days (Figure 5).

Figure 5. The transforming process of the low thinning teak wood at an extended stage before being tested for the soaking and drying technique

The processing of the properties of the wood before testing of all three methods is shown in Table 1.

Physical properties of wood to be changed from the baking, soaking and drying process (Figure 6).

Figure 6. The changes of the teak wood from the process of baking, soaking, and drying

Table 1. The three testing techniques

Technique	Test	Processing	How to Improve the Properties of the Wood
Raw wood	Four Days	1) Cut, 2) processed, and 3) adjusted the size of the wood before testing.	1. Days 3 - 6 for wood processing.
Baked wood	18 Days	1) Cut, 2) processed, and 3) adjusted the size of the wood before baking.	1. Days 3 - 6 for wood processing. 2. Days 7 – 13, the wood is baked at 50°. 3. Days 14 - 20, increased the baking temperature to 80°C.
The wood is soaked in water and exposed to the sun.	23 Days	1) Cut, 2) processed, and 3) adjusted the size of the wood before soaking in water and exposed to the sun.	1. Days 3 - 6 for wood processing. 2. Days 7 - 9 for soaking the wood in water. 3. Days 10 - 23 for bringing the wood to the sun that had a temperature of 36°C during 08.00 – 17.00 Hrs.

- Raw wood: It has a physical appearance with a normal color and water content inside the wood, which made the wood heavy.

- Baked wood: The physical characteristics changed after baking, and the wood had a fresher and more outstanding color with the lighter weight than the raw wood.

- Soaked and dried wood: The physical characteristics changed on the white sapwood that was similar in color to the normal wood color, but the weight of the wood was lighter than the raw wood.

4) Test: This showed the results of the mechanical properties testing according to the Standard Test Methods for Small Clear Specimens of Wood D 143-94 Reapproved 2000 of the Royal Forest Department of Thailand. Then, the 12-year low thinning teak wood was used to test the hardness of the wood and the flexural strength of the wood from the base, middle, and tip of the tree. The test was divided into three methods of fresh, baked, soaked and dry wood (Table 2) and there is a testing process as shown in Figure 7.

Figure 7. Testing of the a) fracture coefficient; MOR (ksc.), b) coefficient of elasticity; MOE (ksc.), c) wood hardness (kg.), and d) moisture content (%)*

1) The hardness value was between 474 - 497 kg; the soaked and dried wood gave the highest value.

2) Fracture coefficient; MOR had a value between 661 - 810 ksc. from the baked, soaked, and dried wood with better flexural fracture resistance than fresh wood.

3) Elastic coefficient; MOE had an increasing MOE value

between 83065 - 104607 ksc. To show greater flexural strength at the same bending distances as in Table 2, which the baked, soaked and sun-dried wood had higher MOE values than fresh wood, while soaked and dried wood had the highest MOE values.

4) Decrease in moisture content resulted from the increasing hardness; MOR and MOE values.

Table 2. Hardness test and bending strength test (n=13)

Teak	Root	Middle	Tip	Average	Test
	492	420	509	474	The hardness of the wood (kg.)
Fresh Wood	687	636	660	661	Fracture coefficient; MOR (ksc.)
	78786	83304	87104	83065	Elastic coefficient; MOE (ksc.)
	13.1	13.9	13.3	13.5	Moisture value (%) *
	491	479	461	477	The hardness of the wood (kg.)
Baked Wood	829	847	753	810	Fracture coefficient; MOR (ksc.)
	87919	100953	93845	94239	Elastic coefficient; MOE (ksc.)
	9.2	9.2	9.4	9.3	Moisture value (%) *
	489	523	479	497	The hardness of the wood (kg.)
Soaked and Dried Wood	770	722	792	761	Fracture coefficient; MOR (ksc.)
	90101	103465	120254	104607	Elastic coefficient; MOE (ksc.)
	10.0	11.2	10.7	10.6	Moisture value (%) *

* Humidity value from the flexural test.

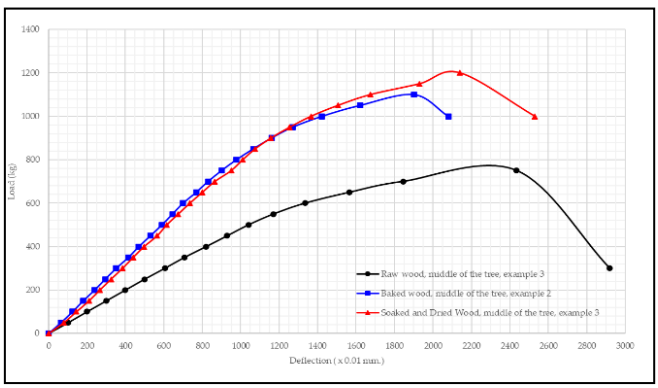

Figure 8. The relationship between weight and deflection distance from the flexural strength test

According to the test results shown in Figure 8, it was found that the baked, soaked, and dried wood had fracture and bending resistance properties. Moreover, the MOR value showed a better value than fresh wood, and when considering the results, they showed that baked, soaked, and dried wood had similar deflection distances and noticeably less bending than fresh wood.

It was concluded that the wood used for the technique of soaking and drying was the best for the flexural strength testing, and this technique was also a method that saved energy and the environment. As a result, it would not cause air pollution as well as preserve the wisdom inherited from the community and help agriculturists reduce production costs on furniture products.

3.2 The results of the determining factors for the structural equation model after the utilization of low thinning teak wood

From the results of the analysis, the teak wood in the product design should be given importance on the creative step factor by dividing into two steps: Step 1: The survey component analysis from the consumer groups to the group variables with EFA, and Step 2: confirmatory factor analysis by CFA and first/second order analysis, where the researchers used a group of variables to test.

Then, the relationship of the observable variables had an effect on the purchasing decision of the product with teak cutting, carding, and expanding the distance as follows:

3.2.1 Step 1 L Exploratory component analysis

The data were grouped into the variables by EFA and collected with the needs of individual consumers. Then, it could find the variables that affected the purchase and consumer satisfaction by assessing the satisfaction of the teak products. Additionally, this was an analytical process to explore the variables and identify the common factors, so to explain the relationship between all the existing observable variables after the researchers used the indicators to check: 1) preliminary agreement before doing the research, and 2) analytical procedures to test the normal correlation, correlation of the observed variables, and others [31].

This research process aimed to find the factors affecting the opportunity to apply young teak wood in the product design. At present, there is no concept for product design from young teak to clearly support about the relationship between the factors affecting consumer satisfaction and the purchasing decision, and the relationship with the measurement of the scores from the evaluation according to the specified indicators by conducting the analysis as follows:

1. Determination of all 33 variables studied.

2. Determination of a reliable minimum sample number; this research should have a minimum sample size of 194 people.

3. Check the common values of the variables by describing the factors or communalities that should have a value > .6 or higher. When checking, it was found that all variables in the research were communalities of 818 - .601. Then, all the analytical variables had a higher synergistic value than. 6, which inferred that all variables could be grouped together. This would be an appropriate factor for the product design from young teak with the value of the communalities that was higher than .6 and had a KMO and Bartlett's Test with higher scores.

4. The process of analyzing the consumer data to group the variables should be analyzed from the elements survey (EFA)

by gathering the needs and perception about 7 - 14 years low thinning teak wood for individual consumers, including finding the variables that would influence the choice of purchase and consumer satisfaction.

The KMO and Bartlett's Test = .946, which was greater than 0.50, and the collected data could show the sample's perception. Hence, the use of teak wood to extend the age of 7 - 14 years was appropriate and could be used for ECA (Chi-square = 4856.423; significance = 0.000). Thus, it could be concluded that there were 33 variables that were related (Table 3).

Based on the results of the analysis, it was found that there are four factors that affect the chances of success in using teak in the future based on the total number of variables. Also, the results showed that 33 variables can be grouped into the four factors to have a significant weight from the highest level to the lowest level as follows: Factor 1 = 50.488, Factor 2 = 5.863, Factor 3 = 3.896, and Factor 4 = 3.390, with a forecast value of 63.637 and all four factors having the same information (Table 4).

Table 3. KMO and Bartlett's test of the need s and perception of the group sampling toward 7 - 14 years low thinning teak wood

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.946
by Bartlett's Test of Sphericity	Approx. Chi-Square	4856.423
	df	528
	Sig.	.000

Table 4. The axial rotation weight factor, the varimax method, and the component weight value at 0.60 or Higher

	[1] Product Knowledge Factor	F/1	F/2	F/3	F/4
D2	Knowledge level in the use of young teak products.	.818			
C1	The ability to apply young teak for use.	.806			
A1	Satisfaction with the utilization of teak products.	.745			
D1	Consistency of teak products with everyday life.	.729			
C4	Awareness level of the price and market significance of young teak.	.723			
F4	The uniqueness of the color of the young teak with a variety of colors.	.601			
	[2] Policy and Social Requirements Factor	**F/1**	**F/2**	**F/3**	**F/4**
E5	Promotion and support from the government of Thailand.		.805		
E4	Appropriateness of the government policies to encourage cultivation in the people's own areas.		.783		
E6	The suitability of the shape of the teak products that should be modern.		.696		
E3	Young teak can help increase the income of the community.		.671		
F3	Young teak products should be able to be disassembled.		.654		
F5	The shape of the product from the sawn teak extended the impact range. Transportation.		.652		
	[3] Material Factor	**F/1**	**F/2**	**F/3**	**F/4**
B2	The identity of the young teak is suitable for creating products.			.722	
B6	Product size conformance to shipping.			.658	
A4	Strength and durability in the use of young teak products.			.640	
	[4] Production procedure Factor	**F/1**	**F/2**	**F/3**	**F/4**
A2	The warping and bending characteristics of teak have influenced the creation of the product.				.751
B1	Appropriate use of techniques for soaking in water and drying in the sun before use.				.701
A5	Appropriateness of the wood drying techniques before use.				.671

variable	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5
A2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A3	.076	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A4	.012	.175	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A5	.139	.100	.151	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B1	.089	.215	.075	.057	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	.137	.208	.055	.043	.279	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B3	.090	.065	.251	.239	.070	.068	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B4	.157	.045	.172	.023	.078	.097	.105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B5	.024	.056	.066	.109	.100	.042	.079	.166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B6	.167	.056	.170	.000	.113	.134	.151	.152	.110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1	.075	.282	.078	.028	.024	.099	.167	.086	.068	.147	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C2	.226	.037	.012	.088	.015	.059	.080	.050	.168	.010	.084	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C3	.116	.141	.101	.007	.090	.079	.049	.033	.065	.032	.110	.100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C4	.087	.065	.085	.096	.005	.048	.059	.185	.133	.026	.013	.085	.104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C5	.048	.113	.016	.006	.092	.109	.156	.079	.032	.013	.159	.112	.038	.021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C6	.211	.263	.014	.123	.240	.012	.088	.126	.215	.192	.056	.000	.185	.143	.158	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D1	.153	.071	.023	.037	.110	.030	.122	.074	.088	.105	.064	.034	.183	.084	.025	.338	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D2	.109	.001	.011	.204	.134	.079	.008	.205	.027	.332	.025	.117	.190	.004	.155	.152	.113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D3	.284	.012	.006	.095	.100	.129	.058	.055	.025	.144	.182	.403	.143	.100	.097	.103	.131	.157	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D4	.111	.137	.128	.103	.020	.225	.014	.020	.134	.106	.037	.076	.080	.172	.089	.002	.100	.039	.053	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D5	.135	.125	.107	.015	.081	.047	.036	.180	.040	.085	.073	.032	.097	.197	.000	.194	.139	.003	.118	.105	-	-	-	-	-	-	-	-	-	-	-	-	-
E1	.172	.149	.035	.041	.007	.008	.009	.024	.170	.056	.259	.117	.162	.080	.191	.089	.188	.004	.027	.192	.174	-	-	-	-	-	-	-	-	-	-	-	-
E2	.009	.098	.049	.077	.074	.031	.061	.093	.149	.080	.121	.168	.047	.138	.134	.076	.035	.139	.098	.001	.015	.196	-	-	-	-	-	-	-	-	-	-	-
E3	.026	.011	.064	.018	.128	.205	.015	.109	.023	.084	.115	.102	.053	.011	.137	.001	.024	.004	.178	.012	.001	.019	.316	-	-	-	-	-	-	-	-	-	-
E4	.023	.034	.076	.084	.135	.137	.004	.036	.193	.093	.013	.050	.029	.009	.087	.085	.193	.012	.033	.134	.084	.152	.051	.407	-	-	-	-	-	-	-	-	-
E5	.077	.024	.075	.188	.052	.039	.053	.094	.117	.195	.036	.082	.045	.134	.193	.047	.017	.171	.032	.051	.107	.098	.101	.029	.204	-	-	-	-	-	-	-	-
E6	.043	.050	.001	.018	.036	.035	.001	.017	.226	.093	.025	.097	.064	.025	.097	.101	.102	.060	.038	.170	.025	.161	.021	.014	.145	.487	-	-	-	-	-	-	-
F1	.019	.067	.062	.035	.114	.013	.017	.056	-.020	.013	.070	.085	.151	.000	.293	.053	.010	.084	.063	.126	.111	.137	.021	.197	.138	.114	.103	-	-	-	-	-	-
F2	.009	.054	.152	.057	.003	.005	.010	.170	.062	.035	.059	.056	.047	.014	.124	.011	.114	.021	.040	.134	.108	.097	.076	.225	.000	.158	.064	.380	-	-	-	-	-
F3	.027	.089	.078	.037	.159	.065	.060	.095	.103	.173	.119	.087	.232	.119	.072	.291	.099	.287	.064	.041	.084	.151	.031	.032	.026	.029	.005	.190	.004	-	-	-	-
F4	.002	.038	.041	.027	.002	.188	.025	.086	.133	.071	.016	.130	.070	.081	.033	.169	.087	.068	.155	.035	.135	.047	.059	.039	.149	.035	.052	.103	.059	.311	-	-	-
F5	.117	.087	.040	.079	.095	.045	.092	.007	.037	.087	.040	.013	.141	.066	.191	.063	.136	.074	.083	.084	.085	.048	.003	.206	.034	.093	.010	.234	.239	.183	.011	-	-
	.100	.083	.029	.059	.112	.047	.103	.084	.099	.009	.194	.001	.058	.018	.118	.066	.043	.093	.010	.018	.202	.158	.120	.180	.181	.138	.163	.208	.025	.008	.118	.267	-

Measures of Sampling Adequacy(MSA)

Figure 9. Analysis of the anti-image matrices (measures of sampling adequacy (MSA))

It can be seen that the variables are related among the four factors as follows:

1) Factor 1: Product Knowledge consists of variables D 2, C 1, A 1, D 1, C 4, and F 4.

2) Factor 2: Policy and Social Requirements consists of variables E 5, E 4, E 6, E 3, F 3, and F 5.

3) Factor 3: Material consists of variables B 2, B 6, and A 4.

4) Factor 4: Production Procedure consists of variables A 2, B 1, and A 5.

From all 33 variables, the number of variables was reduced to only 18 variables for use in the CFA analysis process, which considers the relationships between each variable. Moreover, it can reduce the overlap of the studied variables. In this case, the results of this study demonstrate the importance of knowledge development related to the development of wood preservation techniques for farmers. Thus, it can facilitate the proper processing and preservation of the wood before the harvested teak is used in the production of products with the skills of the entrepreneurs in the community. At this stage, it is necessary to consider the relationships between each factor that affects the chances of success of applying teak wood to meet the needs of consumers in the future (Figure 9).

From the results of the assessment of all 18 variables, these were combined four factors that were used to analyze and know the perception of the consumers. Each factor affected the demand for the utilization of the 7 - 14 years low thinning teak wood (Figure 9).

In this case, the consumers felt the importance of the four factors affecting the use of teak wood in the product design by showing the need to use the benefits of teak cutting to extend the important phase as follows: 1) Production procedure had a high level of satisfaction (Mean = 3.83; SD = 0.71). 2) Policy and social requirements had aa high level of satisfaction (Mean = 3.78; SD = 0.81). 3) Material had a very satisfactory level (Mean = 3.60; SD = 0.81). 4) Product Knowledge was moderately satisfied (Mean = 3.29; SD = 0.94). Additionally, overall, it was found that consumers were satisfied with all four factors at a high level (Mean = 3.62; SD = 0.82). (Table 5).

5) Moreover, the CFA validation process was based on the statistical agreement to refer to the probabilities of the data, and the KMO and Bartlett's Test were appropriate (KMO = .946; Bartlett' Test of Sphericity = 4856.423; Sig. = .000). Therefore, it was found that the eight observed variables were sufficiently correlated for the CFA analysis.

Table 5. Consumers' perception of the focus on all four factors (n=194)

	Factor	Mean	S.D.	Level of Satisfaction
1	Product Knowledge	3.29	0.94	Moderate
2	Policy and Social Requirements	3.78	0.81	High
3	Material	3.60	0.81	High
4	Production Procedure	3.83	0.71	High
	Total	3.62	0.82	High

3.2.2 Step 2: CFA audit

Then, the analysis results were used to confirm the SEM of the teak application, and Cronbach's Alpha (Cronbach 's Alpha) = .938 from the questions used to collect the data. Likewise, there was a very good level of suitability when analyzing, and it could show the results (Table 6).

This was related to the confirmative component analysis of the consumer demand for 7 - 14 low thinning teak products with the Amos program (AMOS), and the model conformance index was obtained according to Schumacker and Lomax's criteria [32]. Thus, this showed that χ^2 = 37.625, df = 86, relative χ^2 = .437, p = 1.000, RMSEA = .0 00, RMR = .030, GFI = .979, AGFI = .958, NFI = .984, TIL = 1.040, CFI = 1.000, CMIN = 37.625, and PGFI = .492, where the conformity index met the specified relative criteria. Additionally, χ^2 was less than the two indexes of RMSEA, and RMR was less than .05 for GFI and AGFI, while NFI and TLI were greater than .95.

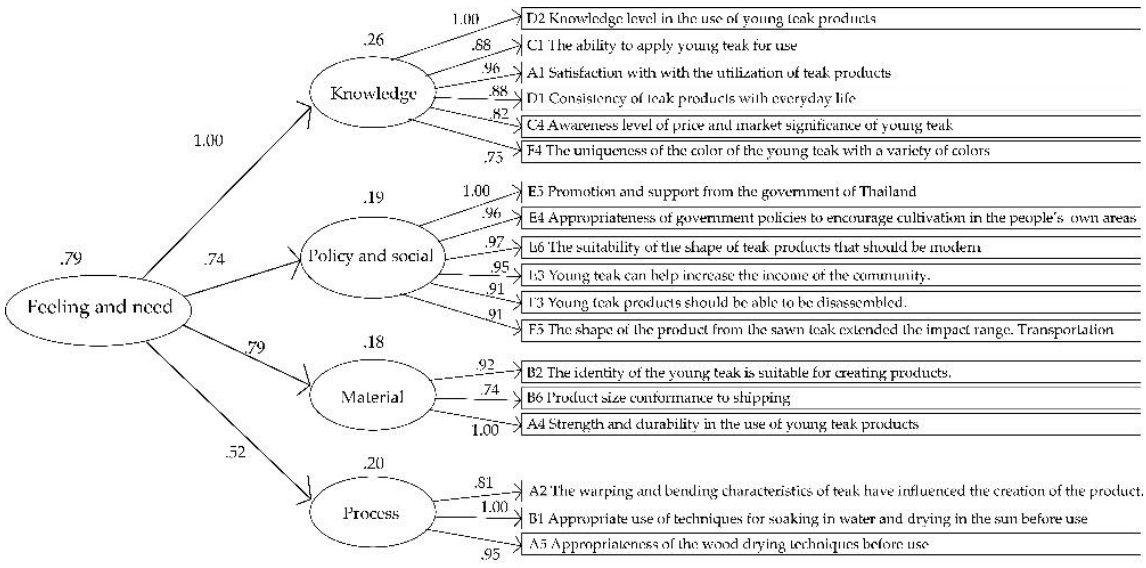

Figure 10. The structural equation model of the factors affecting the benefits from 7 – 14 years low thinning teak wood

Table 6. Second order component analysis

Latent Variable	Knowledge			Policy and Social			Material			Process			r^2
Observable Variable	β_i	b_i	***S.E.***	β_i	b_i	***S.E.***	β_i	b_i	***S.E.***	β_i	b_i	***S.E.***	
Product Knowledge (D2)	1.00	.87	-	-	-	-	-	-	-	-	-	-	.752
Product Knowledge (C1)	.88	.84	.047**										.709
Product Knowledge (A1)	.96	.82	.0.70**	-	-	-	-	-	-	-	-	-	.669
Product Knowledge (D1)	.88	.85	.058**	-	-	-	-	-	-	-	-	-	.724
Product Knowledge (C4)	.82	.79	.060**	-	-	-	-	-	-	-	-	-	.628
Product Knowledge (F4)	.75	.70	.064**										.486
Policy and social requirements (E5)	-	-	-	1.00	.77	-	-	-	-	-	-	-	.600
Policy and social requirements (E4)	-	-	-	.96	.73	.069**	-	-	-	-	-	-	.532
Policy and social requirements (E6)	-	-	-	.97	.81	.082**	-	-	-	-	-	-	.653
Policy and social requirements (E3)	-	-	-	.95	.81	.081**	-	-	-	-	-	-	.650
Policy and social requirements (F3)	-	-	-	.91	.78	.079**	-	-	-	-	-	-	.608
Policy and social requirements (F5)				.91	.80	.080**							.640
Material (B2)	-	-	-	-	-	-	.92	.80	.096**	-	-	-	.636
Material (B6)	-	-	-	-	-	-	.74	.67	.087**	-	-	-	.444
Material (A4)	-	-	-	-	-	-	1.00	.77	-	-	-	-	.592
Production procedure (A2)	-	-	-	-	-	-	-	-	-	.81	.60	.120**	.358
Production procedure (B1)	-	-	-	-	-	-	-	-	-	1.00	.71	-	.511
Production procedure (A5)	-	-	-	-	-	-	-	-	-	.95	.71	.126**	.497

Latent variable	**The utilization from 7 to 14 years old of Thinning Teak.**			R^2
	β_i	b_i	***S.E.***	
Knowledge	1.00	.87	-	.749
Policy and Social	.74	.83	.085**	.693
Material	.79	.86	.087**	.736
Process	.52	.72	.078**	.512

χ^2= 37.625, df = 86, relativeχ^2= .437, p = 1.000, RMSEA = .000, RMR = .030, GFI = .979, AGFI = .958, NFI = .984, TLI = *1*.040, CFI = 1.000, CMIN = 37.625, PGFI = .492

In addition, the utilization factor of the teak wood appeared to show consistency and could be extended to 7 - 14 years. Hence, it could be used with the concept of Suksawang [33] and Schumacker and Lomax [34] with the conclusion that the design of the Sak Tad Sang wooden products extended the age range of 7 - 14 years to be able to meet the needs of the consumers. Moreover, this had to rely on four factors: the first factor was product knowledge, the second factor was the policy and social requirements, the third factor was material, and the fourth factor was the production procedure by relying on all four factors in the design process. Consequently, the product designers would have the opportunity to successfully use young teak wood to create products for consumers, as shown in the 18 indicators (Figure 10) and the determination of the confirmatory components of the demand factors of consumer groups using the Amos program (Table 6).

4. DISCUSSIONS AND CONCLUSIONS

The mechanical property value of 12-year teak in the Northern region of Thailand with the spacing of the rows to be planted at 3x3 utilized three techniques of preparing young teak wood with the wisdom of the community as follows: 1) Raw wood: Was processed within the testing of four days. 2) Baking stick: Was processed within the testing of 18 days. 3) Soaked and dried wood: Was processed within the testing of 23 days by bringing wood from all three techniques to test the mechanical properties, including the MOR, MOE, and hardness. Then, according to all three parts that were the base of the tree, the middle of the tree and the tip of the tree, it appeared that the teak was young and had mechanical properties. Similarly, the raw wood had a root strength of 492 kg, the middle of the tree was 420 kg, and the tip of the tree was 509 kg, respectively, while the soaked and dried teak wood appearing at the base of the tree was 489 kg, the middle of the tree was 523 kg, and the tip of the tree was 479 kg, respectively. Furthermore, the baked wood had the strength at the base of the tree of 491 kg, the middle of the tree was 479 kg, and the tip of the tree was 461 kg, respectively. Likewise, these three techniques were similar to each other [18, 35]. Consequently, a summary could be made that the 12-year-old

teak wood was strong with a good weight with unique beauty to be suitable for producing furniture products. This involved the process of maintaining the quality of the teak wood with all three techniques according to local wisdom, and it could also help reduce production costs and generate income. Therefore, this could add income for agriculturists during cultivation by cutting trees to be able to grow faster and be more abundant [36, 37].

This involved the utilization of teak wood for furniture product design, which was the remainder of the low thinning teak wood during the 7 - 14-year period that depended on the agriculturists to change the times for taking care of each plot throughout the year. Then, the young teak logs aged between 7 - 14 years old was regularly placed in the wood market throughout Thailand. As such, the method of processing into wood sheets for sale was as ready-to-use wood for the manufacture of furniture. The wood should be processed by baking or soaking in water and dried in the sun to reduce the moisture in the wood and reduce warping as well.

The test results showed the mechanical properties and hardness values of the wood based on the baking and drying techniques. Moreover, the strength was not different, but soaking in water and drying in the sun would take longer when compared to drying, which was consistent with the research of Lai and Chang [38]. In the same way, water was used to soak the wood with the same color, and if the water was boiled, it could be used as a dye with fabric or yarn used in weaving. Hence, this would become the conservation of nature.

According the opportunity factors in cutting teak to extend the distance between the planting rows by using the 33 observed variables, the results showed that the predictive value was at a high level from the four factors, all four of which will be the guidelines for the product design of the designers or entrepreneurs who want to use the teak wood that has been cut. Therefore, this will provide the advantage of increasing the economic value and displaying environmental friendliness. Thus, if these these factors are applied, there will be a high chance of success. In the same way, it should conform with the findings of Lai and Chang's study, which focused on the factors that directly and indirectly influence consumers regarding their level of demand and consumer purchasing decisions [38].

Regarding the product knowledge factor, it is considered to have a high tendency to increase the chance of success by applying the wisdom related to the utilization of teak wood by the entrepreneurs. Therefore, the focus should be on the development of techniques that are part of the indigenous knowledge of their own locality. This is consistent with the concept of Aktan and Anjam, who proposed that by studying the process of consumer needs, an understanding of the product development will gain for the manufacturers. Consequently, they will be able to understand the real needs of customers clearly in order to stimulate a feeling of need in the minds of consumers [39]. Moreover, it can be applied when comparing the results from the two research studies to determine whether that product development has a chance of success in the future by using the forecasts of consumer demand. However, it should be based on input from all product stakeholders by effectively forecasting the needs of consumers that occur. In this case, it is involved with the appropriate response to the needs of consumers in terms of these details: 1) Product Knowledge, 2) Policy and Social Requirements, 3) Material, and 4) Production Procedure. Therefore, all four factors are similar to the results of the study of factors affecting the demand of consumers studied by Suksawang [33], who explained that consumers tend to focus on visual and tactile stimuli. In the same way, the matters that are tangible will stimulate a feeling of need in the minds of the consumers with the possibility to make a decision to purchase the product. Similarly, these feelings will be in their mind, which means that they are difficult to measure in a quantitative way. Nevertheless, the explicit quantitative measurements can help explain consumer needs more accurately than other methods.

According to the structural equation model of the requirements of feelings for teak products including the cutting and expanding for the planting rows, it was shown that all four factors affect the level of consumer satisfaction with the new type of teak products: 1) Product Knowledge, 2) Policy and Social Requirements, 3) Material, and 4) Production Procedure. In this case, there are 18 observed variables from the structural equation model to be assessed according to the specified criteria, and they can be used to design furniture products made from teak that was cut to extend the distance between the planting rows [40]. Furthermore, according to the ideas of Amirkhizi et al. [40], with those four factors, it was shown in the conclusion that there is the emotional feeling of the consumer satisfaction after using the new products. Thus, the results of this research have confirmed that the manufacturers can respond to the feelings of consumers by applying these four factors as part of the new designs. Subsequently, it will help create opportunities for success in the future for the teak furniture products by providing the possibility to cause an increase in purchase decisions regarding products, which depends on the four factors as follows:

Product Knowledge Factor: It is the transferring of knowledge and skills related to the preservation of teak wood from people in the community who investigated and inherited it from their own ancestors. Then, the wood was cut at intervals and made strong and durable by using the wisdom in preserving teak wood with the soaking and sun-drying techniques that have been handed down since the past. Moreover, when scientifically tested, it appears that the teak wood that has been processed with the wood preservation process using the local community wisdom is more durable. Thus, it is also a way to preserve the heartwood, especially for the teak that has the low energy consumption and can also be promoted as a green product. Therefore, this is consistent with the findings of Nikolic et al. [41], which showed the idea that Awareness of environmental responsibility is made up of Attitudes, Behavior and Awareness, and the results appear to be consistent with the findings of this research.

Policy and Social Requirements Factor: The results are accordance with the Thai government's policy to promote reforestation. Moreover, the teak can be used to replace many degraded forests in Thailand, which aims to create green spaces and to earn income from cutting the trees in the distance by growing teak trees commercially. Thus, it is regarded as an additional income for farmers with the nature of the operations. Additionally, it is similar to the sustainable development guidelines of Kara et al. [42], which emphasize creation of sustainability for the community by leveraging the existing local potential to help drive the cycle and balance of sustainability: 1) the environment, 2) society, and 3) the economy, etc., which result from this research. Therefore, it was shown that the sustainability in good environments is in accordance with the criteria of sustainable development by encouraging the creation of green spaces by growing teak trees

and creating additional income for the community. In this way, the strength of the society is created in a fertile environment and the community's economy is expanded due to the increase in the income of the people in the community as a result of relying on the potential of resources and local wisdom.

Material Factor: It can expand the use of cut teak that has a unique color of the wood, especially when it becomes older, that will earn a higher value. On the other hand, with regard to the 12-year-old teak that was formed by cutting with the longitudinal branching, it showed a low value and weak wood properties. Similarly, it requires techniques that help preserve the wood by converting the 12-year-old teak wood that is obtained to the wood that has good quality and is strong enough to be used. Moreover, according to Liese's concept of transforming natural materials [31], it must be clearly targeted in the material processing by comparing the desired results with the processes of the transformation that should be suitable for the potential of the community and the technology available within the community.

Production Procedure Factor: It can test the process for the teak wood obtained from the cutting of teak trees in order to extend the range of the rows. Moreover, they were planted with wood preservation techniques. In this case, according to the wisdom of the community, it was shown that the properties of teak wood resulting from the water soaking and sun-drying techniques are appropriate for communities with low technological potential. Hence, these techniques can be applied in the process by implementing them with the teak wood of their own community. In addition, it is in accordance with the concept of Palanisamy et al. [2], which states the idea that when using young teak wood, it should be well maintained before use. Thus, the wood preservation should be tested to show the results according to the specified test criteria. As a result, in this research, it was compared with the Standard Test Methods for Small Clear Specimens of Timber D 143–94 (Reapproved 2000) by the Royal Forest Department of Thailand to present the technique of soaking wood in water and drying it in the sun as the best method for enhancing the bending strength with a high level of environmentally friendliness.

Therefore, according to the four factors, the importance in the development of methods for utilizing the growing and splitting of teak in response to the needs of consumers is indicated. Thus, according to the potential of the community, it is considered a research study that aims to create green products by the showing of environmental friendliness. In this case, this research will use the wisdom of the community in the preserving of the condition and the testing of the properties of teak wood to meet the standard criteria for furniture production. In addition, it aims to strengthen the ecology, economy and society [41]. Therefore, all four factors will become the knowledge for the community as a guideline for creating products from 12-year-old teak wood that is obtained from cutting in order to expand the planting rows. As a result, it is involved with the local Increase of the economic value and demostration of environmental friendliness, which results in the sustainable development of the community with stability in these fields: 1) the Ecosystem, 2) Economics, 3) Aspects of Society, 4) Ways of Life, and 5) the Promotion of Community Enterprises [42].

In this research, the method of testing using the technique of soaking and sun drying wood has been presented. Moreover, this is a technique that provides higher efficiency of wood properties compared to other techniques. Therefore, when applying the wood preservation techniques obtained from the research in the community, it appears that teak farmers and entrepreneurs of teak wood in the community can apply them in their real life by 1) improving the wood quality, 2) reducing production costs, 3) economic value addition, and 4) creating green products by implementing these four aspects as a response to a strategy for creating sustainable development in the community. In this case, the objective is to encourage communities to be self-reliant in terms of production technology and market response. Thus, the research results are in line with the strategy of the Thai government that require the strengthening of the community's potential. The concept of Newby et al. [6, 7] presents the potential of communities in Southeast Asia to have outstanding natural resource costs by including resources that are different from other areas to create the products. Therefore, it will have a positive effect that will lead to the opportunity to increase sales because of the unique regional identity.

5. RECOMMENDATIONS

This research presents the results of the technique of soaking and sun drying to maintain the quality of the 12-year-old teak wood that results from only the teak trees that have been thinned out. Moreover, it has not been tested in a comparative manner with that of 7 to 10-year-old teak. Therefore, it is still not possible to present a clear comparison of the properties of teak wood that have different ages.

In addition, the water soaking and drying experiment was conducted in Southeast Asia, located between 5° - 21° north latitude and 97° - 106° east longitude, which is a humid tropical area. Thus, when the technique is applied in different regions, it will affect the results and duration of the teak drying time as these will vary according to the temperature and humidity level of each region. As the result, these seasonal factors will affect the duration and strength differently.

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NOMENCLATURE

(SEM)	Structural Equation Model
(EFA)	Exploratory Factor Analysis
(CFA)	Confirmatory factor analysis
MOR	Modulus of Rupture
MOE	Modulus of Elasticity
(ksc.)	Kilogram Per Square Centimeter
(kg.)	kilogram
(%)*	Moisture value