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An SEM Approach for the Barrier Analysis in Lean Implementation in Manufacturing Industries

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Abstract: This paper investigates the barriers that hinder the implementation of lean manufacturing in wood and furniture industries as the adoption of this philosophy in such industries is not promising especially in emerging economies. To this end, a comprehensive review of the literature was performed to identify the barriers and develop a conceptual model. Next, structural equation modeling is employed to examine the model using the collected data from 131 wood and furniture companies. The findings revealed a synergetic effect between three key factors—culture and human attitude, knowledge, and resources—which play a crucial role in implementing lean. The analyses indicated the reasons of companies refused or not ready to implement lean on knowledge and culture and human attitudinal issues, particularly in companies that have limited resources. It is believed that resource issues are an obstacle to lean implementation, but not as important as knowledge and culture and human attitudinal issues. Sufficient knowledge is needed to deploy lean practices as well as changes in culture and human attitude. Investigating the relationships between these three key barriers is a contribution that this study intends to become a forward step for promoting lean manufacturing among under-studied industries. This paper also proposes that through adopting the activities for lean implementation, small and medium enterprises can experience and quantify the positive impacts of lean practices. Government agencies, universities, and professional bodies can support such enterprises in this transition through targeted interventions that address the barriers presented.

Keywords: lean manufacturing; lean implementation; barriers; wood and furniture industries; structural equation modeling (SEM)

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1. Introduction

The lean philosophy should be understood as a journey rather than the final outcome that an organization aims to achieve [1,2]. A lean project should focus on the overall concept rather than on lean tools and techniques [3]. Many researchers have studied the reasons why firms refuse to implement lean individually. Singh et al. [4] emphasize that the top management commitment and government support are most important for the removal of barriers. Abolhassani et al. [5] highlighted that non-practitioners agree that the full implementation of lean requires proper technical knowledge and management commitment. In addition, the apparent resource constraints faced by small and medium enterprises (SMEs) are also taken into account [6] including the lack of infrastructure, human resources, financial resources, and time [7]. The barriers to implementing lean are mainly analyzed to guide SMEs to efficiently and effectively implement lean tools during the journey [8].

Reviewing the literature indicates that lean manufacturing has successfully contributed to a large variety of industries in developed countries through improving operational performance (by improvements in quality, productivity, delivery, and/or minimization of inventory and cost), business performance (by enhancement of profitability, sales, and customer satisfaction), environmental performance (by minimization/elimination of green waste, e.g., energy waste, materials waste, etc.), social performance (by reduction of existing hazards to the health and safety of employees), and, consequently, enhancing sustainable performance via the fulfilment of the triple bottom line requirements [9,10]. However, the adoption of this philosophy in developing countries is not promising, particularly in the forest-based (Finnish SMEs) industries, where lean is considered as a new concept and may have yet been established sufficiently in organization systems thinking [11,12]. This highlights a fundamental research question: "What are the barriers that hinder the implementation of lean manufacturing in wood and furniture industries?"

Thus, the contribution of this study entails the discussion concerning the reasons for not implementing lean manufacturing in wood and furniture industries, analyzing the barriers in 131 non-lean companies from a different perspective. It develops a model using a structural equation modeling (SEM) technique that focuses on the barriers that prevent lean implementation in terms of knowledge, resources, and culture and human attitudinal issues. The importance of these three dominant determinants has been theoretically explained in Section 2, where proposes a conceptual framework of the most relevant factors preventing lean implementation. However, there is a lack of research on what influences wood and furniture industries to do not adopt lean manufacturing.

Accordingly, this paper outlines the research methodology in Section 3, the analyses and results derived from an empirical study in Section 4, an integrative discussion on the findings in Section 5, and finally, conclusions and recommendations in Section 6.

2. Literature Review

The concept of lean manufacturing (LM) and its barriers have been extensively discussed in the past decade. According to Abu et al. [13], one-third (out of the 59 respondents) of the respondents that were familiar with the LM practices had refused or were still not ready to implement the LM practices. There are several empirical studies on the variables contributing to the barriers in adopting lean, as described in Table 1.

To overcome the barriers in lean implementation, further explorations on the contemporary literature were conducted. Going through lean literature reveals that there is very little research on the implementation of lean in wood and furniture companies. For the purpose of this research, the lean implementation issue [14] was extended to include suggested arguments from the integrative discussion by [11].

Table 1. Contemporary studies on the barriers that hinder lean implementation in manufacturing industries.

Empirical Study	Description
Kumar and Vinodh [15]	Take 24 barriers into consideration including: changing governmental policies, poor selection of change agents and improvement teams, lack of top management commitment understanding and support of the system, lack of team autonomy, lack of flexibility, and versatility and lack of customer focus/involvement.
Gaspar and Leal [16]	Outline the difficulties in: completing daily tasks in a standardized way (standard routine), recognizing problems through analyzing key indicators, communicating reg-

	ularly with their employees, interacting with the support areas and higher hierarchical levels, going to the shop floor to realize the problems, prioritizing the identified problems, examining any taken improvements, and presenting the root cause of problems.
Panwar et al. [14]	Investigate nine reasons for not implementing lean: process industries already have continuous; large batch production is necessary for capacity utilization; lack of education and expertise on lean; lack of financial resources; lack of time; cultural barriers (resistance to change); specific characteristics of process industries time, temperature and process dependence; lack of senior management's interest and support; and lean is complex to implement.
Abolhassani et al. [5]	Study on the obstacle and lean strategic practices in implementing lean manufacturing by Pennsylvania and West Virginia manufacturers. Authors view the barriers to lean implementation between lean and non-lean companies. Ten barriers suggested are lack of management commitment, lack of technical knowledge, lack of understanding benefits, lean does not fit the culture, management resistant to change, employee resistant to change, lean is a gimmick, lean is unsustainable, high cost of investment, and previous failures of lean.
Thanki and Thakkar [17]	Highlight the initiatives of Indian Government on propagating lean principles and practices in Indian industries. The authors have observed five causes for employees' reluctant to eliminate the barriers for successful implementation of LM which are existing union work rule, perception of additional workload, oppose to take the initiative and accept the challenges, fear of committing mistakes and losing the job, and lack of monitory reward policy.
Bajjou and Chafi [18]	Categorize nine barriers into two classifications: "(1) *Organizational barriers*—time and commercial pressure, fragmentation and subcontracting, insufficient financial resources and lack of government support. (2) *People-related barriers*—resistance to change, unskilled human resources, lack of knowledge about lean construction concept, lack of commitment from top management and culture and human attitudinal issues."
Chaple et al. [19]	Analyze lean barriers using total interpretive structural modeling (TISM). Authors divided lean implementation barriers into the main areas: "*Knowledge* (1. lack of training, 2. insufficient understanding of the potential benefits, 3. lack of implementation know-how, 4. lack of understanding about lean, 5. insufficient supervisory skills to implement lean, 6. insufficient senior management skills to implement lean, 7. insufficient workforce skills to implement lean, 8. lack of methodology, 9. unwillingness to learn and see); *Conflicts* (1. conflicts with other initiatives, 2. uncertainties in demand, 3. consultants' apathy, 4. frequent changes in design, 5. lack of cooperation from suppliers, 6. disparate manufacturing environments, 7."flavor of mouth" view); *Resource* (1. insufficient investment cost, 2. insufficient internal funding, 3. lack of communication, 4. lack of time, 5. insufficient external funding, 6. lack of labor resources, 7. lack of idea innovation); *Management* (1. insufficient management time, 2. lack of long-term vision, 3. lack of strategic perspective, 4. lack of contingency, 5. lack of organizational structure, 6. pressure from top management); *Technology* (1. lack of technological infrastructure, 2. high cost of advanced technology, 3. technological advancements, 4. requirement of alteration in process methodology); *Employee* (1. employee attitude/resistance to change, 2. human aspects, 3.non-lean behavior, 4. lack of empowerment of employees); *Financial situation* (1. financial benefits not recognized, 2. no direct financial advantage); *Culture* (1. cultural issues, 2. social factor); *Customer* (1. widening customer requirements, 2. pressure from customer, 3. past experience, 4. backsliding/lack of perseverance)."

Coetzee et al. [20]	Interpret the true meaning of Respect for People (RFP) according to the creators of the Toyota Way, which captures the principle of the organizational culture of the company. The Toyota Way is depicted as a house with two pillars—"RFP" and "Continuous Improvement".
Escuder et al. [21]	Outline 17 barriers in implementing lean in health care, which are; terminology (B0); lack of resources (B1); leader to guide the process (B2); lack of training (B3); lacking key performance indicators (KPI) (B4), commitment and support from top managers (B5), resistance to change (B6), lack of an improvement culture (B7); the existence of conflicting requirements (B8); the existence of functional silos (B9); hierarchical structure (B10); lack of motivation (B11); poor communication (B12); health-care regulations (B13); union conflicts (B14); lack of time devoted to the improvement program (B15); poor managerial skills (B16).
Khaba and Bhar [22]	Investigate the key barriers of lean implementation in the Indian coal mining industry. Furthermore, the authors study the perception of lean barriers among lean implemented mines and non-lean mines. 14 lean barriers identified are backsliding to the old ways of working, cultural difference in the workplace, does not address the need of the mining industry, lack of lean understanding, resistance to change, financial constraint, shortage of lean consultants and trainers, lack of performance management systems, poor planning, lack of technical capabilities of the organization, lack of top management commitment and support, lack of effective training, the lean journey is too long to become profitable, lack of inter-department coordination.
Ramadas and Satish [23]	Develop a model using structural equation modeling (SEM) to present key barriers in implementing lean from 128 SMEs companies in India. Three critical factors with 29 significant variables of process barrier factors were identified: *High rejection rate is mainly due to* 1. lack of awareness about the process/machine; 2. lack of training program.; 3. lack of periodical maintenance; 4. low-quality standard materials from suppliers; 5. bad vendor inspection; 6. wear and tear of machines; 7. communication gap between supervisors and workers; *Employee absenteeism is mainly due to* 8. harassment by owners, stress or low morale; 9. personal issues such as festivals and being sick; 10. no monitoring of the period of absence; 11. not offering a flexible time for workers; 12. no motivation for workers in the form of better offers; 13. not conducting parties and rewards for perfect attendance for employees; 14. not maintaining a good employee-employer relationship; 15. not conducting health programs in SMEs; 16. serious accidents and illness because of the absence of safety awareness programs; 17. boredom on the job; 18. no incentive for strong attendance; 19. no punishment for low absenteeism; and *Frequent breakdown is due to* 20. electricity problem; 21. lack of routine maintenance; 22. lack of knowledge or skill of employees; 23. overrunning machines beyond their capability; 24. carelessness in work; 25. not replacing worn damaged parts periodically; 26. ignoring warning signals of machines; 27. no preventive maintenance; 28. untrained personnel to operate equipment; 29. not reading the operator's manual.
AlManei et al. [24]	Propose a lean framework for lean implementation based on drivers and barriers that companies face when they try to implement lean.
Sahoo and Yadav [7]	Consider the relationship between lean practices and performance and analyze major challenges/barriers in Indian SMEs. As such, manufacturing companies with up to three years of lean implementation were coded as "lean beginners" group, three to five years firms were coded as "in-transition lean" group, while companies that have adopted lean more than five years were coded as "lean" group. 13 factors that impede lean implementation in the context were accordingly reported, including: "inadequate knowledge and lean expertise, lack of senior management commitment, organizational culture, inability to quantify benefits, backsliding to old ways of working, lack

of resources, an attitude of workmen, internal resistance, risk of disruption in operations, lack of budget, lack of clarity across functional groups, poor training, and need of integration with business associates."

Most of the previous studies had explored the barriers individually. For instance, Abolhassani et al. [5] in their study on lean and non-lean US manufacturing firms found that generally, both types of companies relate the barriers to lean implementation to different factors including a poor commitment by the management, low technical know-how, resistance to change by both the employees and the management as well as the belief that lean is not sustainable. Therefore, extensive research seems essential to explore the factors preventing companies from adopting lean (for non-lean companies). This study explores three main issues namely knowledge, resources, and culture and human attitudinal issues.

Studies on the wood and furniture industry found that lean implementation barriers related to culture and human attitudinal issue (BCUL) include middle management resistance to change [25], employee resistance to change [25,26], difficulty in implementing lean [25,26], and the belief that lean is a gimmick [25,27]. Following, the lean implementation barriers related to knowledge issues (BKNW) were lack of implementation know-how [25,26,28,29], lack of expertise on lean [26,29,30] and lack of understanding of the benefits [27]. The barriers related to resource issues (BRES) found in the wood and furniture industry had been lack of time [25], lack of capital fund, and lack of labor resources [25,26,31]. On this basis, the following hypotheses, which are clearly illustrated in Figure 1, were set out to further our research purposes:

Hypothesis (H1): *Culture and human attitudinal issues have a positive impact on lean implementation barriers for non-lean companies.*

Hypothesis (H2): *Knowledge issues have a positive impact on the barriers in implementing lean among non-lean companies.*

Hypothesis (H3): *Resource issues have a positive impact on the barriers in implementing lean among non-lean companies.*

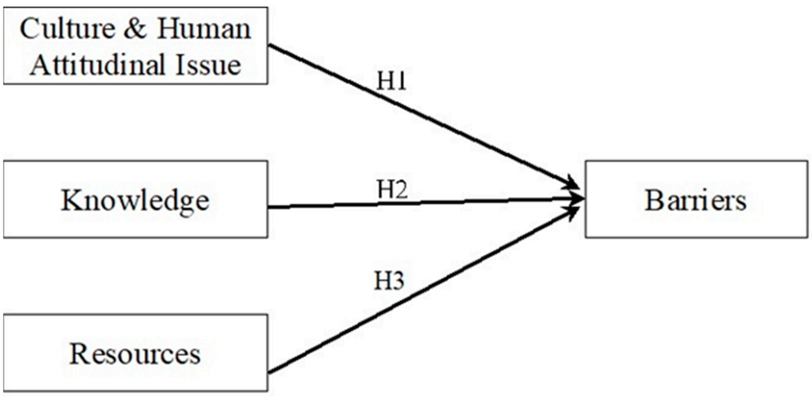

Figure 1. Proposed research framework.

3. Methods

The analysis of the reliability and validity of the model measure was carried out through structural equation modeling (SEM). The most well-known SEM techniques are covariance-based methods as exemplified by the software AMOS. Yet, an alternative technique known as partial least squares (PLS) is also suitable for SEM-based analysis using SmartPLS [32,33].

According to Beckeretal.[32], PLS-SEM requires the computation of construct scores for each latent variable in the path model. This method is capable of handling non-normal data and is flexible enough to scrutinize small samples. Thus, this method was selected due to (a) the theoretical model is not well-formed; (b) there is an uneven number of indicators; (c) there are different modes of reflective and formative constructs; (d) the data distributions are not normal and not highly demanding with respect to sample size, and (e) there is flexibility in modeling beyond the first-generation techniques.

The methods of reporting PLS-SEM were described in two-tiers. The first-tier is by reporting the appropriateness of the second-order construct in PLS-SEM. Preliminary considerations involve the use of repeated indicator approaches with Mode B and the path weighting scheme which would ensure that no biased results will occur [32]. The second-tier entails reporting the considerations and rules of thumb in assessing the results of PLS-SEM. An analytical procedure was implemented to test the measurement model and the structural model [33].

3.1. Specifying the Appropriateness of the Second-Order Construct in PLS-SEM

Firstly, this study focused on the second-order construct that includes formative relationships (reflective-formative, Type II). The conceptual model has one second-order construct (barriers) with three first-order constructs (culture and human attitude, knowledge and resource issues).

Secondly, a repeated indicator approach was used to estimate the construct scores of a second-order construct because the observed variables (or indicators) do not exist. Then, the mode of measurement for the second-order repeated indicators is Mode B/formative constructs. Next, path type was used as the inner weighting for the PLS-SEM algorithm. The repeated indicator approach using Mode B together with the path weighting scheme results in the most paramount parameter estimates for the root mean squared error (RMSE) and mean absolute relative bias (MARB) [32].

Thirdly, this study assessed the first-order constructs. The lower-order constructs of this study have unequal numbers of indicators. Each first-order latent variables have three to six items manifest variables (BCUL/6 items, BKNW/3 items, BRES/3 items). The manifest variables (items/indicators) were used twice: firstly, for the first-order latent variable ("primary" loadings) and secondly for the second-order latent variable ("secondary" weights).

The fourth and final step entailed the assessment of the second-order constructs. The second-order latent variable entails three principal first-order latent variables (CUL, KNW, RES). The second-order latent variables can be specified using all the manifest variables of the principal first-order latent variables, i.e., 12 items for non-lean companies. The path coefficients between the first-order and second-order constructs represent the weights of the second-order latent variable [32].

3.2. Evaluating the PLS-SEM Models

The first step to perform the PLS-SEM test is to examine the reliability (the measurement instruments are free of random errors) and validity (the dimensions have the capacity to show real differences between the objects as related to the characteristic being measured) [34–36].

PLS-SEM analysis was executed to test: firstly, the measurement model and secondly, the structural model. Firstly, the measurement model was tested to validate the instruments. The measurement model was validated by convergent validity (CV) and discriminant validity (DV). CV was assessed through the composite reliability (CR) and average variance extracted (AVE) to evaluates whether the items measure the same concept [37–40]. DV evaluates the level of discrimination between measured variables and various construct criteria [41–43]. According to Hair et al. [43], DV represents the extent of distinctiveness of the constructs in the model (items that differentiate the constructs or measure distinct concepts).

There are two model constructs for CV which are the first-order construct (reflective measurement model) and the second-order construct (formative measurement model). The CV of the reflective measurements was confirmed by loadings, CR and AVE.

CR is one of the reliability tests used to check the internal consistency of the measurement model [32,37]. There are two common methods used for this purpose which are CR and Cronbach's alpha [38]. However, CR provides a more appropriate measure of internal consistency reliability compared to the traditional assessment using Cronbach's alpha [44]. CR is calculated from "(square of the summation of the factor loadings)/[(square of the summation of the factor loadings) + (square of the summation of the error variances)]". AVE is the grand mean value of the squared loading equivalent to communality of a construct "[AVE = (summation of squared factor loadings)/(summation of squared factor loadings) (summation of error variances)]". The AVE of each latent construct should higher than the construct's highest squared correlation with any other latent construct [43,44].

For the reflective first-order construct, the measurement would be acceptable if the loadings of the indicators were above the threshold of 0.5 [34,35]; CR values greater than 0.7 [34–38], and AVE for each construct above 0.5 [34–37]. Subsequently, the formative measurements were confirmed by VIF and path weight. The bootstrapping procedure using 5000 resamples was used to assess the significance of weights of the formative indicators. The yielded variation inflation factor (VIF) values must be less than 5 to ensure that there is no collinearity issue among the constructs' formative indicators [39] whilst the significance of weight should be higher than 0.1 [40,41]. Subsequent to CV verification, the DV was verified using HTMT. The correlations among all of the constructs (HTMT values) were below the suggested cut-off of 0.85, indicating the distinction between all of them i.e., their discriminant validity [42,43].

Secondly, the structural model was examined to test the hypothesis. The basic measures to report were the coefficients of determination (R^2), the blindfolding-based cross-validated redundancy measure (Q^2), and the size and significance of the path coefficients [43–45]. In addition, Hair et al. [43] proposed PLS predict, a new method in measuring the out-of-sample prediction for the model that focuses on the model's key endogenous construct. The Q^2 value in PLS prediction was reported to compare the prediction errors of the PLS path model against the simple mean predictions [43]. Table 2 shows the cut-off point in evaluating the measurement and structural models.

Table 2. Measurement and structural model cut-off values.

Testing	Description	References
	Reflective measurement model	
	Convergent validity (CV)	
1. Reflective indicator loading	Values for loadings are set at > 0.5	[34,35]
2. Composite Reliability (CR)	Recommended CR values within 0.70–0.90 are satisfactory	[42–44]
3. Average Variance Extracted (AVE)	AVE for each construct should be >0.5	[34–37,43]
	Discriminant validity (DV)	
4. Heterotrait-monotrait ratio of correlations (HTMT)	For conceptually similar constructs: HTMT < 0.90 For conceptually different constructs: HTMT < 0.85	[43]
	Formative measurement model	
5. Variation inflation factor (VIF)	Probable (i.e., critical) collinearity issues when VIF >5 Possible collinearity issues when VIF > 3–5 Ideally show that VIF < 3	[43]
6. Statistical significance of weights	*p*-value < 0.05 or the 95% confidence interval (based on the percentile method or, in case of a skewed bootstrap distribution, the BCa method) does not include zero	[43]
	Structural model	
7. Coefficients of determination (R^2)	R^2 result is equal to 1 for repeated indicator approach	[32]
8. Q^2 value	Blindfolding-based cross validated redundancy measure (Q^2)	[33,43]

		Values higher than zero denote meaningful Values larger than 0, 0.25 and 0.50 indicate small, medium and large predictive accuracy of the PLS path model	
9.	PLS predict	Q2 predict values > 0 indicate that the model outperforms the most naïve benchmark (i.e., the indicator means from the analysis sample)	[43,46]
10.	Size and significance of path coefficients		[44,45]

4. Results

4.1. Sample Size

For the adequacy of the sample of the study, a power test was performed to confirm the suitability of the samples. The test power has been estimated with the G*Power software which is considered the most powerful analysis program for a variety of statistical tests in the behavioral and managerial sciences [39,40]. The G*Power analysis showed that the required minimum sample size is 77 respondents to test the model with three predictors. The sample size of this study (131 non-lean companies) was more than the minimum requirement.

4.2. Assessment of the Measurement Model

The proposed models had an uneven number of indicators for the first-order constructs and used the Mode B repeated indicator approach with path weighting scheme on the second-order constructs. The analysis began with an assessment of the measurement models. Following the recommendations of Amin et al. [34], the CV was assessed using factor loadings, composite reliability (CR) and average variance extracted (AVE). The recommended values for loadings were set at > 0.5, CR at > 0.7, and the AVE at > 0.5 (Figure 2).

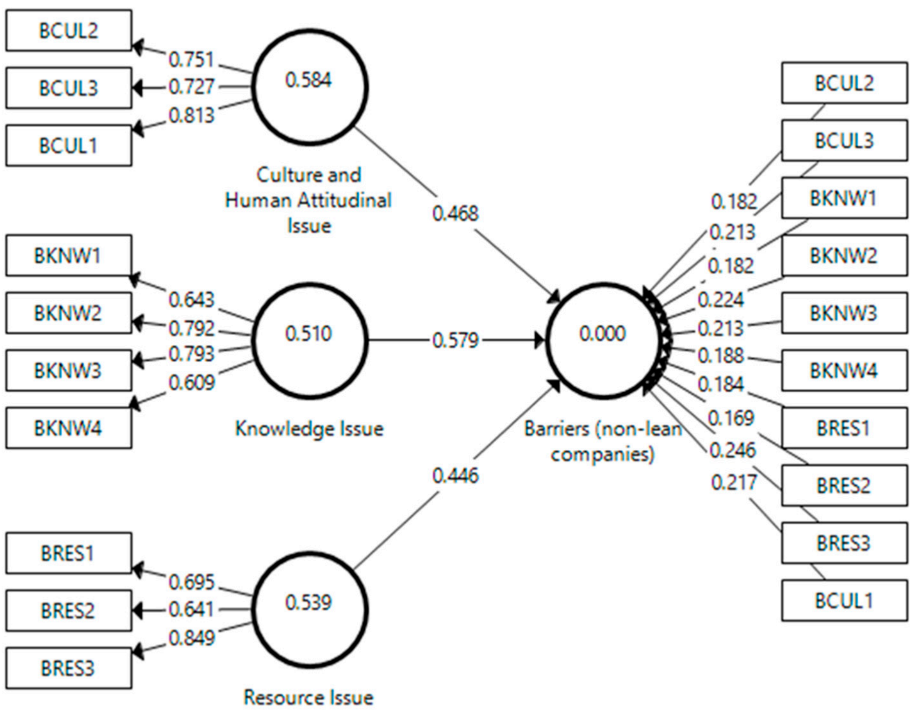

Figure 2. Measurement model results.

Specifically, the factor loadings were assessed first. The results showed that all of the reflectively measured constructs were above the threshold of 0.6. Each item's loading on its underlying construct was above the recommended values of 0.6 [36,47] and 0.5 [34,35].

Lower loading items i.e., BCUL4 (0.548) and BCUL5 (0.622) were dropped to obtain better reliability and discriminant validity.

Next, the CR was examined. The CR varied between 0 and 1. All the CRs had values above 0.8 [48–50], except for the resource issue for the barriers (CR = 0.775). However, CR values of above 0.7 were still considered satisfactory [44,48] and none of the CR values were above 0.9 which is an undesirable value. The internal consistency reliability (after bootstrap) for all the constructs' reliability was considerably higher (lower) than the suggested minimum (maximum) thresholds (p-values < 0.01).

Then, all the AVE assessed were higher than the critical value of 0.5 [38,47,50]. This indicates that the main constructs capture more construct-related variance than error variance [38]. As presented in Table 3, the measurement model's results surpassed the proposed values hence suggesting adequate convergence validity.

Table 3. The measurement model of first-order constructs (reflective).

Construct	Items	Loadings	CR	AVE
Culture and Human Attitudinal Issue	BCUL1	0.813	0.808	0.584
	BCUL2	0.751		
	BCUL3	0.727		
Knowledge Issue	BKNW1	0.643	0.804	0.510
	BKNW2	0.792		
	BKNW3	0.793		
	BKNW4	0.609		
Resource Issue	BRES1	0.695	0.775	0.539
	BRES2	0.641		
	BRES3	0.849		

Finally, after confirming the CV, the DV was assessed using the HTMT method. The DV assessment shows that all the HTMT values were significantly lower than 0.9 (Table 4). The constructs were distinct from each other because they were below the suggested cut-off of 0.90 [38,39]. Bootstrapping determines the significant difference of the HTMT value from 1.00 [51]. All the HTMT values were significantly lower than the threshold value and different from 1.00, except for the resource → knowledge issue for the barriers in lean implementation (p-value > 0.05).

Table 4. HTMT discriminant validity of first-order constructs.

Construct	Relation	HTMT	p-Value
Knowledge → Culture & Human Attitudinal Issue	BKNW → BCUL	0.277	0.007
Resource → Culture & Human Attitudinal Issue	BRES → BCUL	0.414	0.001
Resource → Knowledge	BRES → BKNW	0.175	0.054

Based on Figure 3, the barriers were conceptualized as formative second-order constructs. The repeated indicator approach for modeling the second-order factors in the PLS analysis [34] did not report on the predictive relevance, Q^2 or effect sizes, f^2. The formative measurements were confirmed by the VIF and path weight (Table 5). Firstly, all the predictor constructs' VIF values were assessed to ensure that there is no collinearity issue between the constructs' formative indicators [39]. As all of the VIF values were below the more conservative threshold of 3.3 [41,50], the results presented ideal VIF values (VIF < 3) indicating no multi-collinearity problems.

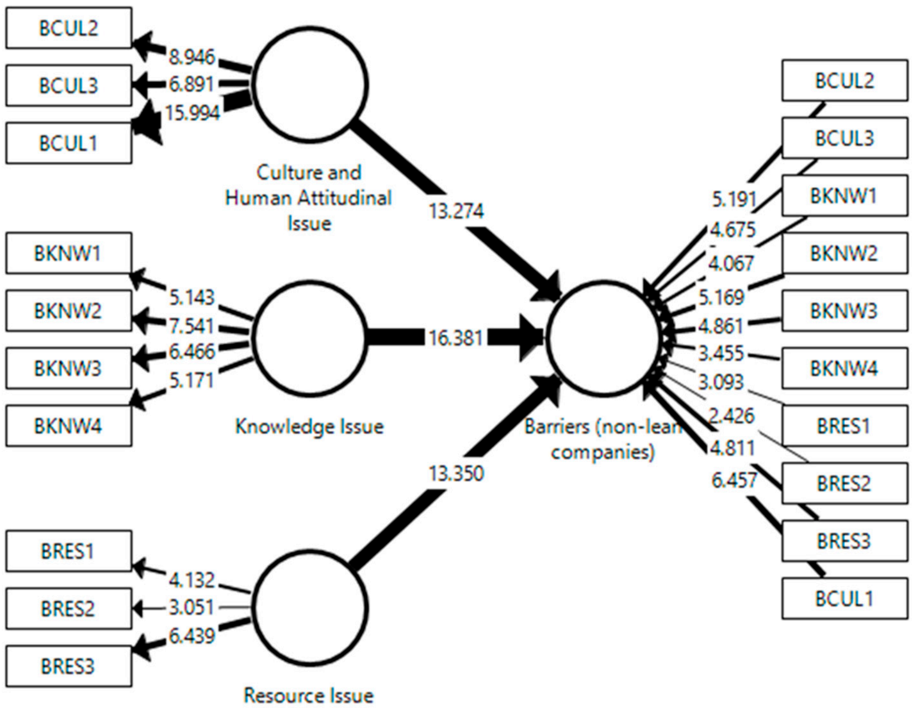

Figure 3. Bootstrapping results. Note: hypothesis testing of bootstrapping procedure using 5000 resamples; inner model shows t-values; outer model shows t-values; and highlight path use relative values.

Table 5. The measurement model of second-level constructs (formative).

Construct	Collinearity (Inner VIF)	Statistical Sig. of Weights	*p*-Value	Confidence Intervals	
				5%	95%
BCUL	1.106	0.468	0.001	0.415	0.525
BKNW	1.035	0.579	0.001	0.520	0.631
BRES	1.076	0.446	0.001	0.392	0.500

Next, the indicators' weights were assessed by bootstrapping to verify their significance. Each indicator's weight significance indicates the relative significance whilst the loading indicates the total significance which is measurable using bootstrapping [39]. All the statistical significances of weights were higher than 0.1 [40], the *p*-value was below 0.01 and the 95% confidence interval (based on the BCa method) did not include zero [43].

4.3. Assessment of the Structural Model

The R^2 was calculated to evaluate the structural models' predictive power [34,48], as presented in Figure 3. By using the repeated indicator approach, all the variances of the higher order construct R^2 were equal to 1 [32] for the barriers (non-lean companies) constructs. This is because the R^2 indicated the amount of variance explained by the exogenous variables [34].

Next, the path analysis was carried out to test the hypotheses generated. The results of the bootstrapping procedure with 5000 samples and using the no sign changes option [46] revealed that all of the structural model relationships were significant. Table 6 shows the structural model analysis. Specifically, significant statistical evidence was acquired for hypothesis H1 (BCUL→ Barriers, $\beta = 0.468$, $p < 0.01$) in line with the outcomes in [22,24]. Similarly, strong and statistically significant evidence was found for H2 (BKNW→ Barriers, $\beta = 0.579$, $p < 0.01$). This confirms the findings in previous studies which reported that the aspect of knowledge is the most influential factor for successful LM implementation

[19]. Moreover, Abolhassani et al. [5] reported a positive effect of knowledge for non-lean companies on the factors for failing to implement lean. Additionally, the findings indicated that the issue of resources has a positive effect on the barriers (non-lean companies) in implementing lean. This study obtained substantial support for hypotheses H3 (β = 0.446, $p < 0.01$). This result is similar to that of Antony et al. [52] and Khaba and Bhar [22].

Overall, culture and human attitude (CUL), knowledge (KNW) and resource (RES) have a significant impact on the barriers (non-lean companies) antecedent constructs. More specifically, KNW and CUL have a significant and meaningful effect on non-lean companies (BKNW; 0.579, $p < 0.01$). The findings indicate that non-lean companies should focus on knowledge issues to be successful in LM implementation. This is in line with the findings of Khaba and Bhar [22]. The authors indicated that there is a significant difference in the perception of KNW (poor understanding of lean) between the lean and non-lean firms. Conversely, the RES had the least meaningful effect and was much less pronounced for non-lean (BRES; 0.446). This confirms the report of previous studies that resource areas have the lowest driving power for successful LM implementation [19].

Next, the Q^2 value was examined because this measure is an indicator of the model's predictive relevance [34]. Amin et al. [34] by referring to Hair et al. [44] indicated that "PLS-SEM exhibits predictive relevance; it can accurately predict the data points of indicators in reflective measurement models of endogenous construct and endogenous single-item constructs". The predictive relevance or Q^2 analysis was conducted via blindfolding with a distance value of 6 [33]. A Q^2 value greater than 0 indicates adequate predictive relevance for the model [34]. The Q^2 for barriers was 0.176 (non-lean companies), both of which are greater than 0 thus confirming predictive relevance. The values represented a small relevance for the endogenous construct or small predictive accuracy of the PLS path model.

In addition, the Q^2 predicted value for barriers was 0.848. The Q^2 predicted value results interpretation was similar to the assessment of the Q^2 values obtained using the blindfolding procedure in PLS-SEM [46]. The Q^2 predicted value was greater than 0 indicating that the model is superior to the most naïve benchmark (i.e., the indicator means from the analysis sample). The Q^2 values for barriers are positive thus indicating that the PLS-SEM models offer better predictive performance. Shmueli et al. [46] emphasized focus on the model's key endogenous construct rather than on discussing the prediction errors in all of the endogenous constructs' indicators. However, the indicators for the endogenous constructs (barriers) are repeated indicators. The root means squared error (RMSE) value for the linear regression model is 0, indicating that the model lacks predictive power (as PLS-SEM < linear regression model for none of the indicators) [46]. Thus, it was not appropriate to compare each of the indicator's RMSE value with the linear regression model value and to report the PLS to predict.

Table 6. Direct relationships for hypothesis testing.

Hypothesis	**Relation**	**Path co-efficient (β)**	**Standard Deviation**	***t*-Value**	***p*-Value**	**BCI**		**Results**
						5%	95%	
H1: BCUL→	Barriers	0.468	0.035	13.274	0.001	0.423	0.542	Supported
H2: BKNW→	Barriers	0.579	0.035	16.381	0.001	0.533	0.650	Supported
H3: BRES→	Barriers	0.446	0.033	13.350	0.001	0.402	0.514	Supported

5. Discussion

5.1. Positive Perception of Lean

Overall, the items deleted from the model were related to culture and human attitudinal issues (CUL). These two items, namely BCUL4 (lean is a gimmick) and BCUL5 (lean does not fit culture) were deleted to increase the AVE values (AVE before: 0.393, after: 0.584). Both questions examined the perception of respondents toward LM. From the results, BCUL4 was deleted first to increase the AVE value (0.393). BCUL4 was selected because it had a loading of 0.548 which is marginally over the cut-off point i.e., 0.5. Next, the BCUL5 with a loading of 0.622 was deleted because the AVE value was still below the threshold of 0.5.

Abolhassani et al. [5] presented a table that indicated whether the responses' median diverged from the "neutral" (equal) agreement level's hypothetical median via the sign test. Based on the item's deleted responses agreement, the "agreed reasons" have an "above" column (agree—strongly agree), whilst the "disagreed reasons" have a "below" column (disagree—strongly disagree).

The non-lean companies' rejection of the negative perception of lean (majority disagreement on BCUL4 and BCUL5) shows that they are aware and understood the importance of LM implementation. A large number of respondents disagree that the implementation of lean has no value. Yet, one sample sign test revealed that the respondents had a significant ($p < 0.01$) neutral view on whether lean is a gimmick or not (BCUL4). This finding is in contrast to that of Abolhassani et al. [5] which indicated that both lean and non-lean firms do not consider lean as a gimmick. Knowledge remains as a prominent issue in lean implementation. Thus, the finding shows that there is still a lack of awareness and understanding of the importance of LM implementation.

In the context of BCUL5, 39% of the non-lean companies disagree that lean does not fit their culture. This figure was very similar for companies that believed lean to be incompatible with their employees' work attitude i.e., at 30%. However, there was no significant agreement on the factor of culture for BCUL5 ($p > 0.10$).

5.2. Culture and Human Attitudinal Barriers

Hypothesis H1 relating CUL to the barriers for not implementing lean was supported. The significant relationship shows that non-lean companies have a problem with culture reluctance and negative perception of LM implementation. Reluctance to change and hesitance to present a new mind-set may hinder LM implementation [1]. Non-lean companies believe that employees and the middle management will resist change and view lean as a difficult practice to be implemented. This finding contradicts with that of previous studies. Panwar et al. [14] found that cultural barriers are insignificant factors to the non-adoption of lean among non-lean companies. Moreover, both lean practitioners and non-practitioners strongly agreed that lean is not a gimmick [5]. Only 23% of the respondents agree that the barrier of "not easy to implement" as the reason that prevents or delays LM implementation [25].

5.3. Knowledge Barriers

The findings indicate that KNW is positively and significantly related to the barriers in implementing lean at the level of 1%; thus, H2 is supported. Undoubtedly, the significant relationship justified that non-lean companies have insufficient knowledge of LM. Four obstacles that prohibit wood and furniture companies from implementing lean are unfamiliarity to the concept of lean, poor knowledge with regards to its implementation, low lean expertise and poor understanding of its benefits. Our study found that unfamiliarity with lean practice was the primary cause of its non-adoption. Abolhassani et al. [5] emphasized that knowledge and experience are crucial to better understand lean manufacturing. Next, lack of implementation know-how is also indicated as a preventing factor to the adoption of LM which is similar to the findings of [25]. Furthermore, Panwar et al. [14] cited skills development as a crucial element in the implementation of LM. However, the concept of lean is new for the Malaysian wood and furniture industry; hence, there is a lack of lean experts working for the companies in this industry. People will need substantial time to comprehend the concept and to cultivate the required skills to implement it [14]. Although shortage of lean consultants and trainers is the least important barrier [22], lack of education and expertise are the reasons why lean is not widely adopted in the Indian industry [14]. Thus, knowledge barrier is considered as one of the most prominent issues for the wood and furniture industry in implementing lean, specifically in the Malaysian context.

Lastly, there is a limited understanding of LM at the conceptual and technical levels [5]. Chaple et al. [19] proposed an initiative to tackle the insufficient understanding about the potential benefits of implementing lean. Firstly, the company needs to properly explain the concept of lean transformation to the employees. Following that, the company must explain the potential benefits of the transformation to give the employees a clear understanding of the changes that will follow suit. Next, the company should carry out low-cost production to overcome the high investment costs due to the limited resources. Lastly, the company must attain funding from external sources which can be achieved via collaborations, mutual R&D initiatives and sponsorships.

5.4. Resources Barriers

The relationship between RES and the barriers for not implementing lean is positive and significant; thus, H3 was supported. The significant relationship shows that both lean and non-lean companies have resources constraint (time, capital fund and labor). This finding is consistent with that of Sahoo and Yadav [7], which cited that most of the companies are concerned about the cost and time involved in implementing LM. Since the benefits of lean may take a while to materialize, the investment returns could be difficult to estimate or justify [53]. Despite being well-known for improving productivity, lean implementation is still a doubtful endeavor for SMEs due to the vague financial costs involved and the potential benefits that may arise from it [7].

5.5. Proposed Activities to Overcome the Barriers

Three initiatives were recommended to tackle the LM implementation barriers namely through: (1) sponsorships and collaborations, (2) aggressive promotions, and (3) basic awareness programs. Evidence from the investigation recommends that lean implementation in the wood and furniture context is by no means an easy task, as it has been heavily burdened through knowledge, culture and human attitudinal and resource-related barriers. Agencies and professional bodies can support SMEs in this transition through targeted interventions that address the barriers presented [54].

To achieve these considerations, further explorations on KNW, CUL and RES were conducted. Firstly, hypothesis H1 relating CUL to the barriers for not implementing lean was supported. The significant relationship shows that non-lean companies have a problem with culture reluctance and negative perception of LM implementation. Reluctance to change and hesitance to present a new mind-set may hinder LM implementation [1]. Non-lean companies believe that employees and the middle management will resist change and view lean as a difficult practice to be implemented. This finding contradicts with that of previous studies. Panwar et al. [14] found that cultural barriers are insignificant factors to the non-adoption of lean among non-lean companies. Moreover, both lean practitioners and non-practitioners strongly agreed that lean is not a gimmick [5]. Only 23% of the respondents agree that the barrier of "not easy to implement" as the reason that prevents or delays LM implementation [25].

Secondly, the findings indicate that KNW is positively and significantly related to the barriers in implementing lean at the level of 1%; thus, H2 is supported. Undoubtedly, the significant relationship justified that non-lean companies have insufficient knowledge of LM. Four obstacles that prohibit wood and furniture companies from implementing lean are unfamiliarity to the concept of lean, poor knowledge with regards to its implementation, low lean expertise and poor understanding of its benefits. Our study found that unfamiliarity with lean practice was the primary cause of its non-adoption. Abolhassani et al. [5] emphasized that knowledge and experience are crucial to better understand lean manufacturing. Next, lack of implementation know-how is also indicated as a preventing factor to the adoption of LM which is similar to the findings of Pirraglia et al. [25]. Furthermore, Panwar et al. [14] cited skills development as a crucial element in the implementation of LM. However, the concept of lean is new for the Malaysian wood and furniture industry; hence, there is a lack of lean experts working for the companies in this industry. People will need substantial time to comprehend the concept and to cultivate the required skills to perform it [14]. Although shortage of lean consultants and trainers is the least important barrier [22], lack of education and expertise are the reasons why lean is not widely adopted in the Indian industry [14]. Thus, knowledge barrier is considered as one of the most prominent issues for the wood and furniture industry in implementing lean, specifically in the Malaysian context.

Lastly, there is a limited understanding of LM at the conceptual and technical levels [5]. Chaple et al. [19] proposed an initiative to tackle the insufficient understanding about the potential benefits of implementing lean. Firstly, the company needs to properly explain the concept of lean transformation to the employees. Following that, the company must explain the potential benefits of the transformation to give the employees a clear understanding of the changes that will follow suit. Next, the company should carry out low-cost production to overcome the high investment costs due to the limited resources. Lastly, the company must attain funding from external sources which can be achieved via collaborations, mutual research and development (R&D) initiatives and sponsorships.

The relationship between RES and the barriers for not implementing lean is positive and significant; thus, H3 was supported. The significant relationship shows that non-lean companies have resources constraint (time, capital fund, and labor). "Governments of many countries around the world are helping and encouraging the implementation and understanding of the lean manufacturing system by providing financial assistance for training professionals and establishing professional associations [23]". This finding is consistent with that of Sahoo and Yadav [7], which cited that most of the companies are concerned about the cost and time involved in implementing LM. Since the benefits of lean may take a while to materialize, the investment returns could be difficult to estimate or justify [53]. Despite being well-known for improving productivity, lean implementation is still a doubtful endeavor for SMEs due to the vague financial costs involved and the potential benefits that may arise from it [7].

Therefore, the following activities were proposed to tackle LM implementation barriers. The development of the LM implementation framework was carried out based on the rule developed by Soetara et al. [55] i.e., identifying the activities that must be done, how they can be executed and why such goals should be achieved (Table 7).

Table 7. Proposed activities to tackle LM implementation barriers.

Issues	What Activities Must be Done?	How Those Can be Executed?	Why Such Goals Should be Achieved?
Culture and human attitudinal (BCUL)	Aggressive promotion	Lean roadshows and workshops	An initiative to tackle the culture reluctant such as employee (BCUL2) and middle management (BCUL1) resist to change, and negative perception that view lean as a difficult practice to be implemented (BCUL3).
Knowledge (BKNW)	Aggressive promotion Basic awareness program	Lean roadshows and workshops Seminar Exhibition	Four obstacles that prohibit wood and furniture companies from implementing lean are unfamiliarity with lean (BKNW1), lack of implementing know-how (BKNW2), lack of expertise on lean (BKNW3), and lack of understanding benefits (BKNW4). To increase the awareness of the lean program.

			To have sufficient knowledge, a better understanding of what lean manufacturing is, and develop required skills for LM implementation. It is notable that the frequency of LM implementation increase when the company is familiar with LM. Employees will be able to cultivate the required skills to implement lean practice from the basic awareness program. To ensure the company understands the tangible and intangible benefits that they may achieve from LM implementation.
Resource (BRES)	Sponsorship and collaboration Aggressive promotion Basic awareness program	Government initiative University collaboration Lean roadshows Workshops Seminar Exhibition	Non-lean companies have resources constraint on time (BRES1), capital fund (BRES2), and labor (BRES3). Lean implementation is still a doubtful endeavor for SMEs due to the vague financial costs involved and the potential benefits that may arise from it [7] The benefits of lean may take a while to materialize, the investment returns could be difficult to estimate or justify [53].

6. Conclusion and Recommendations

This section summarizes the important insights of this study which are applicable when planning the LM implementation strategy in wood and furniture industries. Unlike previous studies that had explored the barriers to lean implementation individually, this study investigated the barriers for not implementing lean based on three main issues namely knowledge (KNW), resources (RES), and culture and human attitude (CUL). A better understanding of the lean implementation issues has been achieved through the results obtained and presented from the survey on the Malaysian wood and furniture companies.

Overall, knowledge is the main barrier that prevents companies from adopting LM (based on the highest value of path coefficient). The non-practitioners significantly believe that RES is an obstacle to LM implementation, but not as important as KNW and CUL issues. Sufficient knowledge is needed to deploy LM practices as well as changes in culture and human attitude. In addition, government institutions and also universities should be promoted as resources to initiate LM since very little information had been found showing previous collaborations between institutions and promoters of LM and the wood industry.

To understand who was participating in the research, data of the respondents' position in the organization was collected; however, this data was not used for analysis. A more meaningful analysis entails the examination of their different views on LM based on their positions. This is because the top-down approach alone in lean implementation is insufficient to transform a conventional manufacturer into a lean manufacturer.

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