# Exploring the determinants of lean manufacturing adoption by textile enterprises in India: An investigation based on the latest World Bank Survey Data

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**ABSTRACT – REZUMAT**

**Exploring the determinants of lean manufacturing adoption by textile enterprises in India: An investigation based on the latest World Bank Survey Data**

*The study aims to identify the factors affecting the adoption of lean manufacturing by textile enterprises in India using the latest World Bank's Enterprises Survey (WBES) 2022 data of India. Three sets of variables namely enterprise characteristics, access to resources, which includes access to electricity, access to land and credit-line while in the last group, certification and competitive development are taken as explanatory variables of lean manufacturing adoption. The chi-square test is employed to investigate the significant association between firm profile and lean manufacturing adoption. Further, a logistic regression model has been applied to determine factors influencing lean manufacturing adoption. The estimates of logistic regression reveal that among firms' characteristics only legal status, access to resources, credit from financial institutions and access to electricity and from the third set of explanatory variables, certification and upgraded machinery and equipment are identified as significant factors in the adoption of lean manufacturing by textile enterprises. The value of the study lies in analysing factors affecting the adoption of lean manufacturing in textile enterprises which is not explored in the case of developing countries like India using comprehensive World Enterprises Survey data.*

***Keywords:*** *India, lean manufacturing, textile enterprises, world enterprises survey, waste minimization*

**Explorarea factorilor determinanți ai adoptării producției de tip Lean de către întreprinderile textile din India: o analiză bazată pe cele mai recente date din Sondajul Băncii Mondiale în rândul întreprinderilor**

*Studiul își propune să identifice factorii care afectează adoptarea producției de tip Lean de către întreprinderile textile din India, utilizând cele mai recente date ale Sondajul Băncii Mondiale în rândul întreprinderilor (WBES) din 2022. Trei seturi de variabile, și anume caracteristicile întreprinderilor, accesul la resurse, care include accesul la energie electrică, accesul la teren și linia de credit, în timp ce în ultimul grup, certificarea și dezvoltarea competitivă sunt considerate variabile explicative ale adoptării producției de tip Lean. Testul chi-pătrat este folosit pentru a investiga asocierea semnificativă dintre profilul firmei și adoptarea producției de tip Lean. Mai mult, a fost aplicat un model de regresie logistică pentru a determina factorii care influențează adoptarea producției de tip Lean. Estimările regresiei logistice relevă faptul că printre caracteristicile firmelor, doar statutul juridic, de la accesul la resurse, creditul de la instituția financiară și accesul la energie electrică și, din al treilea set de variabile explicative, certificarea, mașinile și echipamentele modernizate sunt identificate ca factori semnificativi în adoptarea producției de tip Lean de către întreprinderile textile. Valoarea studiului constă în analiza factorilor care afectează adoptarea producției de tip Lean în întreprinderile textile, care nu este explorată în cazul unei țări în curs de dezvoltare precum India, folosind date cuprinzătoare ale Sondajul Băncii Mondiale în rândul întreprinderilor.*

***Cuvinte-cheie:*** *India, producție de tip Lean, întreprinderi textile, sondaj mondial în rândul întreprinderilor, reducerea deșeurilor*

## INTRODUCTION

Lean manufacturing is one of the techniques that manufacturing organisations are required to use in today's highly competitive and dynamic business environment to improve and preserve their competitiveness on one hand and reduce waste on another hand [1–3]. In recent years, the notion of lean manufacturing (LM) has emerged as a highly significant field of research in operations management. Lean manufacturing (LM) is a multifaceted strategy that comprises a wide range of management techniques to reduce waste and enhance operational performance [4, 5]. The main purpose of lean manufacturing is to eradicate any form of waste within the manufacturing process. Lean manufacturing arose from lean thinking, which offers a solution to waste. Lean thinking enables the identification of value, the sequencing of value-creating operations, and the execution of these activities with less human effort, less apparatus, and less time and space [6]. The successful operation of lean manufacturing in industrial systems effectively reduces inefficiencies, enhances

output and financial gains, improves product standards, reduces cycle time, and minimises work in progress, inventory and raw material usage and expenses [7]. Lean manufacturing promotes continual improvement in a dynamic and competitive setting, helping many companies achieve high financial performance [8]. Companies use lean methodology to avoid waste in the manufacturing process, which provides a cost advantage and makes the company more productive [9]. Lean manufacturing (LM) uses a various approach to minimise wastage and unproductive activities in the production process to maximise customer satisfaction.

The textile sector is a significant contributor to the generation of effluent wastewater owing to its extensive utilisation of water in various wet processing procedures [10, 11]. The wastewater that is discharged contains various chemical components such as acids, alkalis, dyes, hydrogen peroxide, starch, surfactants, dispersing agents, and metallic soaps [12]. The textile industry is believed to have the highest water usage among all industries worldwide, resulting in significant environmental consequences. The textile sector engages in the preparation of fibres, the conversion of fibres into yarn, and the subsequent modification of yarn into fabric. The resulting fabrics then undergo multiple phases of wet processing [11]. Even though the idea of lean production has worked well in industries with a constant process, it has not been used as much in industries with discrete processes. In the process industry, and especially in the textile industry, there is a lot of high-volume, low-product-variety automatic machinery that is not very versatile. Lean production strategies are hard to implement in the textile industry because it perceived as complicated. However, it has been taken as a task to implement lean strategies in the textile market. Various crucial determinants that ascertain the efficacy of incorporating the notion of lean manufacturing in small and medium-sized enterprises (SMEs) have been recognised. The successful implementation of lean manufacturing is contingent upon several key factors, including but not limited to leadership, management, finance, organisational culture, and skills and expertise [13].

The textile industry supports a significant number of jobs in emerging nations like India and provides around 14% to industrial output and 4% to overall GDP. However, since industrial facilities have grown in number, the likelihood of environmental problems has also grown. It has been noted that the Indian process industries are not fully embracing lean manufacturing. According to the findings of Panwar, sectors that have adopted lean have found it particularly effective in cutting down on waste and boosting product quality [14]. Dora et al. [15] argued that Indian companies are not doing a very good job of putting lean to use and knowing it.

Several studies have discussed environmentally friendly practices and the latest technology used in the textile industry [16–18]. There are two major gaps in the literature on lean manufacturing, first, studies do not capture the managerial perspective in the textile industry to influence the adoption of lean manufacturing. Second, there is very limited literature in the context of developing countries about lean manufacturing in the textile industry, however textile sector is sharply expanding in developing countries and requires lean manufacturing to reduce the waste in the production process [19]. Considering the gap in the literature, there is a need to study lean manufacturing adoption in the context of a developing country like India. Therefore, it is imperative to know the factors affecting the adoption of lean manufacturing in the textile industry because there are no such empirical studies which identify these factors. Some studies have identified the barriers and enablers of lean manufacturing but the majority of the studies are expert opinion based while few are case studies [20, 21], a firm-level primary data-based study on textile enterprises is still lacking. Understanding the factors influencing the adoption of lean manufacturing by textile enterprises is important to designing enterprise-level actions, and smooth and efficient production processes in the textile sector. The broad objective of the present study is to identify the factors which influence the adoption of lean manufacturing practices by textile enterprises in India. This study evaluates the relationship between textile firm characteristics and the adoption of lean manufacturing. Further, this research paper explores the factors affecting the adoption of lean manufacturing practices among textile enterprises by using a logistic regression model.

This study contributes both practically and theoretically to the existing literature on lean manufacturing in India's textile industry. The textile sector has serious concerns about waste reduction for sustainable production processes, therefore the present research contributes to filling the gap by analysing the factors affecting the adoption of lean manufacturing. Further, various firm-level factors may influence the adoption of lean manufacturing, this study provides an in-depth understanding of these factors. Knowledge of the determinants of lean manufacturing adoption provides opportunities for future research expansion on the topic. Moreover, the study contributes by establishing a relationship between the characteristics of textile firms that have adopted lean manufacturing and those that have not. This research paper concludes by analysing the factors that influence the adoption of lean manufacturing by textile enterprises, which is crucial for waste reduction in the textile industry. Therefore, identifying the main factors influencing the adoption of lean manufacturing can aid in the development of a more effective waste reduction strategy for textile companies.

The remaining parts of this paper are organized as follows. The next section deals with a review of previous work in the related areas. 3rd section presents the research methodology which includes data source and sample size, survey instrument and variables selection and estimation strategy. Results and

discussion of the study are given in the 4th section. Lastly, the conclusion, managerial Implications and limitations of the research are highlighted in the 5th section.

## REVIEW OF LITERATURE

A substantial body of literature about sustainability concerns within the textile industry exists. This includes works that address issues related to water, and waste management and the works that address energy management [22–25]. There are two ways to discuss lean production: philosophically, in terms of guiding principles and overall goals, or practically, in terms of management practices followed related to tools and methods [26, 27]. Bhasin [28] expresses that though lean manufacturing has been popular since 1990, but still, it is still unclear about the major factors in adopting lean or making it more widespread among companies. In their research work, Jadhav et al. [29] presented twenty-four obstacles in the implementation of lean operations, the leadership and participation of upper management, the attitude of employees, access to resources, and the organization culture played a significant role in the successful implementation of lean.

Lean has been very successful and is known all over the world, but many companies have failed when they tried to use lean. Almutairi et al. [30] list the factors that make it difficult to implement Lean. These factors encompass the necessity for financial investments, limited expertise, insufficient dedication, lack of confidence, previous managerial failures, inadequate comprehension, reluctance to change, and inertia among personnel. Lack of understanding about lean (its theory, principles, and tools), poor leadership, and a lack of top management support, commitment, and involvement are the major barriers to implementing lean operations [4, 31].

According to Prasad et al. [20], a comprehensive examination of operation, set-up, and changeover time (CO) is crucial for successful lean implementation in the textile industry. Additionally, the use of colour coding for volume-mix recognition, the application of kaizen, and the implementation of consistency circles to motivate workers are also important factors. In their study, Singh et al. [32] found that effectively implementing lean methodology in firms requires a focused approach to tackling management and market-related issues. Numerous developing nations' industries employ outdated and antiquated manufacturing methods and do not focus on new-age methods of production [33].

In the study conducted by Scherrer-Rathje et al. [34] lean success can be defined as the achievement of key components of a lean strategy, such as management commitment, utilisation of autonomy, transparency of information, and cultural alignment, together with the successful implementation of many techniques to support lean operational and tactical features. Chiarini [35] discussed the integration of lean orientation and ISO 9001 and found that, in general, the implementation of lean affects ISO 9001 documentation, which includes quality manual, procedure and work instructions. Further, he suggested that the principles, tools and techniques used in the implementation of lean procedures are considerably the same as those used by ISO-certified companies. Chauhan et al. [36] indicate that labour and machine flexibility contribute positively and substantially to lean philosophy-based production methods.

Motherwell et al. [37] point out that except for 5S strategies, managers either hesitate to use lean manufacturing or have limited knowledge of lean implementation.

According to the literature, lean operations in the textile industry are a major concern in India as well as around the globe. The adoption of lean manufacturing is facilitated by several factors, including firm profile, access to resources, new technology and certifications, and employee and machine upgrades. The adoption of lean manufacturing in the textile industry has substantial implications for maximising productivity and minimising waste within a manufacturing operation. Given the significance of waste minimization for sustainable production in achieving the SDGs, it is crucial to have a thorough comprehension of the factors that influence the adoption of lean manufacturing in general and the textile industry in particular. This study addresses two primary research questions: (1) whether there is an association between the adoption of lean manufacturing and the profile of textile firms and (2) which factors influence the adoption of lean manufacturing by textile enterprises.

## RESEARCH METHODOLOGY

### Data source and sample size

This paper uses the recent World Bank Enterprise Survey (WBES). Data was collected by the World Bank using stratified random sampling. The population of establishments is divided into non-overlapping strata, from which straightforward random sampling is then used to select respondents. NielsenIQ (India) Private Limited was in charge of the India 2022 WBES fieldwork. The selection of the implementing agency was conducted by the Enterprise Surveys Manual and Guide's standard procurement procedures. The fieldwork team employs Computer-Assisted Personal Interview (CAPI), an in-person technique in which the interviewer uses a tablet to transcribe responses given during the interview. A total of 9376 enterprises from 24 different states and union territories and 17 major sectors of India were included in the survey. Among the total surveyed firms, 596 are textile firms and from these 596 textile firms, 318 (53.3%) of the firms have given responses on the concern variables "Does establishment use formal lean manufacturing or operations?". Therefore, finally, 318 textile firms are taken for study.

### Survey instrument and variables selection

A structured questionnaire has been used to survey the enterprises. Data has been collected on a wide range of questions related to business situations under fourteen subheads. In the present study, a set of related variables are extracted from the World Enterprises Survey of the World Bank (WBES), 2022. The data has been collected on different scales such as binary, Likert, and rating scales. The dependent variable of the study "Does establishment use formal lean manufacturing or operations?" is recorded on a binary scale, where 1 is used for adoption, while 0 depicts non-adoption. Further, the set of explanatory variables is divided into three groups (i) enterprise characteristics which include firms' age (Age), firm size (Size), legal status (Legal) and export-based enterprises (Expo), (ii) access to resources, under this group access to electricity (Elect), access to land (Land) and credit-line (Credit) has been taken while in last group namely certification and competitive development have four variables international quality certification (IQC), technology license from a foreign company (TLFC), upgraded machines and equipment's (UME) and formal training (Training). Suitable transformation in scale has done to include in the analysis.

### Estimation strategy

In this research paper, the chi-square test is employed to investigate the significant association between firm profile and adoption of lean manufacturing. Using the following formula, the value of chi-square statistics was determined.

$$\chi^2 = \Sigma (O - E)^2 / E \qquad (1)$$

In equation 1, the expected and observed values are denoted by $E$ and $O$ respectively.

Further, an empirical model was developed to identify factors affecting the adoption of lean manufacturing in textile enterprises in India. The variable "Does establishment use formal lean manufacturing or operations" has been taken as the dependent variable while the three groups of variables namely enterprise characteristics, access to resources, and certifications and competitive development are taken as explanatory variables. Logistic regression is used when the dependent variable has only two possible outcomes (1,0), and the independent variables might be categorical, continuous, or a combination of both. In the present study, our dependent variable is adoption of lean manufacturing is measured on a dichotomous scale. It has been converted into a binary scale where 1 depicts the adopters and 0 is given to non-adopters of lean manufacturing by textile enterprises. Therefore, logistic regression is the most appropriate method for investigating the factors influencing the adoption of lean manufacturing. The logistic regression model can be expressed in the following generic form:

$$y_i^* = \alpha + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \qquad (2)$$

The unobserved response to lean manufacturing is $y_i^*$, $X_i$ is the matrix of independent variables comprising enterprise characteristics, access to resources, certification and competitive development, and $\beta_i$ is the vector of regression coefficients. The symbols $\alpha$ and $\varepsilon_i$ represent the intercept and error terms respectively.

Based on the aforementioned variables, the following empirical model was specified and estimated to forecast the likelihood of the following factors influencing the adoption of lean manufacturing by textile companies in India:

$$LMO = \beta 0 + \beta 1 Age + \beta 2\, Size + \beta 3\, Legal +$$
$$+ \beta 4\, Expo + \beta 5\, Elect + \beta 6\, Land + \beta 7\, Credit +$$
$$+ \beta 8\, IQC + \beta 9\, TLFC + \beta 10\, UME + \beta 11\, Training + \varepsilon$$

The following is the specification of the logit model, which is derived from the cumulative logistics probability function:

$$Pi = \frac{1}{1 + e^{-(\alpha + \sum_{i=1}^{n} \beta_i X_i)}} \qquad (3)$$

## RESULTS AND DISCUSSION

The profile of the textile firm differs between those who have adopted lean manufacturing and those who have not. Table 1 depicts the association between the adoption of lean manufacturing methods and the characteristics of textile companies. Of the total textile firms, 18 percent reported that they have adopted lean manufacturing. Results show a significant association between firms' age and adoption of lean manufacturing at a 10 percent level of significant ($\chi^2 = 7.174$, $P < 0.09$). The frequency distribution of firms' age categories across adopters and non-adopters shows that firms' age is significantly associated with the adoption of lean manufacturing. The percentage of adopters is higher in firms' age above 30-year-old textile firms. The chi-square test shows that significant association between the adoption of lean manufacturing and a line of credit from a financial institution ($\chi^2 = 23.500$, $P < 0.01$). 31.6 percent of credit users have adopted lean manufacturing as opposed to 68.4 percent are adopters do not have a credit line, but in the non-adopters category, only 8.2 percent have credit from a formal institution. It implies that credit user relatively more adopts lean manufacturing in the textile industry. Similarly, for the case of international quality certification, a statistically significant association is observed between lean manufacturing and ownership of internationally recognised quality certification ($\chi^2 = 15.874$, $P < 0.01$). 63.8 percent of the lean manufacturing enterprises reported that they have internationally recognised quality certification as opposed to 36.2 percent of adopter firms that do not have an internationally recognised quality certification. It shows that the majority of the adopters have

international quality certifications. Firms' distribution across the adopters and non-adopters of lean manufacturing concerning technology licensed from a foreign-owned company reveals that 37.9 percent of adopters of lean manufacturing have technology licensed from a foreign-owned company. $\chi^2$ test Chi-square reveals that technology licensed from a foreign-owned company is statistically significantly associated with the adoption of lean manufacturing methods in textile enterprises. The association between upgraded machinery and equipment and adoption of lean manufacturing operations is significant ($\chi^2 = 16.179$, $P < 0.01$), implying that firms with upgraded machinery are more adopters of lean manufacturing and operations. The frequency distribution of firms shows that 82.8 percent of the firms adopt lean if they have upgraded machinery and equipment as opposed to 17.2 if do not have upgraded machinery and equipment. As evident from the chi-square test adoption of lean manufacturing is significantly associated with export operation by the firms ($\chi^2 = 7.13$, $P < 0.01$).

### Factors affecting the adoption of lean manufacturing in the textile industry

The estimates of factors affecting the adoption of lean manufacturing among textile firms in India are presented in table 2. The regression coefficient and odd-ratio have been calculated for three sets of explanatory variables namely enterprise characteristics, access to resources and certification and competitive development to predict the adoption of lean manufacturing. Estimates of the omnibus test of model coefficient ($\chi^2 = 75.584$, $P < 0.01$) reveal that all variables in the model are jointly significant, implying that variables taken in the model have significant power to explain the adoption of lean manufacturing. The value of Log-likelihood is negative and adequately high showing good model strength. Among four enterprise characteristics namely firm age, firm size, legal status and export, only one variable legal status is significantly affecting the adoption of lean

Table 1

PROFILE OF TEXTILE FIRMS ACROSS THE ADOPTION OF LEAN MANUFACTURING

| Firms profile | Yes (%) | No (%) | $\chi^2$ | df | Sig |
|---|---|---|---|---|---|
| *Firms age category* | | | | | |
| <10 years | 5.2 | 9.2 | 7.174*** | 3 | 0.067 |
| 10–20 years | 17.2 | 26.9 | | | |
| 20–30 years | 29.3 | 33.1 | | | |
| Above 30 years | 48.3 | 30.8 | | | |
| *Firms size* | | | | | |
| Medium | 36.2 | 44.8 | 1.422 | 1 | 0.233 |
| Large | 63.8 | 55.2 | | | |
| *The legal form of the enterprises* | | | | | |
| Shareholding company | 10.3 | 12.3 | 0.529 | 2 | 0.768 |
| Sole proprietorship | 62.1 | 56.9 | | | |
| Partnership and limited partnership | 27.6 | 30.8 | | | |
| *The establishment has access to credit* | | | | | |
| Yes | 68.4 | 91.8 | 23.500* | 1 | 0.000 |
| No | 31.6 | 8.2 | | | |
| *Does the establishment have an internationally recognised quality certification?* | | | | | |
| Yes | 63.8 | 35.4 | 15.874* | 1 | 0.000 |
| No | 36.2 | 64.6 | | | |
| *Do firm use technology licensed from a foreign-owned company?* | | | | | |
| Yes | 37.9 | 4.7 | 53.622* | 1 | 0.000 |
| No | 62.1 | 95.3 | | | |
| *Firms upgrade machinery and equipment* | | | | | |
| Yes | 82.8 | 54.1 | 16.179* | 1 | 0.000 |
| No | 17.2 | 45.9 | | | |
| *Export firms* | | | | | |
| Yes | 39.7 | 22.7 | 7.13* | 1 | 0.008 |
| No | 60.3 | 77.3 | | | |

Note: *Significant 1 percent, **Significant 5 percent, ***Significant 10 percent.

manufacturing by textile enterprises. The estimated regression coefficient of legal status is positive and significant ($\beta = 1.013$, $P < 0.05$), implying that textile firms having sole proprietorship as legal status are more likely to adopt lean manufacturing as compared to another type of legal ownership. It may be because generally, sole proprietorship firms are small and looking for greater growth and development aspirations. Sole proprietorship ownership type has significant indirect effects on innovation It can be concluded regarding firm profile that it is not very important in the adoption of lean manufacturing in textile enterprises. The findings of the study are in line with the outcome of the previous studies [3, 15, 27].

Further, access to resources improves the ease of doing textile business in India [38]. The logistics regression estimates show that out of a total of 3 variables under access to resources, two variables access to electricity and credit from institutional sources significantly affect the adoption of lean manufacturing in India. The regression coefficient is positive and significant for access to electricity ($\beta = 1.157$, $P < 0.05$), which implies that textile firms that have access to electricity are more likely to adopt lean manufacturing. The odd ratio indicates that firms with access to electricity are 3.181 times more likely to adopt lean manufacturing as compared to the textile which perceived access to electricity as an obstacle for them. Similarly, the analysis for credit lines suggests that it has positively significant effects on the adoption of lean manufacturing ($\beta = 1.288$, $P < 0.01$). The odd value of the credit line is 3.626, which shows that the textile enterprises that have taken credit have 3.626 times more chance to adopt lean manufacturing operations. Previous researchers support the findings that access to resources is essential to adopt new systems like lean manufacturing [13, 39, 40].

Finally, the impact of certification and competitive development on the adoption of lean manufacturing has been analysed. Out of four variables international quality certification, technology licensed from a foreign company, upgraded machines and equipment and formal training, three variables have significant implications on the adoption of lean manufacturing. The international quality certifications have positive and significant effects on the adoption of lean manufacturing ($\beta = 0.814$, $P < 0.05$), the odd value is 2.257, which implies that the textile enterprises with

Table 2

DETERMINANTS OF LEAN MANUFACTURING IN TEXTILE FIRMS

| Determinants | Adoption of lean manufacturing (Yes=1, No=0) | | | | |
|---|---|---|---|---|---|
| | B | S.E. | Wald | Sig. | Exp(B) |
| *Enterprises Characteristic* | | | | | |
| Firms Age (Year In Number) | 0.002 | 0.011 | 0.037 | 0.848 | 1.002 |
| Firm Size (Large=1, Otherwise=0) | 0.192 | 0.368 | 0.273 | 0.602 | 1.212 |
| Legal Status (Sole Prop.=1, Otherwise=0) | 1.013** | 0.405 | 6.277 | 0.012 | 2.755 |
| Export (Yes=1, No=0) | 0.223 | 0.412 | 0.292 | 0.589 | 1.25 |
| *Access to Resources* | | | | | |
| Access to Electricity (Yes=1, No=0) | 1.157** | 0.461 | 6.298 | 0.012 | 3.181 |
| Access to Land (Yes=1, No=0) | –0.13 | 0.46 | 0.079 | 0.778 | 0.878 |
| Credit-line (Yes=1, No=0) | 1.288* | 0.48 | 7.193 | 0.007 | 3.626 |
| *Certification and competitive development* | | | | | |
| International Qty. Certification (Yes=1, No=0) | 0.814** | 0.39 | 4.359 | 0.037 | 2.257 |
| Tech. Licensed from A Foreign Company (Yes=1, No=0) | 1.518* | 0.46 | 10.873 | 0.001 | 4.561 |
| Upgraded machines and equipment (Yes=1, No=0) | 0.98* | 0.422 | 5.381 | 0.020 | 2.664 |
| Formal training (Yes=1, No=0) | 0.51 | 0.457 | 1.247 | 0.264 | 1.666 |
| Constant | -4.564* | 0.738 | 38.299 | 0.000 | 0.010 |
| Chi-square | 75.584* | | | | |
| df | 11 | | | | |
| Sig. | 0.000 | | | | |
| -2 Log likelihood | 218.238 | | | | |
| Cox & Snell R Square | 0.219 | | | | |
| Nagelkerke R Square | 0.355 | | | | |
| Correction prediction (%) | 87.2 | | | | |

Source: Author's calculation based on WBES (2022),*Significant 1 percent, **Significant 5 percent.

international quality certification are 2.257 times more likely to adopt lean manufacturing as compared to the firm which do not have international quality certification. The estimated coefficient and odd value for technology licensed from a foreign company is positive and significant ($\beta = 1.518$, $P < 0.01$) revealing that firms with technology licences are 4.561 more likely to adopt lean manufacturing. The use of upgraded machinery and equipment has significantly positive implications on the adoption of lean manufacturing ($\beta = 0.98$, $P < 0.05$), which implies that upgraded machinery and equipment are instrumental in lean manufacturing adoption in textile enterprises. Access to resources has significant implications for the adoption of lean manufacturing by textile firms in India. To develop sustainably, access to resources by business enterprises such as land, capital, finance, electricity and other fundamental infrastructure is essential. Limited expertise and resources are challenges in implementing the lean manufacturing method. Although lean manufacturing has achieved significant success and worldwide recognition, some firms have experienced failure in implementing lean methodologies. Multiple factors purportedly contribute to the lack of success. Lack of access to financial resources is one of them, which includes funds for investment in training. As the results suggest that quality and technology-certified textile firms are more adopters of lean manufacturing, it may be because facilities that are certified firms generate significantly less waste. Quality certification or the receipt of quality awards has significant implications for adopting the updated management techniques [41].

The ISO 9001-certified factories generate much less waste. Having certifications such as ISO 9001 and ISO 14001 has a favourable impact on an organization's management effectiveness, financial performance, environmental performance, and competitiveness, which may help in the adoption of lean manufacturing.

## CONCLUSION AND MANAGERIAL IMPLICATIONS

Lean manufacturing is the solution to waste in general and textile industry in particular. Waste is one of the most severe problems of the modern era in the industrial sector. Lean manufacturing is a structured method that seeks to eliminate non-value-added activities or waste. This methodology is designed to maximise productivity while minimising waste in manufacturing settings. It focuses on the optimisation of processes, the elimination of waste and inventory, the production of high-quality products, the creation of a more cost-effective and efficient production system, and the reduction of human effort. This present study analyses the factors affecting the adoption of lean manufacturing in the textile industry based on the latest World Bank Enterprises Survey (WBES)-2022 data, the textile enterprises data is extracted from large survey data. Analysis shows that significant association between firms profile and the adoption of lean manufacturing. Test of association indicated that older firms, involved in export and took institutional credit, having international quality certification and technology licence from a foreign-owned company with upgraded machinery and equipment are significantly associated with lean manufacturing adoption in India. Further, the estimates of logistic regression show that among firms' characteristics, only legal status significantly affects the adoption of lean manufacturing, sole proprietorship firms are more likely to adopt lean manufacturing. Moreover, access to resources, credit from financial institutions and access to electricity is positively significant. Moreover, certification and upgraded machinery and equipment are identified as significant factors in the adoption of lean manufacturing.

The present paper offers various implications. It is evident that very limited numbers of firms adopt lean manufacturing however waste minimization is a severe concern among policymakers. There is a need to promote lean manufacturing among textile enterprises. Though the Indian government introduced a lean manufacturing competitive scheme (LMCS), it should be promoted among textile enterprises to be aware of them. Secondly, based on the association between a firm's profile and lean manufacturing, policymakers should encourage young firms to adopt lean manufacturing, it should be linked with the registration process, and the textile enterprises that follow lean manufacturing should be registered only. Thirdly, credit norms should be easy for textile enterprises as it is shown that they significantly affect the adoption of lean manufacturing. Being a significant enabler of lean manufacturing, the textile enterprises should provide the resources at a subsidized rate. Finally, the upgraded machinery seems to have significant implications for the adoption of lean manufacturing, the textile enterprises should be exhilarated to upgrade their machinery and equipment in their inspections of compliance because both quality certification and upgraded machinery and equipment have affected the adoption of lean manufacturing in textile enterprises.

The study is based on the comprehensive survey of the World Bank, the variable related to lean manufacturing is very limited and the measurement scale is binary for the majority of the variables. Which restricted to adoption of advanced econometric methodology and extended the conceptual research model. Future researchers may collect the data on a wide range of questions related to lean manufacturing only on an appropriate scale which may provide the flexibility to adopt the latest data analysis techniques.

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