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ORIGINAL PAPER

# Impact of industry 4.0 technologies on lean manufacturing and organizational performance in an organization

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**Abstract**

Lean is a term that was first used in 1988 with reference to a production system. It is a highly acknowledged production method that focuses on cutting out waste, at the same time ensuring the same quality. An emerging field known as industry 4.0 has recently evolved, with the goal of incorporating current smart technologies into the industrial process. Due to the novel nature of the subject, very little evidence is there to suggest that there is a link between industry 4.0 and Lean production. The study aims to find empirical evidence to show the direct relationship between the introduction of industry 4.0 and Lean process and to find the impact it has on organizational performance. The research is based on data gathered in the form of a survey questionnaire. The measurement scale used for the questionnaire was a five-point Likert scale, the primary respondents of the questionnaires were production engineers, service engineers and sales representatives. The data was analyzed using IBM SPSS software and a correlation between industry 4.0 technologies and Lean manufacturing was obtained.

**Keywords** Industry 4.0 · Lean production · Smart manufacturing · Lean management · Digitalization · Lean automation · Lean practice

## 1 Introduction

The first industrial revolution came with the advent of mechanization and the introduction of steam and waterpower. The second industrial revolution involved mass production assembly lines using electrical power, then came along the third industrial revolution, which involved automated production, IT systems, and robotics. This was succeeded by the fourth industrial revolution, which is sometimes defined as Industry 4.0, and corresponds to the new stage in industrial revolution whose aim is to integrate physical production and operations with smart technology, which mainly includes smart factories, cloud computing, internet of things (IoT), cognitive computing, artificial intelligence, cyber-physical systems, etc. It helps organizations to have better control over their operations and allows them access to a large pool of data because of big data analytics, which helps to boost productivity and improve the overall organizational growth. Lean manufacturing is a method that originated in Japan throughout the 1950s, namely at Toyota Motor Corporation. Lean manufacturing is a method that focuses heavily on reducing and minimizing waste within the manufacturing system that adds no value to the organization and also simultaneously maximizes the productivity within the system; such elimination of waste helps an organization to reduce the cost and complexity, which in turn results in improved efficiency, effectiveness and profitability. Lean manufacturing has helped manufacturers to greatly reduce the waste generated in their operations but it cannot meet the current needs and demands. The introduction of assembly lines in the automobile industry in 1913 prepared the groundwork for the industrial revolution's second phase; similarly, industry 4.0 technologies will cause a dramatic shift in the entire industry when used in a manufacturing sector.

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## 2 Literature review

This segment involves the literature review done on two main topics discussed in the paper: industry 4.0 technologies and Lean production.

### 2.1 Lean production

The Lean manufacturing approach was first originated in Japan in the 1950s and has been used ever since the company managed to get its first truck contract with the Japanese government in 1936. It is a technique that focuses on the reduction of wastes that reduces complexity and cost. According to Rachna and Peter [1], in Lean production, any action that uses resources but provides no value for clients is deemed unproductive and should be discontinued. The basic idea of Lean production is to have a simplified flow of the process to create products at the customers' demand with minimum waste [1]. Dhruv and Pritesh [2] further provided various Lean manufacturing tools that can help to reduce such kinds of waste. They are tools like Just in time (JIT), Kanban, Total productive maintenance (TPM), and Production smoothing. Naveen and Kaliyan [3] argued that although Lean is a swift and compelling tool, organizations may find it difficult to maintain long-term efficiency using this to minimize waste. Lean manufacturing is very demanding and requires consistent efforts and financial backing to overcome several hindrances. Jadhav et al [4] has confirmed this by stating that although Lean manufacturing has helped companies to reduce waste, many companies have struggled to implement the Lean philosophy. Employee team development and Lean culture seminars are two examples of how a company can achieve Lean sustainability [3]. Regardless of all the benefits and uses of Lean, many researchers believe that Lean is outdated and will fail to keep pace with customer's demands and trends of the modern world. Dennis and Detlef [5] summarize that the Lean approach has been tremendously effective, its adaptability to make highly personalized items is constrained. Industry 4.0 is a concept of industrial automation that can satisfy these growing needs [6–8].

### 2.2 Industry 4.0

Industry 4.0, also indicated as the Fourth Industrial Revolution, is the transition of industries from traditional manufacturing to smart manufacturing using modern technologies like machine-machine communication, artificial intelligence, robotics etc. According to Adam et al [9], Industry 4.0 has a significant impact on the industrial environment, resulting in significant alterations in how tasks are carried out. The use of intelligent technology and systems, which enable information gathering and engagement amongst items, operations, distributors, and buyers over the web, is known as the fourth industrial revolution (Sven et al [10]). Likewise, Keliang 11] supports this by enumerating that industry 4.0 aims to create a dynamic manufacturing system for individualized as well as electronic goods and services that allows for direct contact between goods and services while the manufacturing process is carried out. Heiner et al [12] argue that the changes brought about by digital transformation have ramifications not only for modern innovation but also for enterprises. As a result, even in conventional businesses, a shift from product to service orientation is expected. According to Vaidya et al [13] industry 4.0 aims to transform ordinary machines into self-learning machines and increase their overall functionality while at the same time, the goal is to provide an intelligent production infrastructure for industrialized-networked data applicants. Besides, to keep up with individual requirements and yield tailored services, smart manufacturing will play a crucial part in the idea of additive manufacturing. (Luke et al [14]). According to Sinay and Kotianova [15], Industry 4.0 technologies that can benefit the manufacturing sector includes augmented reality, virtual assembly, autonomous robots and machines, intelligent logistics and 3D printing. Ray et al [16] explains how smart production increases flexibility around manufacturing and enables companies with options such as the production of individual personalized products.

### 2.3 Industry 4.0 and lean

The fundamental question that all manufacturers want to be answered is, if Lean and Industry 4.0 are interoperable and can work together and assist one another; some also fear that Industry 4.0 might replace Lean philosophies. According to Roy et al [17], Lean and Industry 4.0 are philosophies that are not very much different from each other but rather synergize and help each other when used together in conjunction. Another important feature used in Lean manufacturing which can greatly impact Industry 4.0 technologies is autonomation. Adam et al [9] describes autonomation as a phenomenon in which an automated process stops completely when a defect is detected and does not allow the defect to further advance in the assembly line. Hence an individual interference would be solely enforced albeit a mistake is observed, rest of the process is completely automated. It is therefore critical to remember that, notwithstanding Industry 4.0's innovative-driven strategy, the non-technology element of personnel and procedural aspects, which are key to Lean, will continue to play a critical role in advanced manufacturing systems and supply chains. According to Frederic et al [18] the automation surfacing from industry 4.0 can bolster production levels by relying on the level of complexity of the decision to be made, the measure of information to be processed, the autonomy of system to make decision. Ana et al [19] indicate that from the diverse array of technologies comprising Industry 4.0, the ones which can impact and improve lean manufacturing production are the IOT, data management, cloud services, artificial intelligence, and automation. Sanjib [20] has stated that the Andon method, a Lean principle applied along with industry 4.0 technology like, use of an augmented operator can help shorten the time between both the incidence of a failure and reporting of that fault. Dennis [21] showed that the Lean manufacturing process has a huge potential to adopt Industry 4.0 technologies in manufacturing. According to Ana et al [19] industry 4.0 technologies hold a great potential to not only influence the manufacturing and industrial sector but also to have a greater impact in other areas such as products and services, skill development, new business models etc. Adam et al [9] supports this by stating that modern technologies can help manufacturing organizations to reduce the obstacle of adopting Lean tools. The combined influence of Lean manufacturing and smart manufacturing technology has the potential to boost productivity and decrease waste. According to Nai et al [22] industry 4.0 technologies can aid minimize and eliminate overproduction, minimize, and eliminate waiting time, minimize inventory and minimize over processing etc. According to Dennis and Detlef [5] lean principles and industry 4.0 technologies have lot of things common between each other as they both aim to promote simple and decentralized structures rather than large and complex structures. Industry 4.0 can help Lean production to keep up with demands of the customers, since personalization and customization has become a major trend (Matteo et al [23]). Christian [24] used the google trend tool to analyze the interest in the field of industry 4.0, they found the interest of people in industry 4.0 has never been stronger in the last few years. The technologies form Industry 4.0 do not cover the integrated-ness of Lean principles but can reinforce the efficiency of these principles although some Lean principles like levelled production and labelled process can come under scrutiny (Frederic et al [18]). Dennis and Detlef [5] states that the integration of industry 4.0 with Lean production is very much feasible and it matches the Lean philosophy while contradicting on the fact that there is lack of comprehensive framework which combines Industry 4.0 technologies with Lean production. Further, Sachin et al [25] emphasized that Lean manufacturing practices can greatly enhance the effect of industry 4.0 technologies on sustainable organizational performance. According to Osti [26] the value creation principles of Lean management which are reducing internal wastes and increasing satisfaction levels of customers along with value creation principles of Industry 4.0, which includes operational efficiency, reduced cost of production and quality assurance, are very similar in a way both assures continuous improvement and products to satisfy customers. Christian [24] further concluded that the use of appropriate information and communication technology (ICT) plays a very crucial factor in Industry 4.0 technology and environment. Osti [26] stated that Lean manufacturing serves as an added benefit for the successful implementation of industry 4.0 solutions. Nai et al [22] added to this by stating Industry 4.0 technology have a positive impact on different types of waste generated during production using Lean manufacturing. Stephen and Brian [27] stated that digital Lean accelerates waste identification and mitigation faster than traditional Lean methods by using industry 4.0 tools which help them to provide targeted and detailed information to the operators to help them identify and reduce waste. Furthermore, Sule et al [28] stated that Industry 4.0 will not solve the problems of mis-managed and weakly-organized manufacturing systems. However, should Lean principles should be applied successfully before automation. Many authors [29–47] illustrated the fact that how industry 4.0 acts as a supporting factor for implementation of Lean manufacturing in an organization. Based on the literature presented above, a conceptual framework model can be established demonstrating the link amongst Lean, industry 4.0 and organizational effectiveness. Figure 1. shows a theoretical structural model depicting industry 4.0, Lean production and organizational performance.

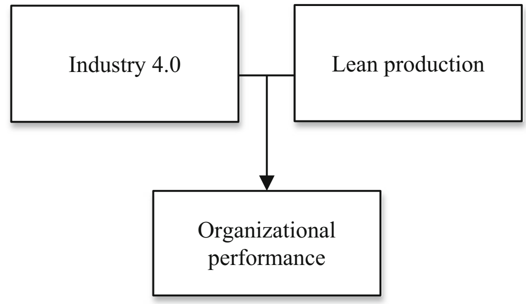


**Fig. 1** Theoretical structure highlighting relationship among Lean, industry 4.0 and organizational effectiveness

From the above Figure industry 4.0 and Lean production are taken as independent variable which means that any changes in it will cause a direct effect or change in an organizational performance which is our dependent variable in this framework model. From the above framework model, the following hypothesis can be described:

(1) H0: Industry 4.0 technologies has no effect on Lean manufacturing.
(2) H1: Industry 4.0 technologies has a positive effect on Lean manufacturing.
(3) H2: Industry 4.0 technologies has a negative effect on Lean manufacturing.
(4) H3: Organizational performance is positively impacted by the integration of industry 4.0 technologies and Lean manufacturing.

Following the data analysis, each hypothesis will be assessed for plausibility in the sections that follow.

**Table 1** Mean and standard deviation

| Variables | Mean | Std. Deviation |
|---|---|---|
| lp1 | 4.04 | 0.676 |
| lp2 | 3.88 | 0.807 |
| lp3 | 3.96 | 0.763 |
| lp4 | 3.59 | 0.840 |
| lp5 | 3.88 | 0.696 |
| lp6 | 3.80 | 0.912 |
| lp7 | 4.02 | 0.777 |
| lp8 | 3.98 | 0.854 |
| lp9 | 3.53 | 0.938 |
| lp10 | 3.88 | 0.949 |
| lp11 | 3.78 | 0.823 |
| lp12 | 3.84 | 0.800 |
| t1 | 3.73 | 0.884 |
| t2 | 3.71 | 0.913 |
| t3 | 3.45 | 1.042 |
| t4 | 3.88 | 0.832 |
| t5 | 3.61 | 1.017 |
| t6 | 3.49 | 1.023 |
| t7 | 3.55 | 0.959 |
| t8 | 3.59 | 1.098 |
| t9 | 3.53 | 1.157 |
| t10 | 3.51 | 1.192 |
| t11 | 3.80 | 0.841 |
| P1 | 4.33 | 0.658 |
| P2 | 4.33 | 0.591 |
| P3 | 4.33 | 0.625 |
| P4 | 4.24 | 0.560 |
| P5 | 4.27 | 0.638 |
| P6 | 4.29 | 0.612 |

**Table 2** Cronbach's alpha value

| Reliability statistics | | |
|---|---|---|
| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
| 0.925 | 0.926 | 29 |

## 3 Research methods

To find the correlation between Lean practices and industry 4.0, a questionnaire-based survey methodology is proposed. The above method is conducted to determine the or link or correlation between lean practices, industry 4.0, and organizational effectiveness. The measurement scale used for the questionnaire was a five-point Likert scale. A sample size of 50 was utilized for the paper and a good response rate of 0.6 was achieved. The Likert scale's extreme points encompassed range from (1 completely disagree) to (5 completely agree). English language has been used to write the questionnaire, and responses are mainly collected from professionals in Lean production and industry 4.0 An email with a survey link was sent directly to the respondents. Production engineers, service engineers, and sales representatives were the primary respondents to the survey. The primary respondents were mainly from UAE with some respondents based in India. The respondents primarily represented companies in manufacturing, automotive, construction, maintenance, and service engineering sectors. The questionnaire is broken down into four parts. The first section involved general questions involving the business type of the organization, number of employees in the company, business operating model of the company, and Lean implementation time duration in the organization. The second section involved questions related to Lean implementation, such as the relationship between suppliers, new product development process, supplier feedback on the quality and customer feedback on the performance of the product or service, predictive maintenance used in the organization, and usage of just in time (JIT). The third section involves questions regarding the acceptance of industry 4.0 technologies in the organization such as robotic stations, a machine with a digital interface, artificial intelligence, augmented reality, cloud computing, RFID tag at working units, and adaptive manufacturing. The fourth and final section involved questions on parameters affecting organizational performance such as improvement in productivity, level of service, inventory control safety at workplace and job quality. The survey questionnaire was later analyzed using IBM SPSS software and non-parametric statistics were used in data analysis. Cronbach's alpha is utilized to measure the reliability and internal consistency among the data. The data was then checked for normality; after that, the data was analyzed by selecting an appropriate statistics test. We perform a parametric test to check if the data collected is normally distributed, whereas we perform a non-parametric test to analyze the data if the data is not normally distributed.

**Table 3** Normality test

| Shapiro–Wilk | | | |
|---|---|---|---|
| Variables, | Statistic, | df | Sig |
| TransLP | 0.988 | 50 | 0.904 |
| TransT | 0.924 | 50 | 0.003 |
| TransP | 0.937 | 50 | 0.010 |

## 4 Findings and analysis

Data analysis is conducted using IBM SPSS software. After collecting the data from the questionnaire, data was stored in excel and analyzed in SPSS. The standard devia-

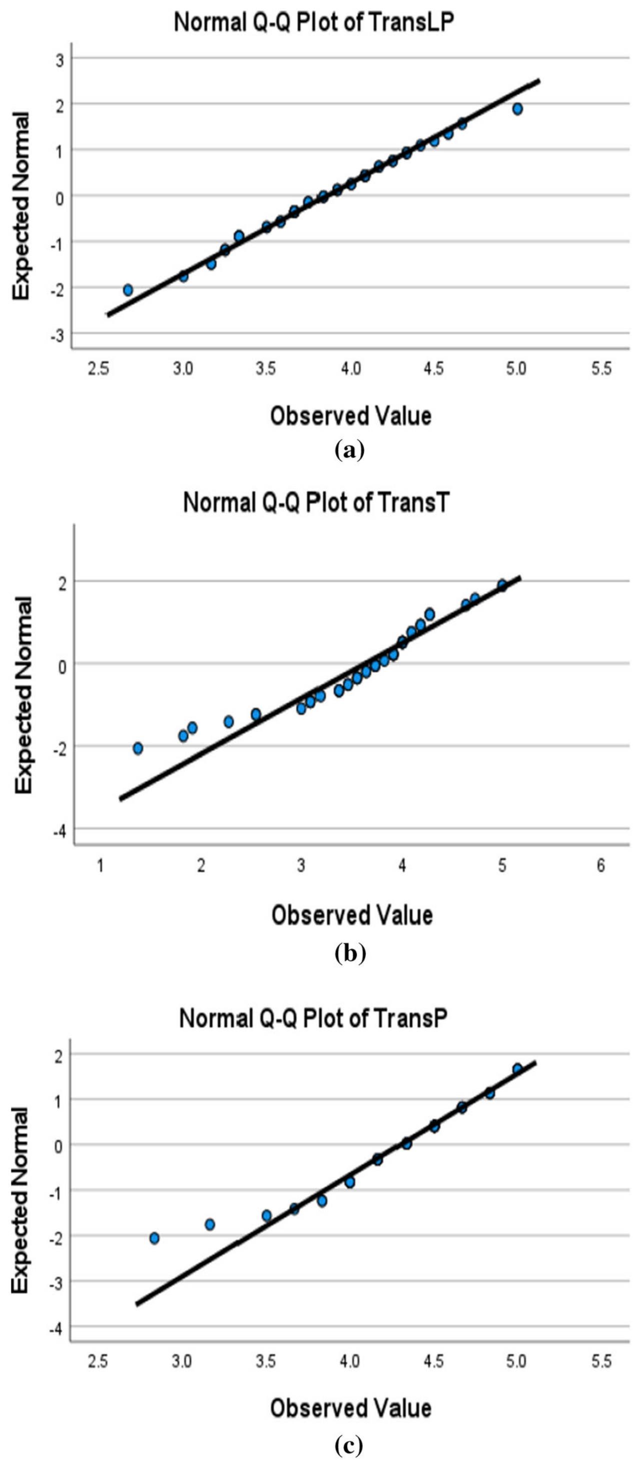


**Fig. 2** Expected normal versus observed values graphs for variables **a** TransLP **b** TransT and **c** TransP

tion and mean of the data obtained from the survey is shown in the Table 1. Here lp is short for Lean production, t is short for industry 4.0 technologies, and P is short for organizational performance.

The Table 1 shows the mean and standard deviation for all the Lean production, industry 4.0 techniques and organizational performance. The mean of organization performance is approximately 4, whereas the mean for Lean production and industry 4.0 technologies is found to be approximately greater than 3. After finding this we can proceed with the data analysis part. The first part of the analysis is to find Cronbach's alpha; it gives us the information on how closely the data in the group are related to each other. It gives us the measure of internal consistency in our data set and measure of scale reliability. After doing the analysis Cronbach's alpha was found out. The below Table 2 shows Cronbach's alpha value for our data set.

From the Table 2, we can see that the Cronbach's alpha score was found out to be 0.926, which reflects excellent internal consistency among the data set. Next, we can proceed with the normality test to decide which statistic test to be used, either parametric test or non-parametric test. If the data is found to be normally distributed, a parametric test is conducted and, if data is not normally distributed, a non-parametric test is conducted. The normality of the data is checked; this is done using various normality test procedures. If the data is normally distributed, regression analysis and Pearson correlation can be used for the analysis if the data is not normally distributed, ordinal regression analysis and Spearman rank correlation shall be used. Before proceeding with the normality test first, we must find the mean and log of the variables. The variable TransLP is the mean of all the data received from questions regarding Lean production, variable TransT is the mean of all the data received from questions regarding industry 4.0 technologies and lastly the variable TransP is the mean of all the data received from questions regarding organizational performance. Similarly, the variable lopLP is the log of data received from questions regarding Lean practices, the variable lopT is the log of data received from questions regarding industry 4.0 technologies and the variable lopP is the log of data received from questions regarding organizational performance. The mean and log of some of the variables are shown below.

After finding the mean and log of the variable, we can proceed to perform our normality test. Kolmogorov–Smirnov method is applied if the number of responses is greater than 100. Since our number of responses are less than 100, we must use the Shapiro–Wilk method to analyze data for normality. If the p-value obtained by the Shapiro–Wilk technique is more than 0.05, it determines the normal distribution of the data; if the p-value obtained by the technique is less than 0.05, it concludes the data is not normally distributed. The results obtained after running the test are shown below.

From the Table 3, we find out the p-value for the variable TransLP is greater than 0.05 and the p-value for the variables TransT and TransP is less than 0.05, which tells us that the variable TransLP is normally distributed whereas the vari-

**Table 4** Mean and log of the variables

| TransLP | TransT | TransP | lopLP | lopT | lopP |
|---|---|---|---|---|---|
| 3.67 | 3.09 | 4.50 | 0.56 | 0.49 | 0.65 |
| 3.33 | 3.64 | 4.00 | 0.52 | 0.56 | 0.60 |
| 3.83 | 4.00 | 4.67 | 0.58 | 0.60 | 0.67 |
| 4.50 | 4.00 | 4.50 | 0.65 | 0.60 | 0.65 |
| 4.58 | 2.55 | 4.00 | 0.66 | 0.41 | 0.60 |
| 4.33 | 1.91 | 2.83 | 0.64 | 0.28 | 0.45 |
| 3.92 | 4.27 | 4.83 | 0.59 | 0.63 | 0.68 |
| 3.33 | 2.27 | 3.17 | 0.52 | 0.36 | 0.50 |
| 3.00 | 2.55 | 4.00 | 0.48 | 0.41 | 0.60 |
| 4.33 | 4.73 | 4.00 | 0.64 | 0.67 | 0.60 |
| 3.25 | 3.09 | 4.50 | 0.51 | 0.49 | 0.65 |
| 4.67 | 3.45 | 4.00 | 0.67 | 0.54 | 0.60 |
| 4.17 | 3.55 | 5.00 | 0.62 | 0.55 | 0.70 |
| 4.08 | 3.00 | 4.17 | 0.61 | 0.48 | 0.62 |
| 4.42 | 3.18 | 4.83 | 0.65 | 0.50 | 0.68 |
| 3.17 | 3.36 | 3.83 | 0.50 | 0.53 | 0.58 |
| 4.17 | 4.18 | 4.83 | 0.62 | 0.62 | 0.68 |
| 4.58 | 3.36 | 4.17 | 0.66 | 0.53 | 0.62 |
| 5.00 | 5.00 | 5.00 | 0.70 | 0.70 | 0.70 |
| 2.67 | 1.36 | 3.67 | 0.43 | 0.13 | 0.56 |
| 3.50 | 1.82 | 3.50 | 0.54 | 0.26 | 0.54 |
| 4.33 | 4.18 | 4.50 | 0.64 | 0.62 | 0.65 |
| 3.58 | 3.73 | 4.50 | 0.55 | 0.57 | 0.65 |
| 3.67 | 4.27 | 4.67 | 0.56 | 0.63 | 0.67 |
| 3.25 | 3.73 | 4.50 | 0.51 | 0.57 | 0.65 |
| 3.33 | 3.55 | 4.33 | 0.52 | 0.55 | 0.64 |
| 3.25 | 3.36 | 4.17 | 0.51 | 0.53 | 0.62 |
| 3.58 | 3.91 | 4.67 | 0.55 | 0.59 | 0.67 |
| 4.08 | 4.00 | 4.17 | 0.61 | 0.60 | 0.62 |
| 3.67 | 3.45 | 4.17 | 0.56 | 0.54 | 0.62 |
| 3.75 | 3.64 | 4.50 | 0.57 | 0.56 | 0.65 |
| 3.33 | 3.55 | 4.33 | 0.52 | 0.55 | 0.64 |
| 3.92 | 4.09 | 4.17 | 0.59 | 0.61 | 0.62 |
| 3.67 | 4.00 | 4.33 | 0.56 | 0.60 | 0.64 |
| 3.67 | 3.73 | 4.17 | 0.56 | 0.57 | 0.62 |
| 3.75 | 3.91 | 4.50 | 0.57 | 0.59 | 0.65 |
| 3.67 | 4.18 | 4.67 | 0.56 | 0.62 | 0.67 |
| 4.00 | 3.91 | 4.00 | 0.60 | 0.59 | 0.60 |
| 4.25 | 4.64 | 5.00 | 0.63 | 0.67 | 0.70 |
| 3.17 | 3.09 | 3.83 | 0.50 | 0.49 | 0.58 |
| 3.92 | 4.00 | 4.17 | 0.59 | 0.60 | 0.62 |
| 4.25 | 3.91 | 4.33 | 0.63 | 0.59 | 0.64 |
| 4.00 | 4.27 | 4.83 | 0.60 | 0.63 | 0.68 |
| 4.08 | 3.91 | 4.50 | 0.61 | 0.59 | 0.65 |
| 3.50 | 3.55 | 4.00 | 0.54 | 0.55 | 0.60 |
| 3.83 | 4.09 | 4.17 | 0.58 | 0.61 | 0.62 |
| 4.08 | 4.00 | 4.33 | 0.61 | 0.60 | 0.64 |
| 4.08 | 3.82 | 4.00 | 0.61 | 0.58 | 0.60 |
| 3.83 | 3.73 | 4.50 | 0.58 | 0.57 | 0.65 |
| 5.00 | 5.00 | 5.00 | 0.70 | 0.70 | 0.70 |

**Table 5** Normality test

| Shapiro–Wilk | | | |
|---|---|---|---|
| Variables, | Statistic, | df, | Sig |
| lopLP | 0.987 | 50 | 0.847 |
| lopT | 0.821 | 50 | <0.001 |
| lopP | 0.897 | 50 | <0.001 |

ables TransT and TransP are not normally distributed. The expected normal versus observed value graph was plotted for all the variables to check how close the various points lie on the normal line.

From the graphs of Fig. 2, it is visible that for variable TransLP, the normal passes through most of the points on the graph, showing that it is normally distributed, whereas for variables TransT and TransP, the normal misses some of the points along its way. Before interpreting these results, we need to cross-check if the results obtained are correct or not. To do so we rerun the normality test again, but this time instead of using the mean of variables, we use log of the variables calculated above in Table 4. Now again, we run the Shapiro–Wilk test for normality; the results obtained from the test are shown in Table 5.

After running the test, we find out that the p-value for variable lopLP is greater than 0.05 and the p-values for variables lopT and lopP is less than 0.05. This suggests that variable lopLP is normally distributed and variables lopT and lopP are not normally distributed. The graph of expected normal vs observed value was plotted to check how close the points lie to the normal line the more the points lie close to normal line the variable is expected to be normally distributed.

From the graphs of Fig. 3 again, we find out that the normal for variable lopLP passes through most of the points and the normal for variable lopT and lopP misses some of the points on the graph; this again validates that the Lean management constructs from our data set are not normally distributed whereas industry 4.0 and organizational performance constructs in our data set are normally distributed. Now in this scenario, when one variable in the data set is normally distributed, and other variables are not normally distributed, we proceed to use non-parametric statistics, which involve ordinal regression analysis and spearman's rank correlation. This

**Table 6** Information about the model

| Model-Fit-test | | | | |
|---|---|---|---|---|
| Model | Chi-Square | -2 Log Likelihood | df | Sig |
| Intercept Only | | 218.805 | | |
| Final | 35.266 | 183.540 | 2 | <0.01 |

method will be used to find a correlation among the variables in the data set. The ordinal regression analysis is conducted; this involves conducting test such as Model fit test, Goodness of fit test, Test of Parallel Lines and Pseudo R-Square. Table 6. shows the information regarding the fit of the model.

We can see from the Table 6 that the computed p-value is much less than 0.05, indicating that the model is correctly specified. The analytically important Chi-Square points that Final model provides an improvement over the baseline intercept model. The results obtained from the following test are shown in Table 7.

From the Table 7, we see that the Pearson and Deviance values from the test results are well above 0.05, which means the data is not statistically significant. Non-significant test values point that model is fitting the data very well. The next information obtained was Pseudo R square. Nagelkerke Pseudo R square (Refer Table 8) value is considered for data analysis.

The value of Pseudo R-Square obtained was 0.512, which suggests that 51.2% of changes in organizational performance are obtained because of Lean practices and industry 4.0 techniques. The next test is conducted, and the results obtained are shown in Table 9.

This test denotes that the odds for each explanatory variable are constant or are the same across different threshold of the outcome variable. From the Table 9 we can see that p-value generated is more than 0.05 which means that test is not violated. After conducting the Test of Parallel Lines, we proceed to conduct Parameter Estimates test. The parameter estimates test is an important test as the output of it tells us about the relationship between our variables. Parameter estimate test is run in SPSS, this test is performed under ordinal regression analysis. The parameter estimates table give us information such as Estimate, Std-Error, Wald, df and p-value. The p-value if found to be more than 0.05 it indicates that variable is not statistically significant. The parameter estimate table gives us a brief outline of the effect each variable has on the other. The parameter coefficient can have either positive or negative sign. The estimate denotes the kind of relationship the variables have with each other. The Table 10 displays the parameter estimates for the variables.

From the Table 10 the parameter estimates for the variable TransLP and TransT are both found to be positive. The estimate for variable TransLP is 0.146 and the estimate for

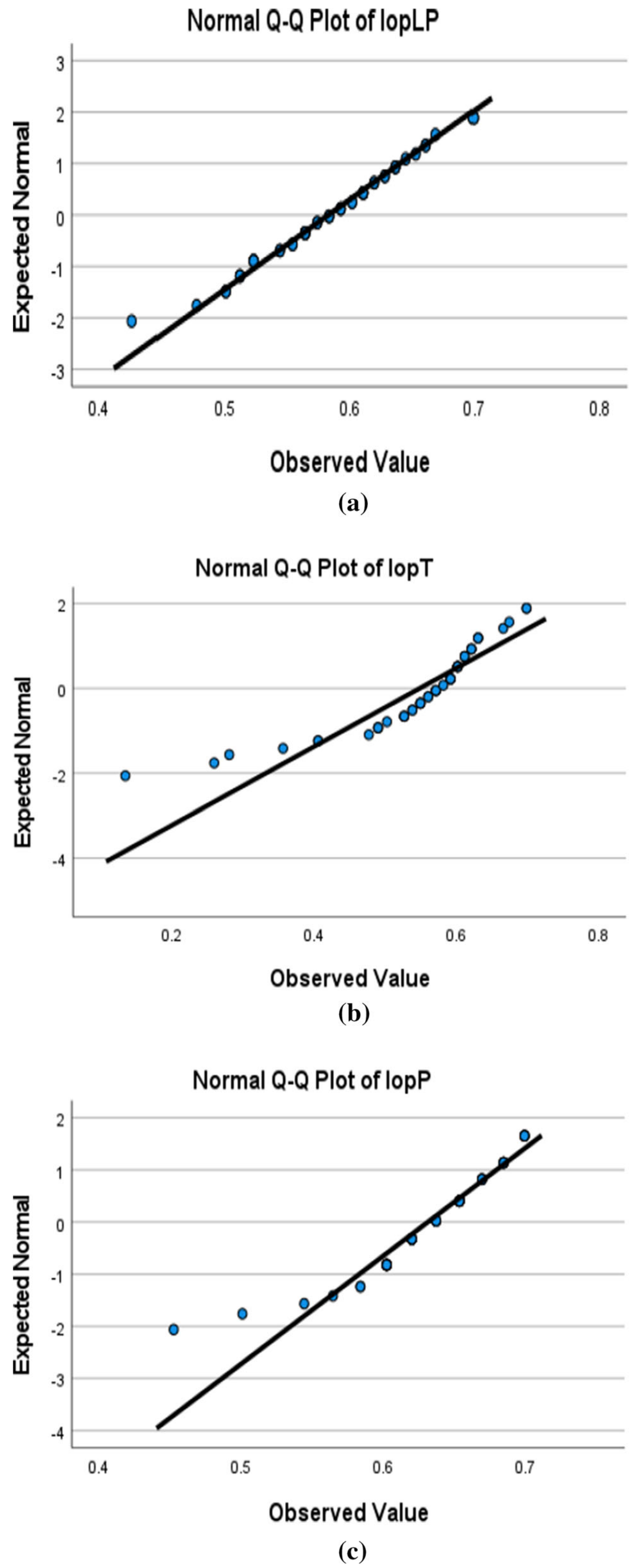


**Fig. 3** Expected normal vs observed values graphs for variables **a** lopLP **b** lopT and **c** lopP

variable TransT is 2.661. This provides significant information regarding the relationship between or dependent or

**Table 7** Goodness-of-Fit test

| Goodness-of-Fit test | | | |
|---|---|---|---|
| | Chi-Square | df | Sig |
| Pearson | 403.181 | 504 | 1.000 |
| Deviance | 182.153 | 504 | 1.000 |

**Table 8** R-Square

| Pseudo R-Square | |
|---|---|
| Cox and Snell | .506 |
| Nagelkerke | .512 |
| McFadden | .160 |

**Table 9** Test of Parallel lines

| Test-of Parallel Lines | | | | |
|---|---|---|---|---|
| Model | -2 Log Likelihood | Chi-Square | df | Sig |
| Null Hypothesis | 183.540 | | | |
| General | 180.218[b] | 3.321[c] | 20 | 1.000 |

independent variables. It is significant to highlight that in this test the threshold coefficients are not interpreted individually. After conducting ordinal regression analysis, we proceed towards performing Spearman's rank-correlation. It is a non-parametric adaptation of Pearson's correlation and is utilized during ordinal regression analysis. Correlation is an important analysis conducted to establish a relationship between two or more variables. In this study our aim is to find whether a relationship exists either positive or negative amongst Lean management, industry 4.0 technologies and organizational performance. It is used to show the direction and strength each variable has on each other. The correlation coefficient can take values ranging from −1 to + 1. The Table 11 shows the result obtained after performing Spearman's correlation.

From the Table 11 we can see that the variable TransLP has a positive 0.420 and 0.309 correlation respectively with variables TransT and TransP. The variable TransT has a positive 0.420 and 0.600 correlation respectively with the variables TransLP and TransP. The variable TransP is found to have a positive 0.309 and 0.600 correlation with the variables TransLP and TransT.

## 5 Results and discussion

After performing data analysis, results obtained from parameter estimates suggests that the parameter value for variable TransLP is 0.146 which means that for every 1-unit change in Lean management there is 0.146 positive change in organizational performance and the parameter value for variable TransT is 2.661 which means that for every 1-unit change in industry 4.0 technologies there is a 2.661 positive change in organizational performance. The value of Pseudo R-square was found to be 0.512 which means that 51.2% changes in organizational performance are obtained because of Lean practices and industry 4.0 techniques. The correlation coefficient for Lean production and industry 4.0 technologies is 0.420 which suggests that they are positively correlated, the correlation coefficient for Lean production and organizational performance is 0.309 which shows that they are positively correlated and the correlation amongst industry 4.0 techniques and organizational effectiveness is 0.600 which proposes a strong positive correlation between the two. The research findings obtained from the literature review are summarized below:

- Lean production requires technological advancements supporting them to keep up with highly personalized customer demands.
- Industry 4.0 not only makes a factory smart but also provides financial benefits by waste reduction.
- Collaborative manufacturing and synchronization of data can help improve supplier feedback.
- Lean and industry 4.0 integration lead to performance benefits in an organization.
- Industry 4.0 presents as an influencer on agile production and serves as a mediating variable lean manufacturing and business performance.
- Industry 4.0 technologies support ideas of sustainability and sustainable development.
- Positive correlation coefficients indicated a synergetic linkage between Lean practices and smart technologies.
- Lean manufacturing when integrated with industry 4.0 has a potential to further increase productivity in an organization.

After conducting the data analysis, we can go ahead with hypothesis testing.

### 5.1 Hypothesis testing

Hypothesis testing is an important tool in statistical analysis which helps us to see if the test results obtained from a survey experiments holds any meaningful results. It provides with valuable information regarding our research, it tells us whether the assumptions we hold before starting our research is true or not. The following hypothesis are tested for plausibility.

**H0** Lean production is unaffected by Industry 4.0 technologies.

**Table 10** Parameter Estimates for variables TransLP, TransT and TransP

| Parameter estimates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Estimate | Std. Error | Wald | df | Sig | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
| Threshold | [TransP = 2.83] | 3.970 | 2.234 | 3.157 | 1 | 0.076 | -0.410 | 8.349 |
| | [TransP = 3.17] | 4.795 | 2.196 | 4.769 | 1 | 0.029 | 0.492 | 9.009 |
| | [TransP = 3.50] | 5.378 | 2.198 | 5.986 | 1 | 0.014 | 1.070 | 9.686 |
| | [TransP = 3.67] | 6.091 | 2.216 | 7.555 | 1 | 0.006 | 1.748 | 10.434 |
| | [TransP = 3.83] | 7.211 | 2.263 | 10.155 | 1 | 0.001 | 2.776 | 11.646 |
| | [TransP = 4.00] | 9.051 | 2.358 | 14.736 | 1 | 0.000 | 4.429 | 13.672 |
| | [TransP = 4.17] | 10.166 | 2.415 | 17.726 | 1 | 0.000 | 5.434 | 14.899 |
| | [TransP = 4.33] | 10.687 | 2.442 | 19.149 | 1 | 0.000 | 5.900 | 15.474 |
| | [TransP = 4.50] | 11.893 | 2.515 | 22.360 | 1 | 0.000 | 6.964 | 16.823 |
| | [TransP = 4.67] | 12.583 | 2.564 | 24.085 | 1 | 0.000 | 7.558 | 17.609 |
| | [TransP = 4.83] | 13.672 | 2.663 | 26.353 | 1 | 0.000 | 8.452 | 18.892 |
| Location | TransLP | .146 | .583 | .063 | 1 | 0.802 | -0.996 | 1.288 |
| | TransT | 2.661 | .532 | 25.059 | 1 | 0.000 | 1.619 | 3.703 |

**Table 11** Correlation

| Spearman's correlation | | | | | |
|---|---|---|---|---|---|
| | | | TransLP | TransT | TransP |
| Spearman's rho | TransLP | Correlation Coefficient | 1.000 | 0.420** | 0.309* |
| | | Sig. (2-tailed) | - | 0.002 | 0.029 |
| | | N | 50 | 50 | 50 |
| | TransT | Correlation Coefficient | 0.420** | 1.000 | 0.600** |
| | | Sig. (2-tailed) | 0.002 | - | <0.01 |
| | | N | 50 | 50 | 50 |
| | TransP | Correlation Coefficient | 0.309* | 0.600** | 1.000 |
| | | Sig. (2-tailed) | 0.029 | <0.000 | - |
| | | N | 50 | 50 | 50 |

To test the null hypothesis one way ANOVA test and one Sample T test are conducted. The results obtained from the test are shown below.

From the above conducted test (Refer Tables 12 and 13), we can see that the p-value generated for both ANOVA and One Sample T test is fewer than 0.05 which suggests that we must dismiss the null hypothesis which states that industry 4.0 technologies have no effect on Lean manufacturing. The literature review supports the statistical analysis.

**Table 12** Anova Test

| Anova Test | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | Sig |
| Between Groups | 7.595 | 21 | 0.362 | 2.068 | 0.37 |
| Within Groups | 4.897 | 28 | 0.175 | | |
| Total | 12.492 | 49 | | | |

**H1** Industry 4.0 technologies have a positive effect on Lean manufacturing.

From the above performed data analysis we discovered that the Spearman's correlation across industry 4.0 and Lean manufacturing is 0.420, indicating a positive relationship between the two, hence we must accept the hypothesis which states that Lean manufacturing is positively impacted by industry 4.0 technologies. The literature review analysis also gives the same indication that there is a positive effect between Lean manufacturing and industry 4.0 technologies.

**H2** Industry 4.0 technologies have a negative effect on Lean manufacturing.

Again, the correlation between industrial revolution 4.0 and Lean management was found to be positive in the data

**Table 13** One Sample T test

| | One Sample T test | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference Lower | 95% Confidence Interval of the Difference Upper |
| TransLP | 54.057 | 49 | <.0001 | 3.86000 | 3.7165 | 4.0035 |
| TransT | 34.472 | 49 | <.0001 | 3.63091 | 3.4192 | 3.8426 |

analysis performed before, thus we must reject the hypothesis that Lean manufacturing is negatively impacted by industry 4.0 technologies.

**H3** Organizational performance is positively impacted by the integration of industry 4.0 technologies and Lean manufacturing.

The results from the data analysis show that Spearman's correlation across industry 4.0 techniques and organizational effectiveness is 0.600 and the correlation between Lean manufacturing and organizational performance is 0.309 which means that we must accept the hypothesis which states that integrated effect of Lean manufacturing and industry 4.0 tools strongly impacts organizational effectiveness. From literature review we find out that both industry 4.0 and Lean manufacturing positively impacts organizational performance.

## 6 Limitations

About integration of industry 4.0 techniques and Lean concept, many studies done are theoretical, more effort is required to work on more empirical studies to establish a correlation between industry 4.0, Lean production and organizational performance. One of the study's drawbacks is that industry 4.0 is a relatively new idea, thus some of the participants' claims may not be entirely found on real life experience. Likewise, Lean is also a concept that is very difficult to implement in an organization, majority of the companies that do not fully understand the architecture of the Lean fail to implement it. Another drawback of the study is low number of sample size that may lead to higher variability and may result in non-response bias. Another limitation is that the analysis conducted displays the cause-effect link amongst industry 4.0 technologies, Lean production, and organizational effectiveness. Nevertheless, these links fail to serve as excellent organizational decision for the professionals using these relationships to support their decision-making process. And lastly the respondents in the present study were from various types of industries and thus implementation of industry 4.0 technologies and Lean production may vary among specific industries, therefore future studies are required to carry on specific industries to build a more established link connecting industry 4.0, Lean production and organizational performance for that specific industry.

## 7 Conclusion

The study aimed to find the effect of industry 4.0 technologies have on Lean production and organizational productivity. A survey using questionnaires was undertaken and results of it were analyzed using appropriate statistical tools. Findings from the survey analysis points out that industry 4.0 technologies do indeed have a positive effect on both Lean production and organizational performance. Results also indicate that higher implementation of industry 4.0 technologies lead to higher organizational performance. The study also upholds the widely accepted presumptions that industry 4.0 is going to change the entire traditional manufacturing landscape which helps to overcome the shortcomings of traditional manufacturing methods and deliver more efficiency, productivity, customizations and create more cost saving designs for manufacturers. All the indication above proposes that Lean production and industry 4.0 technologies cannot only exist among each other but also support and enhance each other. Although industry 4.0 can overcome many challenges faced in the traditional manufacturing landscape, the process of adoption of industry 4.0 in an enterprise needs to face some key challenges that the organization must overcome if they wish to implement industry 4.0. Future research is necessary to develop a strategy or framework for easy adoption of industry 4.0 technologies in an enterprise.

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