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Industry 4.0 and Lean Manufacturing Practices: An Approach to Enhance Operational Performance in Singapore's Manufacturing Sector

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Abstract: Lean Manufacturing Practices (LMP) is a technique to reduce waste and enhance operational performance. On the other hand, the adoption of Industry Relation (IR 4.0) is known as a strategy to provide a greater capability for lean manufacturing practices to enhance the efficiency of the manufacturing line performance and satisfy consumer requirements. The main objective is to examine the integration of lean and IR 4.0 to enhance operational performance. This study was conducted using the survey method. Through this research, a total sample size of 51 validated companies' respondents participated in this research. Multiple regression was the main analysis in this research. The finding of this research showed that the operational performance was in a high and moderate level and there was a positive relationship between the Top Management Leadership (r = 0.540), Employees Training (r = 0.582), Customer Involvement (r = 0.528), Continuous Improvement (r = 0.783), Supplier Partnership (r = 0.542), and Small Group Problem Solving (r = 0.530) as well as Industry Relation 4.0 (r = 0.391). This study also proved that the Lean Manufacturing Practice (LMP) and Industry Relation (IR 4.0) had a significant impact on the operational performance of R-square = 0.644. This research can beneficially contribute to future research in understanding the significance of the IR 4.0 and LMP approaches to improve the manufacturing industry's operational performances.

Keywords: Lean manufacturing practice, Industry relation 4.0, Operational performance

1. Introduction

In a competitive environment, companies have been encouraged to implement lean manufacturing practices in order to compete with their competitors. Lean Manufacturing Practices (LMP) is defined

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as utilizing the decrease in the process work lead-time within the inventory and production stream processes (Dey *et al*., 2020). The competition between organizations has become more increasingly challenging, resulting in the need to improve productivity, efficiency and eliminate waste in production (Cornelissen, 2013). Therefore, lean manufacturing plays a crucial role in the manufacturing industry to enable organizations to remain competitive. (Nassereddine & Wehbe, 2018). Although many organizations have been implementing lean manufacturing practices, many fails to achieve the lean goal. This is because the implementation of LMP is demanding and challenging (Abu *et al*., 2019). This study is significant because operational performance is vital in enhancing the manufacturing industries.

1.1 Research Background

Based on the annual economic survey conducted by the Ministry of Trade and Industry, the manufacturing industry contributes 19.2% growth of GDP in Singapore (Economic Survey of Singapore, 2017). Therefore, globalization and growing competition have made the manufacturing industry more competitive and efficient in delivering its products to compete with the global markets (Nagy *et al*., 2018). Figure 1 illustrates that the manufacturing industry is the highest contributor to Singapore's economic growth (EDB, 2018).

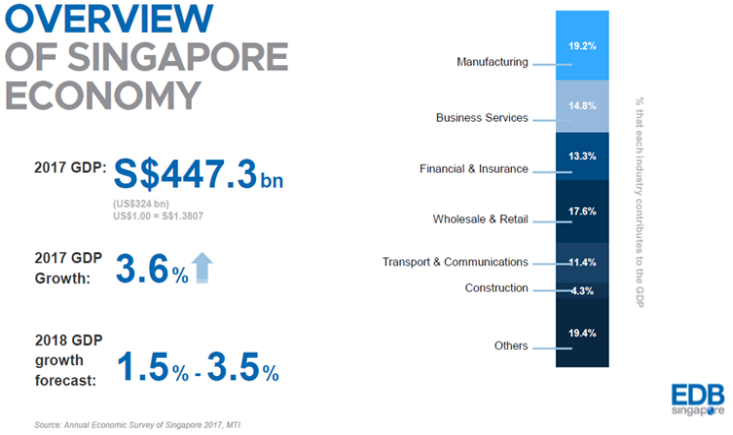

Figure 1: Annual economic survey of Singapore 2018, MTI

The manufacturing industry is as is crucial because it significantly contributes employability to Singaporean citizens. Based on Figure 2, the latest Economic Survey of Singapore 2018 annual report shows that the total number of employability for local Singapore citizens increases yearly from 2016 to 2018. Indirectly, it shows this industry is fundamentally the backbone of Singapore's economic growth.

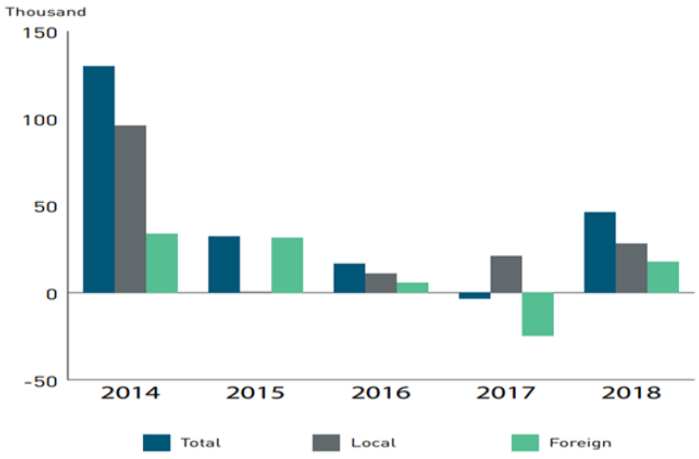

Figure 2: Changes in employment in Singapore by residential status

Lean manufacturing Practices (LMP) is able to achieve waste reduction and become an effective tool to enhance manufacturing and shipping process performances by increasing operational performance and eliminating all wastes from Singapore's manufacturing industry. However, LMP is structured to minimize the period between the customers' orders and the production and delivery of the product to the customer. The aim of eliminating waste is to become extra efficient (Marie & Fritz, 2019).

The implementation of Industry 4.0's (IR 4.0) benefits contribute positively to Singapore's manufacturing industry because it will accelerate the manufacturing industry's creativity speed, and it is very consumer-driven, contributing to a quicker development process. Whereas IR 4.0 allows all of the equipment, manufacturing components, and products to become digitalized by implementing sensing devices within the manufacturing industry (Ghobakhloo, 2020).

1.2 Problem Statements

According to Seow (2019), Singapore's manufacturing industry issue continues to deal with remarkable challenges against growth in the economy due to the slowdown in worldwide economic growth. With the assistance of IR 4.0 with the intention to simplify the operating machines for the workers is considerably easier. The Singapore manufacturing industry had already conducted an assessment on the manufacturing industry to examine whether they are ready to implement IR 4.0 or otherwise. The report conducted by World Economic Forum (2018) highlighted the Readiness Index framework results as shown in the Readiness overall assessment score based on Figure 3. Therefore, it suggests that the Singaporean manufacturing industry has embarked on IR 4.0. The motivation of this study is to fulfill that gap.

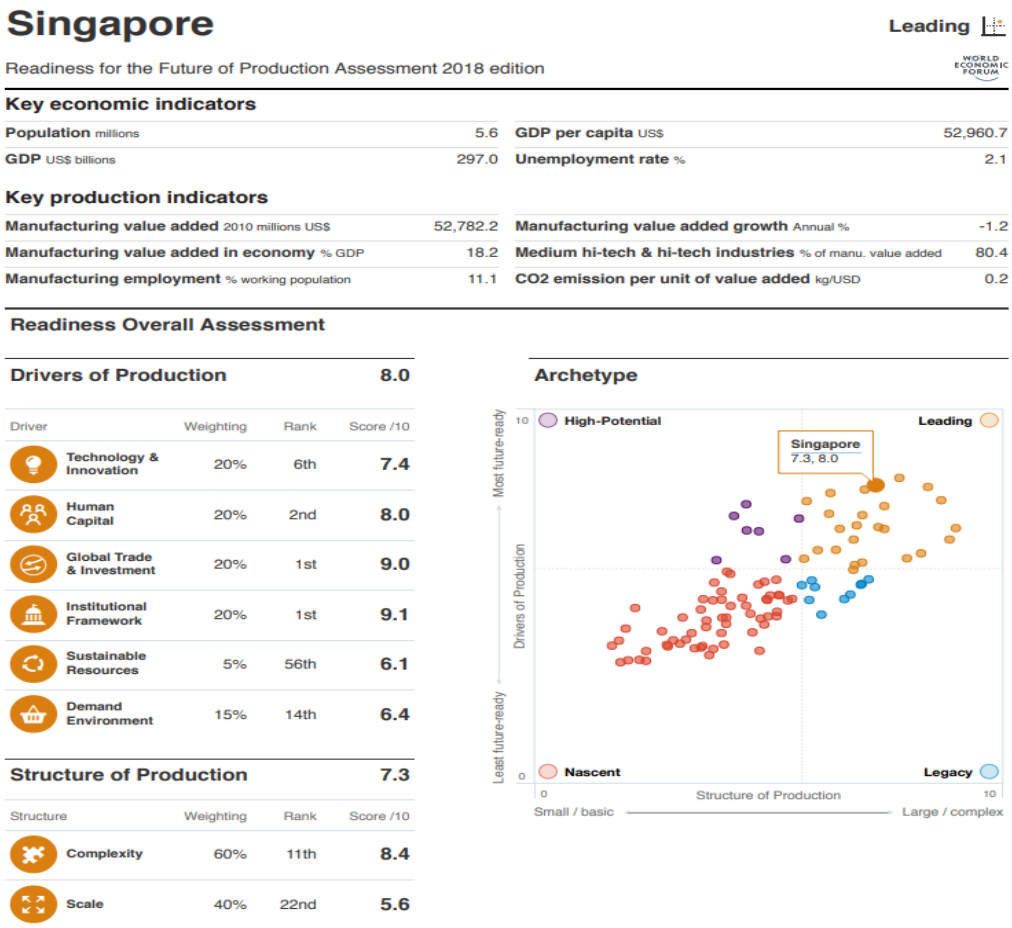

Figure 3: Singapore readiness index for future of production assessment, 2018

Based on Table 1, the literature matrix shows the lack of studies concerning the manufacturing industry in Singapore. Previous research has highlighted that the manufacturing industry should implement both LMP and IR 4.0 to improve the manufacturing industry's operational performance (Kamble *et al*., 2019). Based on the current literature review, a number of researchers recommended integrating LMP and IR 4.0 to be implemented in the manufacturing industry (Bortolotti *et al*., 2015; Tortorella *et al*., 2019; Vita, 2018). Hence, the previous researcher has shown that both LMP and IR 4.0 had been carried out in developed countries and significantly studied, providing a much better knowledge on the topics (Rossini *et al*., 2019). Most of the previous studies were conducted in Portugal (Pereira *et al*., 2019) and Brazil (Tortorella *et al*., 2019), but a lack of studies conducted about Singapore's manufacturing industry was noticeable. In particular, there appears to be a lack of studies that empirically investigate the relation between LMP, IR 4.0, and operational performance. Thus, this study is conducted to fill in the gap. A study aims to develop a framework on the approach of LMP and IR 4.0 to enhance the operational performance of Singapore's manufacturing industry.

Table 1: Summary of literature matrix interaction between Lean Manufacturing practice and Industry Relation 4.0

Article title	Country	Ref.
Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement.	Brazil	Tortorella *et al*. (2019)
The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance.	Thailand	Khanchanapong *et al*. (2014)
Industry 4.0 and Lean Manufacturing: A systematic literature review and future research directions.	Brazil	Pagliosa *et al*. (2019)
The effect of environmental complexity and environmental dynamism on Lean practices.	USA	Azadegan *et al*. (2013)
Interdependencies of Industry 4.0 & Lean production systems: a use cases analysis.	Germany	Dombrowski *et al*. (2017)
The link between industry 4.0 and lean manufacturing: Mapping current research and establishing a research agenda.	Hong Kong	Buer *et al*. (2018)
Smart factory performance and Industry 4.0.	Italy	Büchi *et al*. (2020)
Lean Manufacturing and Industry 4.0: A Holistic Integration Perspective in the Industrial Context.	Brazil	Spó *et al*. (2020)
Lean management and innovation performance: Evidence from international manufacturing companies.	Japan	Abdallah *et al*. (2019)
Organizational and managerial challenges in the path toward Industry 4.0.	Italy	Agostini & Filippini (2019)
Integration of Industry 4.0 and Lean Manufacturing and the Impact on Organizational Performance.	Portugal	Vita (2018)
Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian.	India	Kamble *et al*. (2019)
Successful lean implementation: the systematic and simultaneous consideration of soft and hard lean.	Morocco	Larteb *et al*. (2015)
Successful lean implementation: Organizational culture and soft lean practices.	United Kingdom	Bortolotti *et al*. (2015)
The role and impact of industry 4.0 and the internet of things on the business strategy of the value chain-the case of Hungary.	Hungary	Nagy *et al*. (2018)
Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing.	Germany	Sanders *et al*. (2016)
Towards Lean Production in Industry 4.0	Poland	Mrugalska & Wyrwicka (2017)

1.3 Research Questions

(i) What is the extent of Lean Manufacturing Practices in Singapore's manufacturing sector?
(ii) Does Lean Manufacturing Practice and Industry 4.0 contribute to operational performance?

1.4 Research Objectives

(i) To analyses the extent of Lean Manufacturing Practices in Singapore's manufacturing sector.
(ii) To investigate the impact of Lean Manufacturing Practices and Industry 4.0 on operational performance.

1.5 Scope of the Study

This study was conducted in Singapore. It focused on the manufacturing industry since this industry contributed to the main economic growth of Singapore. Therefore, this research only includes large and medium manufacturing industries in Singapore using the quantitative approach as the data collection method. Thus, the collection of the sample data would focus on the top or middle management levels, and the questionnaire used emphasized the approach of IR 4.0 and LMP to enhance operational performance.

1.6 Significance of the Study

The significance of the findings from this study indicates a clear approach that exists among the IR 4.0 and LMP to enhance operational performance. Hence, this study's primary purpose is to discover both approaches and indicate how LMP can benefit from IR 4.0. Moreover, the most significant aspect of this study reveals how the approach of IR 4.0 and Lean Manufacturing practices can improve operational performances within the manufacturing industry.

2. Literature Review

2.1 Lean Manufacturing Practices and Industry Relation 4.0

The literature review has established that a number of researchers have sought to determine whether implementing modern automation technology in production offers a massive capability that gives credit to the implementation of lean manufacturing practices (LMP) (Kolberg & Zühlke, 2015). According to Dinev and Hart (2006), Industry 4.0 and Lean manufacturing have shown that IR 4.0 and LMP do not suggest ideas about developing a capable LMP that can be properly synergized within the company. It has previously been discovered that the obstacles that arise through LMP may be overcome by adopting IR 4.0 to assist manufacturing companies (Sanders *et al*., 2016). Recent work by the researcher has established that it is expected that enhancing high-quality growing productivity, reducing expenses, and growth flexibility can be achieved slowly in the future when IR 4.0 and LMP are integrated (Buer *et al*., 2018). Numerous studies suggested that the implementation of LMP can be recognized as the primary step because an accurate value flow determines that IR 4.0 plays a vital position (Chen & Chen, 2014; Meudt *et al*., 2017).

2.2 Employee Training

Employee training refers to excellent technique and equipment provided through the necessary training and activities for the workers to enhance operational performance (Alhuraish *et al*., 2014). Talib *et al*. (2013) reported that maintaining high quality within the manufacturing and provider company can be established through training and education. Previous research has shown that employee training has a significant effect on OP (Shafiq, 2018). According to Challis *et al*. (2005),

employee training involves gaining knowledge. As a result, gaining knowledge allows a company to promote persistent organizational renewal by embedding a set of center approaches that nurture a positive inclination to analyze, adapt, and exchange its operational performances (Nangami, 2014; Hernandez-Matias *et al*., 2019).

2.3 Continuous Improvement

Continuous improvement refers to producing beneficial products through primary inputs obtained by continuously developing new products and enhancing existing procedures (Mamat *et al*., 2015). Costa *et al*. (2019) found that continuous improvement supports can be achieved by implementing lean manufacturing practices. This will enhance the operational performance of the company. It has previously been observed that operational performance may be improved through continuous improvement to reduce the manufacturing process variability (Fok-Yew, 2018). The implementation of continuous improvement is expected to provide a positive link with the operational performance.

2.4 Top Management Leadership

Top management leadership is defined as the leadership of senior executives and personal involvement in constructing and preserving a management system, and setting strategic guidelines are instrumental in facilitating excessive organizational learning, organizational performance, and individual improvement (Bortolotti *et al*., 2015). Various studies had established that top management leadership plays a vital position in lean manufacturing practice in order to enhance operational performance by implementing LMP (Ahmad *et al*., 2012; Jong & Hartog, 2007; Lewis *et al*., 2006; Dey *et al*., 2020). As a result, the OP has become a philosophy of the workplace where top management leadership is positively associated with the ongoing improvement of company operational performance (Rahman *et al*., 2018). According to Rahman *et al*. (2019), operational performance excellence is significantly supported by top management leadership (Jeenanunta *et al*., 2018).

2.5 Supplier Partnership

Supplier partnership is defined as a long-term partnership between the company and its providers with the aim of achieving expanded efficiency and productiveness, joint planning, performance, and problem-solving (Arawati, 2011). Vanichchinchai (2019) stated that lean manufacturing practice is important for supplier partnership collaboration to enhance a company's operational performance. As a result, the company's competitiveness and operational performance improvement can be enhanced through growing and strengthening supplier long-term relationships (Shin *et al*., 2019).

2.6 Small Group Problem Solving

Small group problem solving refers to how small group problem solving achieves excellent and operational improvement through contributing group ideas, group opinion through sharing with each other, through group discussions and working as a team to solve the problems that the company faces in order to enhance company performance (Fotopoulos & Psomas, 2009). Recent evidence suggests that lean manufacturing practice is achieved by practicing group problem solving and teamwork (Gollan *et al*., 2014). As a result, operational performance can be enhanced by increasing and involving workers' commitment to the organization (Alharthi *et al*., 2019). It has been reported that small group problem-solving leads to a very responsive and flexible approach to improve company operational performance (Zu'bi, 2015; Hernandez-Matias *et al*., 2019).

2.7 Customer Involvement

Customer involvement is defined as an organization, in an effort to achieve excellent operational performance (Anning-Dorson, 2018). Pesämaa (2011) suggested that the effect of customer involvement could be a positive or negative relation toward operational performance. According to

Al-kalouti *et al*. (2020), the innovation of the products and the speed of the process can be affected by customer involvement. However, customer involvement could additionally enhance the effectiveness of the improvement process to the company's operational performance (Rajapathirana & Hui, 2018). Previous research has found the implementation of lean manufacturing practices indicates that it is the best practice to gain information about the customer and to enhance the operational performance of the company (Wickramasinghe & Wickramasinghe, 2017).

2.8 Industry Relation 4.0 (IR 4.0)

Industrial Relation 4.0 is also known as IR 4.0, and it is defined as successful techniques, manufacturing procedures, and information technology integration which refer to the digitalization manufacturing industry (Lele & Innovation, 2019). Previous research has shown that the IR 4.0 technique integration enhances operational performance, which includes Internet of Things, advanced manufacturing, robotic systems, artificial intelligence, big data analytics, and cloud computing (Kamble *et al*., 2019; Liao *et al*., 2017). Previous research has shown that IR 4.0 might not have a significant positive impact on the manufacturing bottom floor management, but IR 4.0 can organize, manage and enhance the OP of the company (Agostini & Nosella, 2019). According to Kamble *et al*. (2018), the implementation of IR 4.0 technology may significantly influence the manufacturing performance, and other IR 4.0 technology also could accomplish a colossal enhancement in product improvement and service innovation (Tortorella *et al*., 2019).

2.9 Operational Performance

According to Nawanir (2016), operational performance (OP) is defined as the wealth development of the organization's financial performance, which can primarily indicate an increase in reliability, minimized operations cost, minimized manufacturing cycle time, and increase inventory turnover and, reduce material cost. According to Buer *et al*. (2018), operational performance will benefit from integrating IR 4.0 with LMP. In contrast, the dimension of performance is affected by IR 4.0 and LMP integration. The integration involves cost, quality, inventory, flexibility, reliability, and productivity. Studies conducted by Ilangakoon *et al*. (2019) on the operational performance benefits derived from IR 4.0, found improved high-quality service increases productivity, reduces transportation length, and minimizes cost. The results from previous studies demonstrate a strong and consistent association in the integration between IR 4.0 and LMP, which indicates a positive and strong relationship in improving the OP of the company (Vita, 2018).

2.10 Research Framework

This research focused on the hypothetical model (Figure 4) of the IR 4.0, and Lean Manufacturing practices approach to enhance operational performances.

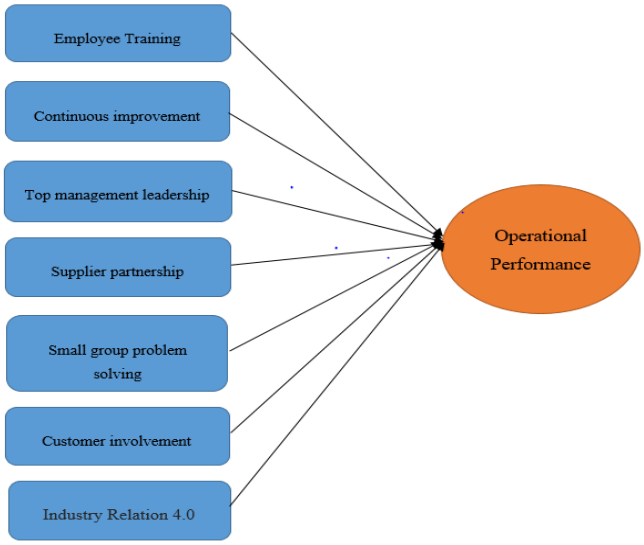

Figure 4: Conceptual research framework of the study

2.11 Hypotheses Development

The focus of this research is on the established conceptual model. The following hypotheses were developed to achieve the research objectives:

H1: Employee training has a positive relationship with operational performance.

H2: Continuous improvement has a positive relationship with operational performance.

H3: Top management leadership has a positive relationship with operational performance.

H4: Supplier partnership has a positive relationship with operational performance.

H5: Small group problem solving has a positive relationship with operational performance.

H6: Customer involvement has a positive relationship with operational performance.

H7: Industry Relation 4.0 has a positive relationship with operational performance.

3. Research Methodology

3.1 Research Design

Research design is the method of constructing a framework used by a researcher to combine many information and data so that the research objective and question can be efficiently handled. It summarises the data collection procedures by conducting a study and establishing the blueprint for analyzing the data. The researcher used a quantitative approach to fulfill the research objectives. Besides collecting the data, the quantitative data are analyzed using SPSS software to identify the connection between the dependent and independent variables.

3.2 Questionnaire Design

The process of the researcher collecting the data is called data collection. It can be gathered from various sources. The data that has been collected can be converted into information. A questionnaire is the main tool used in this research, and it was modified from a previous study. Table 2 shows the questionnaire instrument, which consists of four sections.

Table 2: The description of questionnaire format

Section	Description
Section 1: General Information	• The first section consists of general information about the respondent and the company. • The general information includes gender, position in the company, education background, working experience, and the number of employees.
Section 2: Lean Manufacturing Practices (i) Top Management Leadership (ii) Employee Training (iii) Customer Involvement (iv) Continuous Improvement (v) Supplier Partnership (vi) Small Group Problem Solving	• This section 2, 3 and 4, consists of 8 main constructs, which form the main part of the questionnaire. • The first part, six constructs are Lean Manufacturing practices (LMP). • LMP such as top management leadership, employee training, customer involvement, continuous improvement, supplier partnership, and small group problem-solving.
Section 3: Industry Relation 4.0 (IR 4.0)	• The second part is Industry Relation 4.0. • IR 4.0, which includes Internet of Things, advanced manufacturing, cloud computing, artificial intelligence, robotic systems, and big data analytics.
Section 4: Operational Performance	• The third part is operational performance. • All constructs were derived from a systematic literature review in Chapter 2 and the preliminary study discussed in Chapter 3. • The purpose is to examine the respondent's perception of LMP and IR 4.0 implementation and investigate the impact of LMP and IR 4.0 towards achieving operational performance.

3.3 Reliability Test

Based on Table 3, the Cronbach Alpha results for all the variables indicate that the reliability test in this research is considered trustworthy and reliable because the range is located between 0.764 – 0.892, which implies that all the items are acceptable.

Table 3: Reliability test analysis for all variables

Variables	Cronbach's Alpha	No of Items
Customer Involvement (CUST)	0.764	7
Top Management Leadership (TML)	0.865	6
Employee Training (ET)	0.854	7
Small Group Problem Solving (SGPS)	0.829	5
Supplier Partnership (SP)	0.892	7
Continuous Improvement (CI)	0.842	7
Industry Relation 4.0 (IR)	0.847	6
Operational Performance (PER)	0.781	6

3.4 Normality Test

Based on the normality test shown in Table 4, the value of the skewness and kurtosis range between -2 to 2 where the data are normally distributed for each variable.

Table 4: Statistical test of normality

	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Customer Involvement	51	-0.504	0.333	-0.716	0.656
Top Management Leadership	51	-1.260	0.333	0.770	0.656
Employees Training	51	-0.458	0.333	-1.261	0.656
Small Group Problem Solving	51	-0.504	0.333	-1.241	0.656
Supplier Partnership	51	-0.087	0.333	-1.542	0.656
Continuous Improvement	51	-0.986	0.333	-0.227	0.656
Industry Relation (IR 4.0)	51	-0.023	0.333	-0.979	0.656
Operational Performance	51	-1.139	0.333	1.797	0.656

4. Results and Discussion

4.1 Descriptive Analysis for Demographic

Table 5 shows the overall summary of the respondents' profiles to provide comprehensive information about the respondents who took part in this survey research.

4.2 Descriptive Statistic Analysis

This research's first objective is to analyze the level of Lean Manufacturing Practices in Singapore's manufacturing sector. Descriptive analysis was conducted using SPSS in order to obtain the data and achieve the objective.

4.3 Descriptive Analysis for the Extent Level of LMP

Table 6 shows the summary descriptive analysis of the mean and standard deviations of each variable. Based on the results, each of the items is classified according to their central tendency level. Hence it can be seen that all the variables have recorded a mean score at a high level; the mean value of each variable is between 4.54 - 4.72. Meanwhile, the standard deviation value is in the range of 0.308 - 0.399. This shows the data points are closely grouping around the mean. The highest value of the mean score is 4.72, and a standard deviation of 0.308 is obtained after continuous improvement, which makes it ranked as the priority. The highest second-ranked is top management leadership with a total mean score of 4.71 and a standard deviation of 0.399, and the thirdly-ranked is employee training with a mean score of 4.65 and a standard deviation of 0.344.

Table 5: Overall summary of respondent profile

Demographic	Frequency (N)	Percent (%)
Gender		
Male	45	88.2
Female	6	11.8
Race		
Malay	2	3.9
Chinese	47	92.2
Indian	2	3.9
Age		
25 - 30 years old	2	3.9
31 - 36 years old	18	35.3
37 - 42 years old	27	52.9
43 - 48 years old	3	5.9
49 - 54 years old	1	2.0
Educational level		
Diploma	10	19.6
Bachelor's degree	40	78.4
Master's degree	1	2.0
Current position in the company		
General Manager	2	3.9
Manager	14	27.5
Team Leader	12	23.5
Senior Engineer	18	35.3
Engineer	3	5.9
Senior Executive	2	3.9
How long have you been working in this company?		
4 – 6 years	15	29.4
7 – 9 years	17	33.3
10 years and more	19	37.3
How long have you been in the current position?		
1 – 5 years	34	66.7
More than 5 years	17	33.3

Demographic	Frequency (N)	Percent (%)
Number of employees		
51 – 100 employees	15	29.4
101 – 200 employees	26	51.0
More than 200 employees	10	19.6

Table 6: Summary descriptive analysis of mean and standard deviation for variables

Variables	N	Mean	Standard Deviation	Level	Ranking
Customer Involvement	51	4.58	0.358	High	5
Top Management Leadership	51	4.71	0.399	High	2
Employees Training	51	4.65	0.344	High	3
Small Group Problem Solving	51	4.62	0.382	High	4
Supplier Partnership	51	4.54	0.394	High	6
Continuous Improvement	51	4.72	0.308	High	1

4.4 Person's Correlation Coefficient

Based on Table 7 the strength of the Person's correlation coefficient indicates the table of absolute value r and its indicator that is used to analyze the results obtained.

Table 7: Pearson's correlation between LMP, IR 4.0 and operational performance

	1	2	3	4	5	6	7	8
1. Customer Involvement	1.000							
2. Top Management Leadership	.646**	1.000						
3. Employees Training	.619**	.620**	1.000					
4. Small Group Problem Solving	.453**	.659**	.522**	1.000				
5. Supplier Partnership	.776**	.640**	.680**	.611**	1.000			
6. Continuous Improvement	.528**	.643**	.674**	.556**	.560**	1.000		
7. Industry Relation (IR 4.0)	.351*	.340*	.373**	.330*	.539**	.426**	1.000	
8. Operational Performance	.528**	.540**	.582**	.530**	.542**	.783**	.391**	1.000
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

Table 8 summarises the results of the correlation test based on the hypotheses. Based on Table 4.4, Hypotheses H1, H2, H3, H4, H5, H6, and H7 are accepted since the p-value of significance (2-tailed) is less than 0.01. Thus, all the null hypotheses are rejected.

Table 8: Summary of results for hypotheses interpretation

Hypotheses	Variables	Coefficient Value	Interpretation	Inference
H_1	Employees Training (ET) and Operational Performance	0.582	Moderate Positive	Yes (accept H_1)
H_2	Continuous Improvement (CI) and Operational Performance	0.783	Strong Positive	Yes (accept H_2)
H_3	Top Management Leadership (TML) and Operational Performance	0.540	Moderate Positive	Yes (accept H_3)
H_4	Supplier Partnership (SP) and Operational Performance	0.542	Moderate Positive	Yes (accept H_4)
H_5	Small Group Problem Solving (SGPS) and Operational Performance	0.530	Moderate Positive	Yes (accept H_5)
H_6	Customer Involvement (CUST) and	0.528	Moderate	Yes (accept H_6)

H_7	Operational Performance Industry Relation (IR 4.0) and Operational Performance	0.391	Positive Weak Positive	Yes (accept H_7)

4.5 Multiple Regression Analysis

The second objective of this research is to investigate the impact of Lean Manufacturing Practices and Industry 4.0 on operational performance in Singapore's manufacturing industry. Hence, multiple regression analyses were conducted using SPSS in order to obtain the data and achieve the objectives.

4.6 Impact of LMP and IR 4.0 on Operational Performance

Table 9 illustrates the multiple regression analysis between the Lean Manufacturing Practice (LMP) and Industry Relation (IR 4.0) on operational performance. The seven significant factors that can predict operational performance are Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relations (IR 4.0). The R-value in Table 9 is 0.803, which is close to 1, which is considered a good value. The R square is 0.644, which represents 64.4% of the variance for operational performance by Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relation (IR 4.0). The standard error of the analysis is used for identifying the accuracy of the prediction. The smaller the value of the analysis's standard error will indicate that higher prediction will be more accurate. The value for the standard error of the estimate is 0.1930, which represents a good value for this research. Lastly, a better range for Durbin-Watson statistics value is within 1 to 4. The value for Durbin-Watson in this research is 2.312, which means the independence of observations for the research data has been achieved.

Table 9: Multiple regression model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.803[a]	0.644	0.586	0.1930	2.312

a. Predictors: (Constant), Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relation (IR 4.0)
b. Dependent Variable: Operational Performance

Table 10 shows the ANOVA test results for the seven significant factors that predicted operational performance: Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relation (IR 4.0). The data shows that F (7, 43) = 11.114, p-value (Sig.) = 0.000, where P is less than 0.05, and R2=0.644. Therefore, the operational performance has been statistically and significantly predicted by Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relation (IR 4.0), and it is a good fit for the data in this research.

Table 10: ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.897	7	0.414	11.114	0.000[b]
	Residual	1.601	43	0.037		
	Total	4.498	50			

a. Dependent Variable: Operational Performance

b. Predictors: (Constant), Top Management Leadership, Employees Training, Customer Involvement, Continuous Improvement, Supplier Partnership, Small Group Problem Solving, Industry Relation (IR 4.0)

Based on Table 11 the β-value result shows all independent variables namely Top Management Leadership (β = -0.075), Employees Training (β = 0.012), Customer Involvement (β = 0.135), Continuous Improvement (β = 0.645), Supplier Partnership (β = -0.003), Small Group Problem Solving (β = 0.107), and Industry Relation (IR 4.0) (β = 0.025). Hence, Continuous Improvement (β = 0.645, $t(43) = 4.768$, $p < 0.01$) has a significantly effect on operational performance. The β-value of the unstandardized coefficients is 0.645, which implies that the operational performance is predicted to increase by 64.5% when the continuous improvement increases by one unit. In contrast, the standard error is known for identifying the average distance between the values that have been observed fall from the line of regression.

The smaller the value for standard error means that the observation is closer to the fitted line. The standard error is 0.2789, which represents the observed values are closer to the fitted line. The p-value (Sig.) is less than 0.05, which indicates that the continuous improvement has significantly and directly affected the operational performance in Singapore's manufacturing industry. Therefore, a continuous improvement is statistically significant, which accounts for a significant amount of unique variance contribution towards operational performance. This outcome is supported by Costa *et al*. (2019), in which continuous improvement support is obtained by implementing LMP, which in turn will enhance the operational performance of the company. A prior researcher claimed that the implementation of continuous improvement is expected to provide a strong positive and significant effect on OP. It has been observed that continuous improvement is an endless challenge for every company to enhance operational performance to remain competitive. It can improve every aspect of the organization (Chiarini *et al*., 2015).

Table 11: Regression coefficients analysis table

Regression Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	0.700	0.471		1.486	0.144		
	Customer Involvement	0.135	0.132	0.161	1.021	0.313	0.332	3.016
	Top Management Leadership	-0.075	0.113	-0.100	-0.664	0.510	0.369	2.713
	Employees Training	0.012	0.126	0.014	0.094	0.926	0.398	2.511
	Small Group Problem Solving	0.107	0.105	0.137	1.026	0.311	0.467	2.143
	Supplier Partnership	-0.003	0.141	-0.004	-0.019	0.985	0.240	4.161
	Continuous Improvement	0.645	0.135	0.663	4.768	0.000	0.428	2.338
	Industry Relation (IR 4.0)	0.025	0.074	0.037	0.334	0.740	0.662	1.511

a. Dependent Variable: Operational Performance

Besides that, it has previously been observed that operational performance may be enhanced through continuous improvement to reduce the manufacturing process variability (Fok-Yew, 2018). According to van Assen (2018), continuous improvement has a significant impact on operational

performance. This outcome also aligns with a past study by Adelabu *et al*., (2017), which showed that the IT companies that implemented Information Technology (IT)-based manufacturing systems had been supported through LMP, and they achieved greater outcomes in productiveness and avoided spending a huge sum of money. Therefore, growing its return on investment indicates that LMP has a direct and significant effect on the OP of a company. It is important for the successful implementation of LMP to be based on organizational characteristics, which consists of continuous improvement programs, maintenance optimization, advanced precision equipment, advanced technology, high-quality performances, and problem-solving groups. However, the implementation of LMP has significantly affected operational performance (Pagliosa *et al*., 2019; Tortorella *et al*., 2019; Mrugalska & Wyrwicka 2017).

5. Conclusion

In conclusion, the hypotheses and objectives of this research have been answered by the overall findings and results. As a result, two objectives have been achieved, and seven generated hypotheses accepted. According to Pearson's correlation analysis, there is a significant relationship between IR 4.0, LMP, and operational performance in Singapore's manufacturing industry. From the results in the first objective, continuous improvement from LMP is the factor that most influences operation performance. The operational performance of the company will be affected significantly by the implementation of LMP and IR 4.0, based on the results of the regression analysis. Furthermore, the researcher also establishes the limitations of the study and recommends further improvements in the future. This study provides a valuable contribution to understanding IR 4.0 and LMP to improve operational performances within the manufacturing industry.

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