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Effectiveness of Lean Manufacturing Technologies on Improving Business Performance: A Study of Indian Manufacturing Industries

Saumyaranjan Sahoo, Sudhir Yadav

***Abstract*—**Indian manufacturing firms operating in rapidly changing and highly competitive market, over the last few decades, have embraced organization-wide transformation to achieve cultural and operational excellence. In recent years, numerous approaches have been proposed to improve business and manufacturing performance. Lean practices in particular, Total Productive Management (TPM) and Total Quality Management (TQM) have received considerable attention, as they being adopted and adapted for raising the performance standard of Indian manufacturing firms to world class levels. The complementary nature of TPM and TQM is being practiced in many companies to achieve synergy. Specifically, this research investigates whether joint TPM-TQM implementation contribute to higher business performance when compared to individual implementation. Data from 160 manufacturing firms were analyzed that demonstrate synergetic implementation of both TPM-TQM practices over a reasonable period of time, contributed in delivering better business performance as compared to individual implementation strategy.

***Keywords*—**Total productive management, total quality management, Indian manufacturing firms, business performance.

I. Introduction

FOR the past three decades, competition among manufacturing firms is getting tougher, and hence, manufacturing firms across the globe are under persistent pressure to reduce costs as well as maintaining high level of quality, while at the same time meeting customer's expectation. Global competition has reached every part of the world and every area of business. As the market environment is characterized by an increase of technological advancement and rapid economic changes, many manufacturing firms have embraced the strategic importance of lean manufacturing practices to improve and optimize their manufacturing productivity to stay competitive [26]. These firms have worked to improve quality, production efficiency, flexibility and delivery using the principles of lean management [16].

Two major implementation programs adopted by such firms for enhancing manufacturing productivity are TPM and TQM [37]. TPM is a maintenance manufacturing program that focuses on improving the overall equipment effectiveness by eliminating the waste, through effective participation of workforce [31]. TQM is a manufacturing program aimed at managing the entire organization in a way that excels on all dimensions of product and services that are important to the customers [7]. Both TPM and TQM aim at organization wide elimination of waste through continuous improvement and employee participation to maximize production effectiveness [9]. By integrating TPM and TQM implementation programs, a comprehensive and consistent set of manufacturing practices can be derived to further improve a firm's performance as compared to standalone implementation [26].

The findings of several studies [5], [14], [15], [19], [22], [27], [30], have indicated that either TPM or TQM standalone implementation programs have not only enhanced operational performance, but also improved their financial performance. Also, these studies have highlighted the need of future studies for a structured comparative analysis of standalone and combined approach of manufacturing practices to differentiate between high and low performing plants. Also, several studies [23], [26], [37] have indicated the impact of an integrated approach in enhancing the overall business performance. However, most of the research studies on lean manufacturing technologies investigate these programs separately. Very few research studies have been done to comparatively evaluate the effectiveness of a standalone and a joint implementation of lean manufacturing programs.

Lean manufacturing technologies for the manufacturing industry are capital intensive and yield fruitful results in the long run [7]. In light of these divergent views, manufacturing unit's owners in India are unclear about which lean manufacturing implementation strategy to adopt. To resolve this conflict, an empirical exploration is necessary to analyze the relationship between lean manufacturing practices and a firm's performance. The purpose of this paper is to present an empirical analysis of the relationship between three implementation drives (i.e. TPM alone, TQM alone and Integrated TPM & TQM) and business performance, particularly for Indian Manufacturing Industries. The paper also aims to discuss how synergetic implementation of maintenance and quality functions in the organization can boost business performance to meet the challenges of the highly competitive environment in the manufacturing sector.

Saumyaranjan Sahoo is with the School of Petroleum Management, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat 382007 India (phone: +91-79-23275128, e-mail: saumya.sphd15@spm.pdpu.ac.in).

Sudhir Yadav (Prof.) is with the School of Petroleum Management, Pandit Deendayal Petroleum University, Gandhinagar, Gujarat 382007 India (e-mail: sudhir.yadav@spm.pdpu.ac.in).

II. Literature Review

Achieving manufacturing excellence is seen as essential to survival and economic growth for any country in this age of globalization [24]. Due to the ever-changing customer demand for high quality products at low cost and prevailing intense worldwide competition, manufacturing organizations are continuously improvising and optimizing their manufacturing productivity to stay competitive [27]. To prosper in the present economic environment, any organization must be dedicated to never-ending improvement, and more efficient ways to obtain products and services that consistently meet customers' needs [23]. Hence, manufacturing companies need to pay attention to the reliability of their production processes as well as to their quality management approach [23]. In response to these challenges, various techniques such as just-in-time (JIT), TQM and TPM are used to achieve world class performance, but the most widely accepted amongst those are TQM and TPM [35].

A. Characteristics of Total Productive Maintenance

The TPM concept was first introduced in Japan in 1971 by Nakajima as productive maintenance carried out by all employees through small group activities to ensure that equipment was operated at 100% capacity and 100% of the time [31], [32]. TPM is a production-driven improvement methodology that is designed to optimize equipment reliability and ensure plant utilization through the use of employee involvement and empowerment, by linking manufacturing, maintenance and engineering functions [27]. The TPM concept is used to maintain equipment in optimum condition in order to prevent unexpected breakdown, speed losses and quality defects occurring from process activities [21]. Furthermore, TPM can be defined as an improvement program establishing a comprehensive productive-maintenance system throughout the entire life of the equipment, encompassing all equipment-related fields, and with the participation of all employees, to promote productive maintenance through motivation and voluntary team-based activities [10]. Hence, it is a holistic approach that encourages operator's participation in the maintenance of the machines that they operate, thereby institutionalizing the implementation of continuous improvement, employee empowerment, and standardization of maintenance activities, as well as embodying the culture of lean across the organization [38]. TPM seeks to increase productivity of a plant and equipment in such a way as to achieve maximum productivity with only a modest investment in maintenance [23]. It strives to maintain optimum equipment conditions in order to prevent unexpected breakdowns, speed losses, and quality defects arising from process activities [3]. The ultimate aim of TPM is zero equipment downtime and zero defects through eradication of equipment error [6]. Hence, a TPM program typically enlarges the responsibility of production employees from operating machines for detecting machine failures, performing basic maintenance, and keeping work areas clean and organized [21].

B. Characteristics of TQM

TQM is a management approach which started in Japan in the early 1980s, which seeks to enhance quality and productivity in a business organization. In the 1990s, TQM gained popularity among companies, who started adopting this management philosophy which focuses upon customer satisfaction and improves organizational performance [4]. TQM is a well-known "quality management" concept. But, it is more than product or service quality. "Quality" has been defined in a variety of ways, such as "fitness of use", "conformance to requirements", "the amount of unpriced attributes contained in each unit of priced attributes", among many other [18]. TQM is basically a business philosophy i.e. a way of doing business. It is concerned with ways to manage people and business processes to ensure total customer satisfaction at each and every stage [17]. TQM is an integration of two basic functions i.e. total quality control and quality management. TQM is a long-term strategy for an organization focusing upon continuous improvement and innovation, covering customer satisfaction, employee satisfaction and product quality assurance in all its stages. On the other hand, quality management is a way of planning, organizing and directing that will facilitate and integrate the capabilities of all employees for continuous improvement of anything and everything in an organization to attain excellence [23]. Hence by integrating all quality-related functions throughout the company, TQM tools and techniques implementation have the power to create a sustainable competitive advantage for the organization that meets or exceeds customer's expectations. A TQM movement cannot succeed unless employees are involved at various business processes and they are being trained to become more competent [25].

C. Relationship between Total Productive Maintenance and TQM

The relationship between each of the implementation drives have been discussed in only few of the research studies in an empirical way. TPM and TQM share many threads of commonality such as employee involvement, cross-functional approach, organization-wide diffusion and continuous improvement [8]. TQM aims at cutting costs by improving quality and TPM targets increasing machine efficiency and establishing maintenance system [9], [15], [23], [29], [37]. TPM, a comprehensive improvement drive is said to have originated from TQM's concept of zero production defects [39]. The main objectives of TPM and TQM are quite similar i.e. cost reduction and quality enhancement through continuous improvement, organization wide involvement and reduction of waste [26]. The primary difference between TPM and TQM is that TQM primarily addresses product improvement, whereas TPM emphasizes improvement of the facility and equipment [34]. TPM-specific practices are autonomous and preventive maintenance, technical emphasis, and team based maintenance. TQM-related techniques include cross-functional design, customer focus, i.e. satisfying the customer's needs and expectations, supplier involvement and

process control management [26]. The complementary nature of TQM and TPM as emphasized by experts [11] is being practiced in many companies to achieve synergy [33], [36], and to expand the scope of manufacturing effectiveness by simultaneous implementation. With respect to their fundamental goals, a comparison of the two improvement programs indicates substantial similarities, i.e. both TPM and TQM strive for continuous improvement, organization-wide involvement, and the reduction of waste [9], [26], [37].

With "Make in India" ambitious vision of our Honorable Prime Minister of India, India's manufacturers have a golden chance to emerge from the shadow and seize more of the global market. The Indian manufacturing sector needs to embark on productivity and quality programs to be more competitive in the global market. With a national target for the Indian manufacturing sector to grow six-fold, to reach $1 trillion by 2025 [13], the production efficiency centric practices should be adopted and adapted by the Indian manufacturing sector for raising performance standards to world class level. Though the research study related to the simultaneous implementation of lean manufacturing practices seems to be relatively under-researched [30], [37], the interrelationship of various operational (LEAN) initiatives with business improvement drives have to be evaluated to provide evidence supporting the compatibility of the quality and maintenance practices in improving production efficiency. Now that we have realized that these lean manufacturing practices are either more technically-oriented or process-oriented, a research framework has been developed to empirically test the effectiveness of whether the simultaneous implementation of both practices lead to superior performance, when compared to standalone implementation. The major goal of this research is to determine whether or not integrated implementation of lean manufacturing practices associated with TQM and TPM, explain differences in the performance among manufacturing plants. Thus, the present study will motivate more Indian entrepreneurs to implement various manufacturing practices in combination, and enlighten them how benefits in business performances can be obtained by synergizing various lean manufacturing techniques.

III. Variables and Hypothesis

A review of several researches on TQM and TPM showed the use of multidimensional performance parameters that were commonly adopted in their research framework. The performance parameters considered for the study are Market Share (PF1), Return on Investment (PF2), Profit Margin (PF3), Productivity (PF4), Quality (PF5), Cost (PF6), Delivery (PF7), Safety and Hygiene (PF8) and Employee Morale (PF9). Table I exhibits the commonly suggested performance parameters of standalone and integrated approach, along with the literature supporting it.

The effect of the implementation of either TPM or TQM or integrated approach has been empirically assessed by many researchers. In order to analyze the impact of standalone and combined strategy, the research study has been carried out for three time periods or phases to examine the short-, medium- and long-term effects on business performance. The identification and selection of these time phases has been adopted for this research on the basis of earlier research work [2], [12]. These are:

1) **Period of Transition (Up to three years of Implementation):** The period during which the company invests in the strategy adoption with efforts to bring incremental changes in traditional work practices, and restructuring the work culture and policies. This phase accounts for three years, during which the firm primarily focuses on orienting the workforce as per the requirements of the new implementation strategy.
2) **Period of Stability (More than three years and up to five years of implementation):** This is a period during which the improvement drives are stabilized and the organization starts realizing the benefits of TQM and TPM. The period of stability is taken as more than three years and up to five years of implementation.
3) **Period of Maturity (More than five years of Implementation):** Over a long period, the benefits accrued from improvement drives offer a strategic and competitive edge in terms of cost, delivery, flexibility and customer satisfaction in comparison to competitors.

TABLE I
Commonly Suggested Performance Parameters of TPM, TQM and Integrated (TPM+TQM) Practices

Business Performance Factors	TPM Literature					TQM Literature					TPM+TQM Literature			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
PF1 [Market Share]		X	X			X			X			X	X		X
PF2 [ROI]		X	X			X			X			X	X		X
PF3 [Net Profit]		X	X			X			X			X	X		X
PF4 [Productivity]	X		X	X	X	X	X	X	X	X	X	X	X	X	X
PF5 [Quality]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PF6 [Cost]	X		X	X	X		X	X	X	X	X	X	X	X	X
PF7 [Delivery]	X	X	X	X	X		X	X	X	X	X	X	X	X	X
PF8 [Safety & Hygiene]	X	X	X	X	X		X					X	X	X	X
PF9 [Employee Morale]	X	X	X	X	X	X	X		X			X	X	X	X

A [21]; B [41]; C [3]; D [27]; E [20]; F [19]; G [25]; H [28]; I [1]; J [40]; K [9]; L [26]; M [36]; N [23]; O [37]

It is an assumption among researchers that an implementation drive focusing upon a single strategy will not have such a strong impact on business performance as that of simultaneous implementation. Based upon the literature review, the hypotheses have been formulated for the current study, by taking nine performance parameters (PF1 – PF9) as dependent variables and implementation drives (TPM, TQM, and integrated TPM-TQM) as independent variables. Furthermore, it is proposed that no performance differences exist between single implementation (of either TPM or TQM) and simultaneous implementation. Hence, the hypotheses formulated for the current study are:

– **H0A:** Improvement in Performance Parameters contributed by TPM alone implementation drive, is the same as TQM alone implementation drive.

- **H1A:** Improvement in Performance Parameters contributed by TQM alone implementation drive is higher than TPM alone implementation drive. (Or vice versa)
- **H0B:** Improvement in Performance Parameters contributed by combined TPM-TQM strategy is the same as either TPM or TQM alone.
- **H1B:** Improvement in Performance Parameters contributed by combined TPM-TQM strategy is higher than either TPM or TQM alone.

IV. Research Methodology

A. Development of Measurement Instrument

The present study has been carried out on the basis of primary as well as secondary sources of information. The researchers have developed a questionnaire based on the scales and measures suggested by researchers, as shown in Table I. The researchers submitted this survey instrument for a pilot study to two experts with knowledge in the implementation of operational management systems based on lean manufacturing. The questionnaire was mainly adopted from previous studies [23], [26], [36], where relevant and related work has been done and slight modification to the performance measurement scale has been carried out on the basis of pilot study undertaken to reflect the characteristics of Indian medium and large-sized manufacturing organizations. The improvements in performance parameters were measured on a five-point scale (1="No improvement at all in performance parameters"; **2**="Less than 5% improvement in performance parameters"; **3**="5%-20% improvement in performance parameters"; **4**="21%-50% improvement in performance parameters"; **5**="More than 50% improvement in performance parameters"). Reliability of the scales has been checked through Cronbach's alpha and all the constructs were found to be reliable, as all alpha coefficients have exceeded the minimum accepted value of 0.7 [37]. The survey questionnaire was sent to only those manufacturing organizations in India (all regions) that have implemented or are in the process of implementing TPM alone, TQM alone and TQM-TPM both, to study the comparative analysis of business performance enhancements accrued through these quality improvement drives.

B. Data Collection

The research study was conducted in the period between October 2015 and March 2016 among top management and operations management executives. For online data collection, a questionnaire was posted as a Google document and was mailed to 626 medium and large-sized Indian manufacturing organization's management executives, which include the heads of operations, directors, vice-presidents, heads of quality assurance, manufacturing managers, and general managers etc., selected based upon their organization's adoption of strategic standalone or integrated implementation initiatives. The organizations were selected based upon references suggested by industry practitioners, lean consultants, academicians and councilors. These organizations were contacted through emails and telephone to explain the context of present research work, its significance and to clarify any doubts/queries to facilitate comprehensive and specific responses to the questionnaire. Out of the 626, responses of only 160 companies (respondent's profile are shown in Table II) were received, which were retained for analysis, as respondents has provided usable responses on all study variables, which accounted for a response rate of 25.5%.

TABLE II
Descriptive Statistic of Respondents

SAMPLE DESCRIPTION	**N = 160**	
	F	**Percentage**
Position in Company		
Top Management	47	29.4%
Operations Executive	113	70.6%
Areas of Responsibility		
Quality Management	57	35.6%
Production Management	42	26.3%
Maintenance Management	61	38.1%
Respondent Tenure with the Company		
< 5 Years	52	32.5%
5 - 10 Years	69	43.1%
>10 Years	39	24.4%
Company's Certification with ISO/Quality Service		
Yes	154	96.2%
No	6	3.8%
Revenue in Last FY		
< 10 Million USD	19	11.8%
10 – 20 Million USD	58	36.3%
20 – 30 Million USD	40	25%
> 30 Million USD	43	26.9%
Number of Employees in the Organization		
< 50 Employees	41	25.6%
50 – 250 Employees	64	40%
> 250 Employees	55	34.4%
Company's Involvement in Lean Management Practices		
< 3 Years	49	30.6%
3 - 5 Years	42	26.2%
> 5 Years	69	43.2%
Type of Manufacturing Firm		
Electronics	22	13.7%
Mechanical	34	21.3%
Chemical	15	9.3%
Automobiles	32	20%
Textile	14	8.7%
Plastic	20	12.5%
Others	23	14.5%

Statistical tools such as two tailed t-test and Single Factor ANOVA, along with analysis software like Excel and SPSS were used based upon availability of data, for comparative assessment of different manufacturing approaches during a particular implementation phase. The statistical techniques adopted by the researchers for the analyzed sample of responses for different years of implementation phases are shown in Table III.

C. Data Analysis

The main purpose of this study is to empirically evaluate the effectiveness of a separate and simultaneous implementation of TPM and TQM, upon improving performance parameters. Descriptive statistics reported in Table II and III provide a general picture of nature of the company and implementation strategy adopted over three time periods in the analyzed sample of the companies. Since the assessment of improvement in performance parameters for each strategy is calculated by means and standard deviation, the comparative assessment is carried out using two-tailed test and single factor ANOVA during each phase. The choice of these tests is completely based upon availability of data during each phase. We use t-statistic to test whether the difference in performance parameters between the examining subsample are statistically significant. The significance of the result is measured conservatively by reporting two-tailed tests of significance. We repeat our test using ANOVA (Analysis of Variance) for comparative assessment among the three implementation strategies.

TABLE III
DATA ANALYSIS AND STATISTICAL TOOL USED

Years of Implementation	Number of Responses	Comparative Analysis between approaches	Statistical Technique Used
Less than 3 years	TPM – 26 TQM – 23 TPM + TQM – 0	TPM and TQM	Two-tailed t test with 5% significance level
3 to 5 years	TPM – 14 TQM – 15 TPM + TQM – 13	TPM, TQM and combined approach	Single Factor ANOVA and two-tailed t test with 5% significance level
More than 5 years	TPM – 19 TQM – 21 TPM + TQM – 29	TPM, TQM and combined approach	Single Factor ANOVA and two-tailed t test with 5% significance level

V. FINDINGS

A. Analysis Results for the Transition Phase

The analysis results for the transition phase are shown in Table IV. The values of mean and standard deviation obtained for TPM and TQM indicate that both standalone strategy hold resemblance to the most extent in performance outcome during this phase.

The mean values for performance parameters PF1 to PF9 for both strategies lie between 1.0 and 2.20. With critical values of t-statistic at p=0.05 being 2.02, the results of two-tailed t-tests at a 5% significance level for each performance parameter indicates that the hypothesis H0A is supported for all performance parameters excluding PF6- "cost" (t = -5.05) and PF9- "employee morale" (t = -2.07) parameters. The mean values of TQM are higher than those of TPM during this phase, which means improvement in the "Cost" and "Employee Morale" parameters contributed by TQM is higher than that of TPM, i.e. H1A holds true for these parameters.

TABLE IV
T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES: IMPACT OF TPM VS. TQM IMPLEMENTATION DRIVE ON PERFORMANCE PARAMETERS DURING IMPLEMENTATION PHASE

Performance Parameters	TPM (n=26)		TQM (n=23)		t-values
	Mean	Standard Deviation	Mean	Standard Deviation	t-Criticalα =0.05 = 2.02
PF1 [Market Share]	2.12	0.19	2.05	0.24	0.55
PF2 [ROI]	2.20	0.17	2.14	0.12	0.57
PF3 [Net Profit]	1.96	0.12	2.09	0.18	-1.14
PF4 [Productivity]	1.9	0.08	2.07	0.15	-1.79
PF5 [Quality]	1.88	0.07	2.09	0.17	-1.87
PF6 [Cost]	1.39	0.29	2.07	0.15	-5.05*
PF7 [Delivery]	1.69	0.12	1.75	0.19	-0.55
PF8 [Safety & Hygiene]	1.54	0.17	1.75	0.19	-1.72
PF9 [Employee Morale]	1.32	0.16	1.70	0.30	-2.77*

* t-value obtained > t critical at $\alpha = 0.05$

B. Analysis Results for the Stability Phase

The analysis results for the stability phase are shown in Table V. The values of mean for the TPM/TQM standalone strategy and the combined strategy indicate that improvement in performance parameter, as a result of combined TPM-TQM approach, is higher than that of the standalone approach. Reviewing the t-test analysis related to the performance parameters, as shown in Table V, provides interesting results that supports H0A. The mean values for performance parameters PF1 to PF9 lie between 1.95 and 3.20. It is also interesting to observe regarding comparative assessment using t-test analysis between both cases of simultaneous approach vs. standalone; H0B is rejected for most performance parameters. For example, the performance outcome of manufacturing firms that invest in TPM may hold resemblance with the manufacturing firm adopting the simultaneous approach (TPM+TQM) on these parameters: PF4 (Productivity), PF7 (Delivery) and PF8 (Safety & Hygiene), as t-value is within the t-critical values. The mean values of performance PF - 4, 7, 8 for simultaneous TPM-TQM implementation is higher than standalone TPM implementation, and hence, H1B is supported for these parameters. Similarly, the performance outcome of manufacturing firms that invest in TQM may hold resemblance with the manufacturing firm adopting simultaneous approach (TPM +TQM) on these parameters: PF8 (Safety & Hygiene) and PF9 (Employee Morale), as t-value is within the t-critical values. It is not unexpected that inherent properties of standalone implementation program (either of TPM or TQM) is reflected in simultaneous implementation (TPM +TQM), which is evident from the analysis. The mean values of performance PF – 8, 9 for simultaneous TPM-TQM implementation is higher than standalone TQM implementation, hence H1B is supported for these parameters. The results of the ANOVA test indicate that the F-values of all performance parameters are higher than the critical F value at p=0.05, which indicates there is a significant difference in all values of performance parameters contributed by three different strategies. Moreover, the mean values of

performance parameters of simultaneous implementation are higher than that of standalone implementation, which supports H1B, and therefore, H0B has to be rejected.

TABLE V
SINGLE FACTOR ANOVA AND T-TEST: COMPARISON OF IMPACT OF TPM VS. TQM VS. (TPM + TQM) IMPLEMENTATION DRIVE ON PERFORMANCE PARAMETERS DURING STABILITY PHASE

Performance Parameters	TPM (n=14)		TQM (n=15)		TPM + TQM (n=13)		ANNOVA-values		t-values		
	Mean	Variance	Mean	Variance	Mean	Variance	F-Value F-Critical (α=0.05) =3.24	P Value	TPM&TQM t-Critical (α=o.o5)=2.05	(TPM+TQM) &TPM t-Critical (α=o.o5)=2.07	(TPM+TQM) &TQM t-Critical (α=o.o5)=2.08
PF1 [Market Share]	2.57	0.263	2.67	0.238	3.15	0.474	4.09	0.02	- 0.51	-2.47*	-2.12*
PF2 [ROI]	2.35	0.247	2.53	0.266	3.07	0.410	6.20	0.00	- 0.93	-3.24*	-2.44*
PF3 [Net Profit]	2.64	0.25	2.60	0.257	3.15	0.475	3.99	0.03	0.22	-2.19*	-2.39*
PF4 [Productivity]	2.55	0.079	2.42	0.276	3.20	0.268	4.73	0.02	0.81	-2.07	-2.32*
PF5 [Quality]	2.43	0.144	2.27	0.353	3.05	0.721	5.89	0.01	0.87	-2.43*	-2.79*
PF6 [Cost]	1.95	0.407	2.00	0.222	2.69	0.675	5.45	0.01	-0.23	-2.60*	-2.68*
PF7 [Delivery]	2.21	0.335	1.91	0.260	2.56	0.564	3.92	0.03	1.47	-1.35	-2.64*
PF8 [Safety & Hygiene]	2.21	0.142	2.16	0.380	2.79	0.893	3.59	0.04	0.25	-2.06	-2.04
PF9 [Employee Morale]	2.07	0.225	2.26	0.173	2.57	0.243	4.10	0.02	-1.73	-2.70*	-1.78

* t-value obtained > t critical at **α** = 0.05

TABLE VI
SINGLE FACTOR ANOVA AND T-TEST: COMPARISON OF IMPACT OF TPM VS. TQM VS. (TPM + TQM) IMPLEMENTATION DRIVE ON PERFORMANCE PARAMETERS DURING MATURITY PHASE

Performance Parameters	TPM (n=19)		TQM (n=21)		TPM + TQM (n=29)		ANNOVA-values		t-values		
	Mean	Variance	Mean	Variance	Mean	Variance	F-Value F-Critical (α= 0.05) = 3.13	P Value	TPM&TQM t-Critical (α=o.o5)=2.04	(TPM+TQM) &TPM t-Critical (α=o.o5)=2.01	(TPM+TQM) &TQM t-Critical (α=o.o5)=2.01
PF1 [Market Share]	2.94	0.497	2.80	0.562	3.42	0.965	3.54	0.03	-0.60	-1.91	-2.46*
PF2 [ROI]	2.83	0.500	2.85	0.344	3.36	0.833	3.60	0.03	-0.07	2.00	-2.97*
PF3 [Net Profit]	2.95	0.385	2.67	0.233	3.24	0.979	3.44	0.04	1.58	-1.26	-2.71*
PF4 [Productivity]	3.01	0.351	2.49	0.229	3.35	1.777	4.95	0.01	-3.06*	1.19	-3.21*
PF5 [Quality]	2.89	0.296	2.76	0.657	3.50	1.203	5.03	0.01	0.61	-2.53*	-2.74*
PF6 [Cost]	2.85	0.386	2.73	0.140	3.47	0.940	7.25	0.00	0.78	-2.66*	-3.74*
PF7 [Delivery]	2.72	0.497	2.58	0.543	3.32	0.871	5.77	0.01	0.57	-2.53*	-3.10*
PF8 [Safety & Hygiene]	2.84	0.612	2.30	0.561	2.89	0.578	4.04	0.02	2.19*	-0.23	-2.71*
PF9 [Employee Morale]	2.58	0.312	3.23	0.865	3.45	0.684	7.01	0.00	-2.74*	-4.34*	-0.82

* t-value obtained > t critical at **α** = 0.05

C. Analysis Results for the Maturity Phase

The analysis results for the stability phase are shown in Table VI. For each of the performance parameter of both standalone and integrated strategy, the mean values lie between 2.30 and 3.50. The mean values of all performance parameters of simultaneous implementation are higher than those of both standalone implementations. However, for the results of the t-test shown in Table VII, the means are not significant at p=0.05. The t-test analysis results for the maturity phase imply that hypothesis H0A is supported for all performance parameters except PF4 – Productivity, PF8 – Safety & Hygiene and PF9 – Employee Morale. The results also imply that hypothesis H1A is not supported for all performance parameters except PF9 – Employee Morale. For the ANOVA analysis results, the F-values of all performance parameters are higher than those of F-critical, which implies that there is significant difference in improvements contributed by three improvement drives. With the mean values of performance parameters of simultaneous implementation being higher than that of standalone implementation, this result is consistent even in the maturity phase as well, and is providing essential results to support hypothesis H1B. This phase of analysis indicates the operational practices of a plant that provide a better explanation of plant performance than that of the other phase, in which a plant operates.

TABLE VII
RESULTS OF DATA ANALYSIS

Phase	Hypotheses Type	Test Results	
Implementation	**A**	**T-test analysis**	
		H0A accepted for all performance parameters excluding 2 parameters: Cost and Employee Morale	
	B	Not Applicable	
Stability	**A**	H0A accepted for all performance parameters	
	B	**(TPM+TQM) vs. TPM**	**T-test analysis** H0B rejected for all performance parameters excluding 3 parameters: Productivity, Delivery and Safety & Hygiene parameters **ANNOVA analysis** H0B rejected for all performance parameters
		(TPM+TQM) vs. TQM	**T-test analysis** H0B rejected for all performance parameters excluding 2 parameters: Safety & Hygiene and Employee Morale parameters **ANNOVA analysis** H0B rejected for all performance parameters
Maturity	**A**	H0A accepted for all performance parameters excluding 2 parameters: Productivity & Employee Morale	
	B	**(TPM+TQM) vs. TPM**	**T-test analysis** H0B rejected for all performance parameters excluding 4 parameters: Quality, Cost, Delivery and Employee Morale **ANNOVA analysis** H0B rejected for all performance parameters
		(TPM+TQM) vs. TQM	**T-test analysis** H0B rejected for all performance parameters excluding 1 parameter: Employee Morale **ANNOVA analysis** H0B rejected for all performance parameters

VI. DISCUSSION

As the manufacturing organization's responses have been classified into three categories, depending upon experience gain over an extended period of time, i.e. transition phase, stability phase and maturity phase, this research suggests two main findings. First, the mean values of the performance parameters show obvious sign of improvement right from the beginning of implementation; although, these have been very marginal during the transition phase. Second, synergetic implementation of quality and maintenance practices, concurrently appears to make a substantial contribution to operational performance over the individual approaches.

The means values of the synergetic implementation strategy in the maturity phase are significantly higher than those in the stability phase. Also, the mean values of standalone implementation adopted by organizations in the maturity phase (over five years) and stability phase (3-5 years) are significantly higher than those obtained in the transition phase (1-3 years). This is due to the continuous efforts made by Indian organizations over the relevant periods of time, in adopting strategic TQM-TPM initiatives at the organization. The improvement in the stability and the maturity phase has been considerable in justifying the effectiveness of both TPM and TQM in improving business performance over a considerable period of time.

VII. CONCLUDING REMARKS

This study is one of the few research studies to empirically demonstrate the importance of simultaneous implementation of lean manufacturing programs. The main research findings can be summarized in Table VII. The study presents evidence that is consistent with what respondents say, as well as what researchers have highlighted in their previous findings about the long-term impact of the simultaneous implementation of TPM-TQM program on organizational performance within Indian manufacturing organizations. The results provide insightful guidelines for production managers to adopt simultaneous implementation, as they have significant potential to improve plant performance. The simultaneous implementation of TPM-TQM has placed strong emphasis on quality and maintenance practices in manufacturing units, which have resulted in the realization of enhanced organizational performance and enhanced financial returns. Hence, the simultaneous deployment of TPM-TQM implementation drives has contributed towards improving manufacturing performance in the Indian manufacturing sector.

VIII. SCOPE FOR FUTURE RESEARCH

The research results must be interpreted with caution, as with all research endeavors, as this paper has some limitations that should be highlighted and provide avenues for future research. As for the scope, the researcher relied on the experience of top and operational management executives of national and multinational companies in India, who worked with the implementation of either TPM or TQM or both, in the last decade. In-depth case studies are needed to further validate these findings empirically. Further, survey studies that use a larger cross-sectional random sample may provide a clearer understanding of the results found in the study. In spite of these limitations, the empirical results of this study provide some valuable managerial insights.

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