Synergies of Three Letters Syndrome for Revitalizing Manufacturing

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Abstract— **Research on Just-in-Time (JIT), Total Quality Management (TQM), Total Productive Maintenance (TPM), Supply Chain Management (SCM), and Theory of Constraints (TOC) generally investigate the implementation and impact of these programs in isolation. However, many researchers believe and argue conceptually the value of understanding the joint implementation and effect of manufacturing programs. This paper investigates the relationship among these three letters paradigm and describes a synergistic relationship among JIT, TOC, TPM, TQM, and SCM. The survey results of 45 Indian manufacturing industries underlines the need of joint implementation for revitalizing manufacturing. The theoretical argument leads to conclusion that the organization which have implemented jointly will outperform the organizations that have implemented only one or none.**

Index Terms— **JIT, SCM, Synergy, TOC, TPM, and TQM.**

I INTRODUCTION

Operations management is probably the prime producer of three letter acronyms and over the past several decades, several philosophies have emerged. In these times of irrepressible competition and trend towards a borderless commerce on a real global scale, academics and practitioners are in constant search for concepts and means that could render firms a consistent enhancement of performance in terms of productivity, quality and delivery. Firms are competing in increasingly turbulent and technologically complex markets.

Nevertheless, the adoption of concepts and techniques derived from single paradigm may not be powerful enough to deliver the improvements and innovations that are required nowadays to insure the survival and growth of a firm. Only recently, more researchers have begun to discuss the importance of synergistic approaches. Just-in-time (JIT) has been a widely recognized production philosophy. JIT traditionally addresses internal operations and emphasizes continuous improvements, quality and reduced inventories. Theory of constraints (TOC) also aims the objectives of JIT but it subordinates all activities to the system constraints.

The principles and techniques of JIT can be transferred to an entire supply chain management (SCM) to strengthen organizations SCM strategy in pursuit of improved organizational performance. Total Quality Management (TQM) offers potential for improving SCM performance. Synergy exists between JIT and TQM and overlapping practices are more coincidental and mutually supportive for continual improvement in quality and productivity. Total Productive Maintenance (TPM) paradigm can be complementary to JIT and TQM.

This paper is organized in four parts. In the first part the literature of joint implementation studies are reviewed to identify the synergies of two paradigms. The survey results of 45 Indian manufacturing industries on JIT efforts are included in the second part. The analysis of these survey results is made in the context of factors impeding the successful implementation are covered in the third. The last section theoretically illustrates how the synergistic relationship of three letter syndrome can be helpful to overcome these impeding factors. The concluding remarks and directions for future research are presented at the end.

II LITERATURE REVIEW

A. Review of Concepts

The following paragraphs review the concepts of these paradigms.

JIT is a philosophy aimed at to produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled in to finished goods, fabricated parts just in time to go into assemblies, and purchased materials just in time to be transformed in to fabricated parts. The primary goal of JIT is to continuously reduce and ultimately eliminate all forms of waste. The focus is on minimizing raw material, work-in-process, and finished goods inventory with a view to cutting inventory costs and also helping to expose other more serious inefficiencies in the manufacturing cycle. JIT implementation elements are designed to eliminate these productivity problems. JIT implementation involves two broad principles: elimination of waste, and full utilization of people, equipment, materials and parts. These principles are embodied in a set of ten consistently discussed programmes. These are focused factory; reduced set-up times; group technology; total preventive maintenance; multifunctional employees; uniform plant loading; *kanban*; quality control; quality circles; and JIT purchasing [1,4].

TQM is a manufacturing program aimed at continuously improving and sustaining quality products and processes by capitalizing on the involvement of management, workforce, suppliers, and customers, in order to meet or exceed customer

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expectations. In the literature of TQM, the practices identified are cross-functional product design, process management, supplier quality management, customer involvement, information and feedback, committed leadership, strategic planning, cross-functional training, and employee involvement. In the literature, quality management frameworks typically stress the importance of cross-functional product design and systematic process management. Furthermore, they emphasize the involvement of customers, suppliers and employees to insure quality products and processes.

TPM is a manufacturing program designed primarily to maximize equipment effectiveness throughout its entire life through the participation and motivation of the entire work force. The literature identifies autonomous maintenance and planned maintenance, equipment technology emphasis, committed leadership, strategic planning, cross-functional training, and employee involvement as the most commonly cited practices of TPM. To maintain equipment effectiveness, daily maintenance by operators is crucial. Unexpected breakdowns can be prevented through carefully-planned maintenance and the improvement or development of equipment. To conduct this maintenance, cross-functional training is necessary to improve operator skills. It is also important that all employees from management the shop floor are committed to the maintenance process, providing the time and resources to improve equipment performance [4].

SCM is a process oriented, integrated approach to procuring, producing, and delivering products and services to customers, covering the management of material, information and financial flows. SCM has a broad scope that includes sub suppliers, suppliers, internal operations, trade customers, retail customers, and end users. SCM can form a loop that begins with the customer and ends with customer covering the entire product cycle. Managing the supply chain implies the reducing and streamlining the supplier base to facilitate managing supplier relationship, developing strategic alliance with supplier to ensure that expectations are met, and involving suppliers early in the product development stage to take advantage of their capabilities and expertise.

TOC is a management philosophy, by Goldratt and Cox, emphasize continuous improvement, quality and reduced inventories subordinating all activities to the system's constraint (its most limited resource) [8]. TOC uses different size transfer batches and seeks to reduce variation only at the constraint. It is considered a waste to expend resources to reduce variations at non constraints since their variations are absorbed by their excess capacity. While TOC advocates agree that inventory is waste, this is the case only if the inventory is buffering a non-constraint. TOC breaks the dependency of the workstations by creating an inventory buffer only at the constraint; non constraint workstations have a capacity buffer (excess capacity). TOC requires the identification of the resources, within the system, that have the least capacity (the constraints) and maintaining an adequate inventory in front of these constraints to ensure that they are never idled by disruption [8].

B. Synergistic relationship among three letters paradigm

1. Synergistic relationship between JIT and TQM:

Most of the discussions in prior studies have centered on either JIT or TQM but an increasing number of researchers have begun to explore the issues relating to a joint implementation of JIT and TQM. Many previous studies have encountered difficulty in precisely listing the practices comprising JIT and TQM because of the extensive overlap between these approaches [2]. The overlapping practices of JIT and TQM are more than coincidental and they may be mutually supportive. However, the effectiveness and mutual supports for a joint JIT and TQM implementation have only been empirically tested in rare occasions recently [5,7]

Using data on forty-two plants in three US industries, Flynn *et al*. [5] provided an extensive review and analysis of the practices and performance of JIT and TQM. They divided the relevant manufacturing practices into three groups: unique JIT practices, unique TQM practices, and common infrastructure practices and evaluated their impacts on cycle time and quality (i.e. JIT and TQM performance measures, respectively). Their study suggested that the use of TQM practices improved JIT performance through process variance reduction and reduced rework time, thereby providing the levels of quality that allow production to proceed with minimum safety stock inventory while remaining on schedule. In turn, the use of JIT practices improved quality performance through problem exposure and improved process feedback. Not only did their study demonstrate that there are relationships and interactions between JIT and TQM practices and performance, but they also showed that, although JIT and TQM function effectively in isolation, their combination yields synergies for further performance improvements. While the unique JIT and TQM practices added predictive power of the JIT and TQM related performance, the most significant factor turned out to be the common infrastructure practices (including information feedback, management support, plant environment, workforce management, and supplier relationship). As a result, Flynn *et al.* [5] suggested that management needs to carefully assess an organization's culture and strive to match elements of JIT and TQM with it. In another independent study, Vuppalapati *et al.* [1] presented a discussion on JIT and TQM philosophies and suggested that those companies implementing both JIT and TQM jointly would outperform those implementing only one of these, or none. Their study suggested that all major elements of JIT are embedded in a more comprehensive TQM campaign because TQM has a much broader focus on improving the overall effectiveness of an organization. Further, the authors argued that management should not treat JIT and TQM as being exclusive business strategies. Rather, management should take an integrated view of joint JIT-TQM implementation. In the absence of results from any empirical study, Vuppalapati *et al.* [1] claimed that they have found support for their thesis through discussions with management in several organizations implementing such approaches. The synergistic nature of JIT and TQM was later tested empirically in another study by Sriparavastu and Gupta [7]. Their study generally further substantiated the benefits of joint JIT-TQM implementation.

While there are many factors crucial to internalizing JIT-TQM implementation, factors relating to employee involvement, work relationship and communication are further investigated by Lau [2]. The data collected from 382 manufacturing companies reveals that joint JIT-TQM implementation indeed offers synergistic benefits to businesses. However, these benefits link mostly to the workforce practices and can be achieved through successful TQM implementation. Finally, TQM was found in this study to have a spillover effect on JIT implementation and should be first implemented before JIT techniques are introduced in the workplace.

2. Synergistic relationship between TPM and TQM:

As TQM and TPM paradigms are becoming comparably popular and widely diffused across a multitude of industries, the comparison of these two paradigms has attracted increasing attention over recent years. The combination of both approaches as a contrivance to exploit their complementarity and thus attain enhanced overall performance. Miyake and Enkawa [9] have developed a structured comparative analysis of these two paradigms *vis-a - vis* a set of qualitative and functional dimensions. Taking into account the normative models of TQM and TPM, it seems that one extends over the other' s domain with respect to the effort of building a structure for securing product quality. While the former prescribes the necessity of establishing a QA system, the latter prescribes the adoption of quality maintenance (QM) activities. However, the activities undertaken under the frameworks of QA and QM are not redundant, but complementary to each other. They have pointed out that that, until 1996, a total of 44 individual manufacturers had been awarded both the DP and the TPMAw, which indicates that the deliberate matching of TQC and TPM has been realized as a promising, strategic pattern in Japanese industries.

McAdam and Duffner [6] have illustrated the case study of Harris Ireland Ltd., Florida of implementation of TPM in support of an established TQM. This approach has resulted in increase in employee involvement in decision making, team work, improved skills and training. The benefits have been achieved through a complete change in the maintenance strategy through TPM to maximize the effectiveness of equipment.

The survey of 121 Indian industries by Seth and Tripathi [11] have identified factors, which are significant to TQM and TPM, both when implemented individually and in tandem as combined approach. As many companies across the globe are striving to achieve the synergy of TQM and TPM, emphasis on these factors in the right context can help in realizing greater benefits through such improvement strategies. Total productive maintenance (TPM) aims to reduce failures, set-ups, and other causes of poor or reduced production by involving the operators in the maintenance of their machines, as an integral part of the TQM philosophy.

3. Synergistic relationship between JIT and SCM:

JIT and SCM represent alternate approaches to improving the effectiveness and efficiency of an organization's operations function. While differences in their motivations and objectives have sometimes led to them being presented as being distinct and separate, it is short sighted to view them as being unrelated. Both JIT and SCM seek improvements in quality, the former by way of improvements in production processes, the latter by integrating development and production processes throughout the supply chain. Successful JIT implementation depends on the coordination of production schedules with supplier deliveries, and on high levels of service from suppliers, both in terms of product quality and delivery reliability. This requires the development of close relations with suppliers and the integration of production plans with those of suppliers. It can be surmised that while the two approaches have certain defining characteristics, they represent elements of an integrated operations strategy [1].

Vise versa JIT principles can be also used to increase the effectiveness of SCM. When looking at supply chains from a JIT perspective, a fundamental issue is that a chain is not stronger than its weakest link. In order for a supply chain to be competitive, and thus for the individual company in the supply chain to be competitive, the various organizations in the supply chain must all be efficient with respect to cost, quality, delivery speed and reliability and flexibility. The fundamental change in scope between internal operations and supply chain operations is the product and time perspective, in that the total supply chain product structure and cumulative lead-time are deeper and longer, respectively [10].

4. Relationship between JIT and TOC:

Sale and Inman [8] have compare the performance and the change in performance of companies reporting TOC adoption, those reporting JIT adoption, those reporting to have adopted both, and those reporting to have adopted neither (traditional manufacturing). Results indicate that the greatest performance and improvement in performance accrued to adopters of TOC. They have further reported that the idea that the combining of two philosophies (JIT and TOC) may result in a synergy, i.e. a performance higher than each one alone, was not substantiated. They could not find support to this as low number of firms (six) in the mixed methods (JIT/TOC) category may somewhat limit the generality of the results. In addition, the results obtained may be affected by the small size of the sample, especially for those firms claiming usage of both JIT and TOC (six).

The study by Ferguson [12] advocates that though, a number of JIT implementations have failed or have lead to some undesirable effects , such as a temporary plant shut down due to the lack of supplies, the Thinking Process (TP) of TOC provide a useful set of tools for analyzing what to change to and how to cause the change.

Very few studies have been reported so far addressing the combined approach. But the JIT and TOC comparison reported in [10] reveals that TOC is effective in reducing WIP and producing greater output. So, this clue can be used to combine these approaches so as to use strengths of JIT and TOC and also TOC can be utilized in order to analyze JIT and improve the effectiveness of JIT [12].

5. Other studies of synergistic approaches:
Kannan and Tan [3] have studied the relationship among JIT,

TQM, and SCM; and their linkages and impact on business performance. The results demonstrate that at a strategic level, linkages exist between JIT, TQM, and SCM. While some companies may understand the inherent relationships between the three and actively exploit their synergy, those that do not maybe inadvertently achieving the benefits of synergy. By explicitly and effectively integrating JIT, TQM, and SCM practices into operations strategy, the potential exists to add value and to better position oneself to respond to competitive pressures. At an operational level, JIT, TQM, and SCM practices can be deployed together to create value.

Kua, McKone, and Schroeder [4] have studied the relationship between TQM, JIT, and TPM. The results of the second stage analysis suggest that simultaneous implementation of TQM, JIT, and TPM will result in higher performance than implementation of practices and techniques from only one of TQM, JIT and TPM. In addition, while it is not conclusive which particular manufacturing practices have stronger effects on specific performance dimensions, this study shows that there are different configurations of specific practices that should be implemented depending on the strategic importance attributed to a performance dimension.

III A THESIS FOR INTEGRATED VIEW

Most of the discussions in prior studies have centered either on JIT, TQM, TPM, SCM, or TOC; but an increasing number of researchers have begun to explore the issues relating to a joint implementation of JIT and TQM[1,2,7]; TPM and TQM [6,9,11], JIT and TOC[8]; JIT, SCM and TQM [3]; and JIT, TQM and TPM [4]. All these studies concluded that there exists synergistic relationship between/among these different paradigms. But broader perspective is still missing. Fig. 1 illustrates our proposed model for joint implementation. These entire paradigms aimed at reducing cost; improving quality, flexibility, delivery performance and overall weighted performance. The literature shows that these programs include some common practices that are shared by all programs and other practices that are unique to each program as summarized in Table II. The support for the model can be theorized using the survey results.

The survey of 45 Indian manufacturing industries were carried out to identify the extent of practicing the elements of JIT and major problems they are facing, using 5 point scale, to become globally competitive. These JIT practices are then grouped into the unique JIT; TQM; SCM; and TPM practices, and common human strategic- oriented practices.

While analyzing the survey results, it is apparent that even though the rate of JIT implementation is increasing, the efforts are on ad hoc basis. To realize the JIT implementation in true sense, the manufacturing industries have to use TQM, TPM and SCM paradigms and synergies among them and the tools of TOC. These paradigms will not only help in overcoming the problems they are facing but also accelerate the rate of using these practices so as to reduce cost; improve quality, flexibility, delivery performance and overall weighted performance.

TABLE I
DEGREE OF DIFFICULTIES FACED BY RESPONDENTS

Difficulties Faced	Wt. Avg.
Lack of cooperation of suppliers in correctly supplied materials	4
The lack of resources to invest in direct linkages with vendors	3.785
Lack of formal cross training programs for workers	3.535
Lack of formal training/education	3.5
Lack of cooperation from vendors in the form of inconsistent lead times and capacity constraints imposed by suppliers	3.428
Lack of an accurate forecasting system	3.428
Lack of strategic planning	3.321
Problem in maintenance time reduction through machine modification or replacement of existing equipment	3.214
Quality problems with supplied material	3.107
Lack of cooperation of suppliers in timing of supplied materials	3.071
Reduction in the levels of work load variability	3.035
Problems with machines (Machine failures and reliability)	3.035
Lack of information and communication with suppliers	3
Inability to meet schedule	3
Lack of communication between workers and management	2.8957
Problem in line balancing	2.892
Lack of performance measure	2.857
Problem in lead times reduction	2.821
Problems in layout modification	2.821
Lack of team work spirit	2.821
Departmental conflicts	2.785
Poor quality	2.535

The survey items and statistics are summarized in Table I and Table II. The problems faced by Indian industries includes lack of formal cross training programs for workers; lack of formal cross training programs for workers; lack of strategic planning; lack of an accurate forecasting system; lack of communication between workers and management; lack of team work spirit; and departmental conflicts. These problems are well consistent with literature [4]. Moreover, for the socio-technical systems the joint optimization of practices that are socially- and technically- oriented should lead to good performance. The importance of building manufacturing competitiveness upon the integration and coordination of

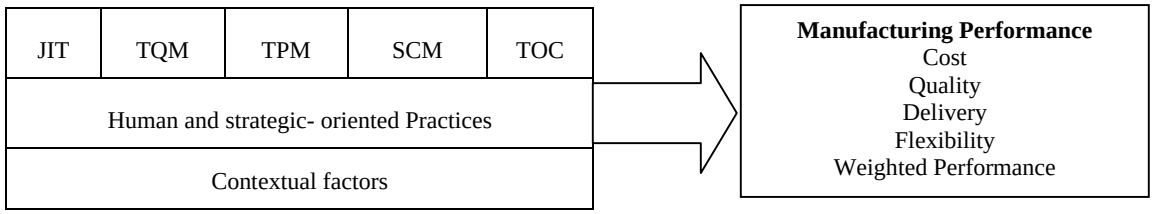

Fig.1.Theoretical Framework

TABLE II
DEGREE OF PRACTICING JIT ELEMENTS BY RESPONDENTS

Element	Wt. avg
Just-in-Time (JIT)	
Factory scheduling	4.444
Process rationalization and standardization	4.2
Reduced Tuning / set-up time	4.2
Emphasis on inventory reduction	4.2
Minimum WIP and mfg. inventory	4.177
Smoothing of production/ process balancing	4.111
Under capacity scheduling / Capacity planning	4.044
Smooth built up rate	3.977
Zero deviation from scheduling	3.866
Component routing standardization	3.866
Small lot size with exact quantity	3.866
Close proximity of suppliers	3.822
Fewer suppliers / Supplier rationalization	3.711
Buffer stock removal	3.577
Factory flexibility and Flexible equipment	3.555
Small batch production	3.377
High level Integration and coordination of support system	3.266
Inventory management compatible with JIT	3.133
Focused factories / Plant-within-plant	3.022
Mixed model progressive value adding assembly concept	2.777
Use of small multiple machines	2.755
Manufacturing and support system integration inline	2.733
Proximity of work stations / Plant compression	2.711
Use of Cellular Manufacturing (GT)	2.6
Dedicated layout	2.444
JIT purchasing training to the purchase personnel's	2.311
KANBAN	2.177
Layout for JIT	1.888
U shaped kanban cells	1.622
Total Quality Management (TQM)	
Customer feedback	4.4
Freedom to solve problems / No restrictive practices	4.311
Design and standardization of jobs/ operation	4.2
Integrated over all control	3.933
Quality circles	3.933
100 % quality (zero defects)	3.911
Focused storage	3.888
Good forecasts	3.866
Improved accounting methods	3.844
Worker centered quality control	3.733
Statistical Quality Control (SQC)	3.711
Evolving new performance measures centered around flexible force	3.711
Product design quality	3.688
Vendor development	3.644
Computer integrated design	3.622
KAIZEN	3.622
Automation and Computer techniques	3.6
Statistical Process Control (SPC)	3.533
Research and Development	3.444
High Quality from the supplier	3.444
Design for manufacturing and assembly	3.177
House keeping	3.177
Modular design for product flexibility	3.133
Component item standardization	3.133
Min. product specification to the supplier	3.133
Elimination of incoming inspection	3.088
Visual control system / Andon light board system	3.022
Autonomation / POKA-YOKE	2.933
High level BOM diversification	2.911
Emphasis on performance not specification	2.822
Suppliers contribution in design	2.577
Authority to worker to stop the line	2.355
Suppliers contribution in design	2.577
Authority to worker to stop the line	2.355
Total Productive Maintenance (TPM)	
TPM	4.111
Operator responsible for maintenance	3.355
Common practices of JIT, TQM, SCM, TPM and TOC	
Respect for humanity	4.444
Improved and frequent communication	4.377
Team work and spirit of co-operation	4.222
Increased judgment and responsibility of employees	4.133
Continuous improvement across departmental boundaries	4.111
Long term employment	4.088
Education and public relations	4.066
Added value incentive schemes	4
Quick Feedback system	3.977
Improved, frequent and direct communication	3.933
Work culture	3.888
Quality based payment schemes	3.844
Information accuracy regarding stock	3.755
Employee empowerment	3.755
Multi function worker	3.711
Cost control	3.688
Product costing information system	3.488
Variable working hours and Paid overtime	3.466
Wage system revision	3.4
Remuneration mode revaluation	3.4
Change management	3.2
Relationship with unions	3.088
Organization structure with few grades/ levels	3.066
Electronic Data Interchange (EDI)	2.822

strategy, structure, culture, and human resource subsystems within a complex, changing environment will help in negotiating these problems. The concept of a balanced socio-technical system is reflected in all subsystems of successful Japanese transplants. The common practices provide a supporting mechanism for the implementation of TQM, JIT, TPM and SCM basic techniques.

It is our opinion that the implementation of basic techniques will not provide as strong an impact on manufacturing performance as the combined institution of the common practices and implementation of the basic techniques. Both the social and technical subsystems should be jointly optimized to achieve the best possible performance. The study by Lau [] clearly identifies differences between joint JIT-TQM companies and companies with no JIT or TQM implementation in terms of common workforce practices. Specifically, the results showed that joint JIT-TQM companies had higher employee involvement, better work relationships among departments and with suppliers, and more communication between line workers and management.

The operational level problems related to quality management such as quality problems with supplied material; in-house poor quality can be dealt with using TQM. The survey results on the extent of use of TQM practices (Table II) reveal that managing the suppliers' quality is still very difficult. This can be accomplished without difficulty using JIT-TQM. The another major problem is related to logistics (inbound and outbound) as well as lack of cooperation of suppliers in correctly supplied materials; lack of cooperation from vendors in the form of inconsistent lead times; lack of participation at the design stage and capacity constraints imposed by suppliers. SCM has a broad scope that includes sub suppliers, suppliers, internal operations, trade customers, retail customers, and end users. Managing the supply chain implies the reducing and streamlining the supplier base to facilitate managing supplier relationship, developing strategic alliance with supplier to ensure that expectations are met, and involving suppliers early in the product development stage to take advantage of their capabilities and expertise.

Problems with the machines like failure; reliability and problems in maintenance time reduction is also of great concern to assure the plant availability; smooth operations and thereby quality. TPM will be crucial tool to overcome these as it has synergistic relationship with JIT and TQM.

TOC can be viewed as an umbrella for the improvement approaches. In JIT, TOC can be used effectively to reduce WIP and producing greater output. Linking TOC to other initiatives such as TPM, SCM can be a key in relentless pursuit of productivity.

IV CONCLUSION

From this study, it can be concluded that at strategic level, linkages exist between JIT, TQM, TPM, SCM and TOC. While some companies may understand the inherent relationships among these and actively use their synergy, those that do not may be inadvertently achieving the benefits of synergy. By explicitly and effectively integrating JIT, TQM, TPM, SCM and TOC practices into operations strategy, the potential exists to add value and to better position oneself to respond to competitive pressures. At an operational level, JIT, TQM, TPM, SCM and TOC practices can be deployed together to create value. Each component of the integrated framework represents a different aspect of improvement initiatives aimed towards product, process, equipment development, and delivery. There exist different configurations of practices that are best suited for improving specific performance dimensions, however, each of these configurations consists of practices belonging to all programs and includes both socially- and technically-oriented practices. This demonstrates that the components of our framework are mutually supporting in achieving high levels of manufacturing performance.

Future research studies could pinpoint the exact nature of the interaction among practices. While this study provides a foundation for TQM, JIT, SCM, TPM, and TOC within a single framework, it is only through further research that a full understanding of the relationship among these three letters paradigm will be obtained. Another paradigm such as ERP and BPR can also find the place in the study.

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