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REENGINEERING THE SUPPLY CHAIN HUMAN DIMENSIONS USING SIX-SIGMA FRAMEWORK

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Abstract: *The greatest continuing area of weakness in management practice is to evaluate human dimensions. The aim of this research is to evaluate the human dimensions which can prove for successful implementation of Six- sigma through teams. This paper discusses the available dimensions of supply chain management (SCM) practices in literature and develops an integrated framework (6σ+SCM) based upon ten human dimensions of SCM practice ((i) Self management, (ii) Participation, (iii) Flexibility, (iv) Training, (v) Managerial support, (vi) Communication and cooperation, (vii) Feedback and reward, (viii) Leadership, (ix) Information sharing and (x) Process improvement orientation). The framework has been used to analyze the performance of teams based upon the above dimensions which helps in improving the performance. Various performance metrics i.e. Sigma level (within) and sigma (overall), yield, Cp and Cpk have been calculated to find out the scope for improvement with respect to SCM dimensions based upon team characteristics.*
Keywords: *Supply chain, Six-sigma, Performance, Team, SMEs.*

1. INTRODUCTION

In today's challenging business environment, accelerated competition among the companies have forced them to strengthen and measure their supply chain performance. As a result, supply chain management has become an important means for a company to gain a competitive advantage. In order to optimize a supply chain and strengthen business competitiveness, companies need an integrated performance measurement system. For measuring the supply chain performance, managers in many industries are trying to make better use of SCM by implementing a variety of different techniques/philosophies such as just-in- time (JIT), total quality management (TQM), lean production (LP), computer generated enterprise resource planning schedule, Kaizen and activity -based costing (ABC) and Six sigma approaches (Bititci et al 2002, Lockamy et al. 2004, Farhad Nabhani and Alireza Shokri 2008, Mishra and Sharma 2011). Based on the case study Bititci et al (2002) conclude that appropriately designed performance systems, if supported through appropriate IT platforms will improve visibility, communications, teamwork, decision making and proactive management style. Lockamy et al. (2004) explained that information technology solutions are only part of the answer to improved SC performance and its management. Farhad Nabhani and Alireza Shokri (2008) discussed that practicing successfully six-sigma methodology improve SC objectives in a food distribution SMEs through reducing the lead time as lean waste and a quality defect to improve customer satisfaction.

The principal focus of supply chain performance measurement is to reduce waste and increase efficiency and to measure each process subject to the entire supply chain or its individual members. It has been argued that the integration of 6σ with other comprehensive quality standards is practical and could provide the best outcomes (Raisinghani et al., 2005). This has later been supported through the daily 6σ works in Samsung that 6σ and SCM would be two pillars of business improvement. Benefits of 6σ in supply chain includes both tangible and intangible benefits i.e. the project discipline, sustaining business results; human resource development and quantitative strength (Yang et al., 2007). These benefits are possible outcome of team work. It has been argued that teamwork offers greater adaptability, productivity and creativity than one individual can offer (Salas et al.2000, 2005). The application of different quality programmes by teams to reduce the operational inefficiencies and waste requires top management commitment to provide adequate resources and training so that teams can implement the methodology to eliminate defects, reduce variation effectively which helps in improving the performance of supply chain.

Dasgupta (2003) applied 6σ metrics to measure and improve supply chain processes, and he suggested that human attributes should be integrated into the performance measurement systems. G. Knowles et al. (2005) proposed an integrated model which includes

Balanced Scorecard, SCOR model and DMAIC methodology in a two– level framework. An improvement model by integrating both six-sigma and Capability Maturity Model Integration (CMMI) method and a detailed application procedure in the auto industry was presented by Lin and Li (2008).

Traditional performance measurement system in supply chain were based on accounting figures such as sales turnover, profit, debt, and ROI which might serve well as warning flags about performance problems, but at the same time they do not convey the reasons for the problems. Shepherd and Gunter (2006) highlighted a range of limitations pertinent to supply chain performance measurement, no long-term performance measurement; no focus on strategic issues; little supply chain context; and lack of systematic approach. Their studies stressed the need for new measurement systems and metrics to address these deficiencies. Recently, some researchers (Bhagwat and Sharma, 2007, 2008, Thakkar et al., 2011) have attempted to respond to the limitation by designing systematic and balanced performance measurement systems and framework for SMEs. Few authors have worked on various SCM dimensions such as supplier partnership, outsourcing, purchasing, supply chain integration, logistics, education, postponement, IT adoption for improving SCM performance. But still key strategic issues, such as top management commitment, leadership, training, cooperation, communication etc. remain unanswered by the authors.

The purpose of this study is to summarize and prioritize various team characteristics which play important role in improving SCM performance based upon strategic SCM dimensions. An integrated performance measurement framework has been developed to analyze the performance of teams. Based upon literature studies various team characteristics such as self management, participation, flexibility, training, managerial support, etc. are considered for analysis.

The remainder of paper is organized as follows. Section 2 presents the literature review of SCM practices. The research methodology is presented in the third section. Section 4 presents the Integrated (6σ+ SCM) performance measurement framework. Six-sigma metrics and formula presented in section 5. Section 6 presents case study, calculation of six-sigma and sample of questionnaire. Section 7, 8 presents the discussion and conclusions.

2. LITERATURE REVIEW

2.1 Evolution of Supply Chain Performance Measurement (SCPM)

Supply chain performance measurement has emerged as one of the major business areas where companies can obtain a competitive advantage. It is a key strategic factor for increasing organizational effectiveness and for better realization of organizational goals such as enhanced competitiveness, better customer care and profitability (Gunasekaran, 2001). According to Gomes et al. (2004), performance measurement in supply chain evolved through two phases. The first phase was introduced in the late 1880, while the second phase in the late 1980s. The first phase was characterized by its cost accounting orientation. It incorporated financial measures such as profit and return on investment.

Table1- Evolution of supply chain performance methods

Category	Period	Characteristics	Nature/Contribution
Phase 1	Before 1980	Cost accounting orientation. Performance measurement dominated by transaction costs and profit determination.	Traditional financially based
Phase 2	1980-1990	Dominant theme was a discussion of problems of performance measurement systems, recognizing and discussing the weaknesses of measurement systems and their organizational impact.	Globalization
Phase 3	1990-2000	A mixed financial and nonfinancial orientation. Measurement framework were developed like BSC, SCOR model etc. to identify the problems of an organizations.	Strategic alignment and Automation of business process.
Phase 4	2000-2010	Empirical and theoretical analysis of performance measurement frameworks and methodologies. Analysis of impact of PMS on organizations. Theoretical verification of frameworks.	E-commerce, e-supply chain.
Phase 5	2010 onwards	Innovative performance measurement systems. (SCM+ Six-sigma, Logistics + Six-sigma), JIT, TQM.	Agile supply chain, sustainability in SC and SMEs.

The mid 1980 was a turning point in the performance measurement literature. This phase was associated with the growth of global business activities and 1990's were significant with automation processes. The 2000's saw the emergence of e-commerce and implementation of model in the supply chains. Late 2005- 2010 witnessed growth of different supply chain agile, lean and leagile frameworks for improving the process and quality of the supply chain. A key feature in the business environment is that supply chains, not companies, compete with one another (Christopher, 2005). The evolution of SCPM briefly presented in Table 1.

2.2 SCM practices

Supply chain management practices involve a set of activities undertaken in an organization to promote effective management of its supply chain. The literature in Table 2 is replete on the dimensions of SCM practices undertaken in an organization to promote effective management of its supply chain performance from variety of perspectives. Donlon (1996) describes the latest evolution of SCM practices, which includes supplier partnership, outsourcing, cycle time compression, continuous process flow and information technology sharing. Tan et al. (1998) used purchasing, quality, and customer relations to represent SCM practices, in their empirical study. Li et al. (2005) attempted to develop and validate a measurement instrument for SCM practices. Their instrument has six empirically validated and reliable dimensions which include strategic supplier partnership, customer relationship, information sharing, information quality, internal lean practices and postponement. T.S Khang et al. (2010) proposed 6 dimensions of supply chain practices which include customer orientation, knowledge sharing, IT adoption, partnership, leadership and training to examine their impact of organizational performances. In more recent study Charlene A. Yauch (2011) identified 7 variables related to agility improvement and assess their importance across an entire supply chain rather than for single manufacturing enterprise which includes customer satisfaction, quality improvement, cost minimization, delivery speed, new product introduction, service level improvement, lead time reduction. Thus, the literature portrays SCM practices from a variety of different perspectives with a common goal of ultimately improving organizational performance but with least stress upon supply chain dimensions based upon human characteristics.

Table2- SCM practices in the literature

Saraph et al. (1989) Top management leadership Role of quality department Training Product design Supplier quality management Process management Quality data reporting Employee relations	**Donlon (1996)** Supplier partnership Outsourcing Cycle time compression Continuous process flow Information technology sharing	**Black and Porter (1996)** People and customer management Supplier partnership Communication of improvement information Customer satisfaction orientation External interface management Teamwork structure for improvement Operational quality planning Quality improvement measurement systems
Tamimi (1998) Top management commitment Supervisory leadership Education Cross functional communication to improve quality Supplier management Quality training Product/ service innovation Providing assurance to employees	**Tan et al.(1998)** Purchasing Quality Customer relations	**Joseph et al. (1999)** Organizational commitment Human resources management Quality information systems Quality policy Supplier integration Operating procedures Training Role of quality department Technology utilization
Alvarado and Kotzab (2001) Concentration on core competencies Use of inter-organizational systems Elimination of excess inventory levels	**Tan et al. (2001)** Supply chain integration Information sharing Supply chain characteristics Customer service management Geographical proximity JIT capability	**Ulusoy (2003)** Logistics Supplier relations Customer relations Production

Chen and Paulraj (2004) Supplier base reduction Long term relationship Communication Cross functional teams Supplier involvement	**Min and Mentzer (2004)** Agreed vision and goals Information sharing Risk and award sharing Cooperation Process integration Long term relationship Agreed supply chain leadership	**Li et al. (2005)** Strategic supplier partnership Customer relationship Information sharing Information quality Internal lean practices Postponement
Burgess et al. (2006) Leadership Intra-organizational relationship Inter-organization relationship Logistics Process improvement orientation Information systems Business results and outcomes	**Suhong Li et al. (2006)** Strategic supplier partnership Customer relationship Level of information sharing Quality of information sharing Postponement	**Koh Lenny et al. (2007)** Close partnership with suppliers Close partnership with customers Just in time supply Strategic planning Supply chain benchmarking Few suppliers E-procurement Outsourcing and 3PL
Comm and Mathaisel (2008) Strategic concept Logistics and distribution IT Supplier collaboration	**Tai Siaw Khang et al.(2010)** Customer orientation Knowledge sharing IT adoption Partnership Leadership Training	**Charlene A. Yauch (2011)** Customer satisfaction Quality improvement Cost minimization Delivery speed New product introduction Service level improvement Lead time reduction

Most of the SCM practices are related to strategic supplier partnership, customer relationship, and information flow across a supply chain, postponement, market share, and financial performances of an organization. It should be pointed out that even though the above dimensions capture the major aspects of SCM practices but they cannot be considered complete. They have focused on the study of information flow across the supply chain but they failed to grasp the idea of how the information flows within the supply chain. There is no common metrics for evaluating different processes on the same scale. As they have not incorporated the team structure dimensions to measure the supply chain performance.

Relying on the extant of literature available on SCM practices, this study identifies a set of 10 SCM practices to examine their impact on SCM performances: (i) Self management, (ii) Participation, (iii) Flexibility, (iv) Training, (v) Managerial support, (vi) Communication and cooperation, (vii) Feedback and reward, (viii) Leadership, (ix) Information sharing and (x) Process improvement orientation.

Therefore our study focuses on team characteristics which help management to improve supply chain performance. An integrated framework (6σ + SCM) has been developed for continuous improvement in supply chain management performance. The framework has been used to evaluate the performance of teams within the supply chain using 6σ metrics.

3. RESEARCH METHODOLOGY

‘ Figure1. Presents an overview of research methodology adopted in the study.

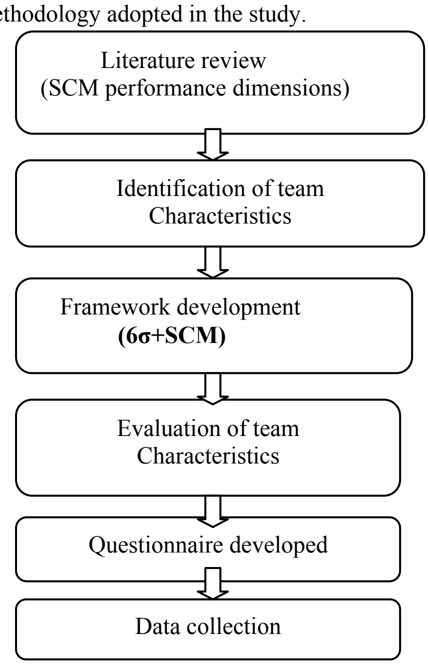


Figure1- Research Methodology

4. INTEGRATED SCM PERFORMANCE MEASUREMENT FRAMEWORK

A framework consisting of 4 stages imbibing 6σ team culture for measuring supply chain team performance is shown in Figure-2. The 4 stages in the framework are explained briefly.

Stage1. Identification of performance model: Based upon the requirement, build performance model. The model should take care of the customer needs, elimination of waste, defect prevention, cycle time reduction, cost savings and variation reduction in supply chain to improve the quality and performance.

Stage2. Mobilization: This stage includes formation of teams and mobilization of necessary resources to train and educate the employees for collecting, interpreting and analyzing the information related to various entities in the supply chain i.e. supplier, manufacturer, distributors, transporters, warehouse and customer shown in Figure 3. The 6σ team consisting of members frame helps in achieving organizational goals. Leadership is provided by a team of champions (E1): senior champion, deployment champion and projects champion at corporate, unit and department level, respectively, supported by a team of experts. The experts are referred as Master Black Belts (E2) (who provides mentoring, training and expert support to the Black belts. Black Belts (E3) who usually work full time on projects at process level to solve critical problems and achieve bottom- line results and Green belts (E4) are the employees who take up six sigma implementation along with their job responsibilities, operating under the guidance of Black Belts. Yellow belts (E5) employees that have basic training in Six-Sigma tools.

Stage3. Execution: Under this stage, the flowcharts are drawn to identify all the activities and parameters related to processes. The flow chart consists of five process of six-sigma i.e. define, measure, analyze, improve, control (DMAIC) as shown in Figure 2. Define determine which process to improve from the point of view of customer, supplier and operators. Measure, collect all the necessary data and measure current performance, Analyze, identify the root of problem , poor performances and variation, Improve take action to reduce the amount of defects and Control reduce defects via a change in the process .

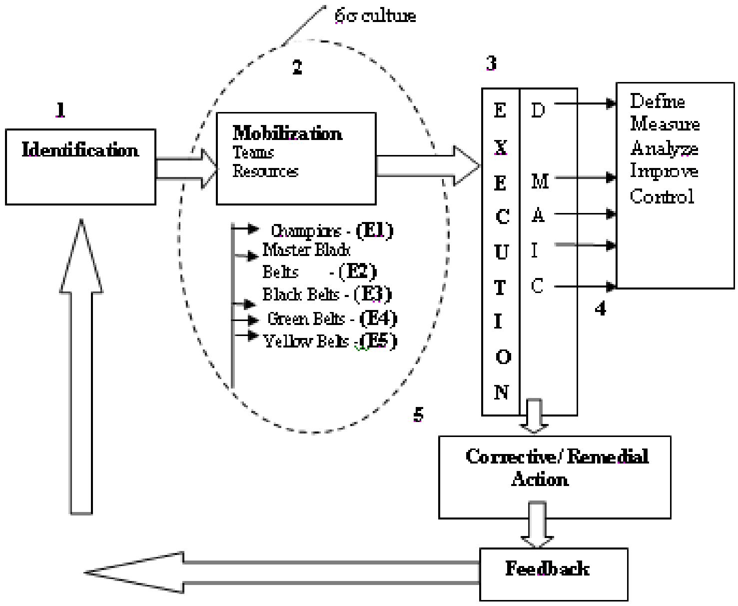


Figure 2: Performance measurement framework

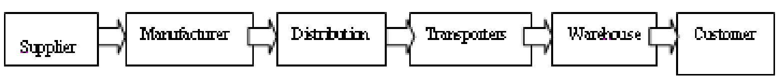


Figure 3- Supply Chain Process

Stage4. Corrective action: Based on results obtained in stage 3 improvement action can be planned by analyzing measures. We can take corrective actions by rationalizing the measure structure, preparing gap analysis and process reengineering.

5. SIX-SIGMA

Six- Sigma was introduced in 1987 and adopted by GE to achieve remarkable benefits. Sigma, σ, is the letter in the Greek alphabet used by statistician to measure the variability in any process. Six- Sigma was defined by Harry (1997) as an improvement approach, a strategy, and also a goal. The six- sigma metrics includes DPU (defect per unit), DPMO (defect per million opportunity), Z- value (sigma level), FTY (first time yield), RTY (rolled throughput yield). Six- sigma is systematic problem-solving approach based on five stages of define, measure, analyze, improve, and control (DMAIC). Few of the matrices used for calculation in the paper are as follows:

Z- value: Z value calculation, it is necessary to precisely measure the process output and obtains consecutive survey data. Based on the data both the mean value (X) and standard deviation(S) of the process output could be figured out. Then these two parameters contribute to the outcome of Z value (sigma level), which represents the capability of meeting customer requirements. Equations for computing various sigma metrics are as follows:

$$Z\ upper = \frac{USL-\mu}{S} \quad \textbf{(i)}$$

$$Z\ lower = \frac{\mu-LSL}{S} \quad \textbf{(ii)}$$

$$Z = \min(Z\ pu + Z\ pl) \quad \textbf{(iii)}$$

Where, USL and LSL stand for the upper limit and lower limit of standard respectively, while Zpu and Zpl are respectively for the Z values of two tails in normal distribution curve.

Yield: Yield is simply the number of good units produced divided by the no of total units going into the process.

Process capability (Cp): Process capability can be calculated by following equation

$$Cp = \frac{USL - LSL}{6\sigma} \quad \textbf{(iv)}$$

Where, USL and LSL stand for the upper limit and lower limit of standard.

Cpk: Cp and Cpk are for computing the index with respect to the sub grouping of data (different shifts, machines, operators, etc.).

Cpk = Min (CPL, CPU) (v)

CPL measures how close the process mean is running to the lower specification limit.

CPU measures how close the process mean is running to the upper specification limit.

6. AN ILLUSTRATIVE CASE STUDY

The following case study is based on the paint company which is in a process of an ongoing program on application of six sigma methodology. The aim was to evaluate the team characteristics for successful implementation of six sigma and SCM performance framework to meet the customer demands. The process of paint production is shown in Figure4.

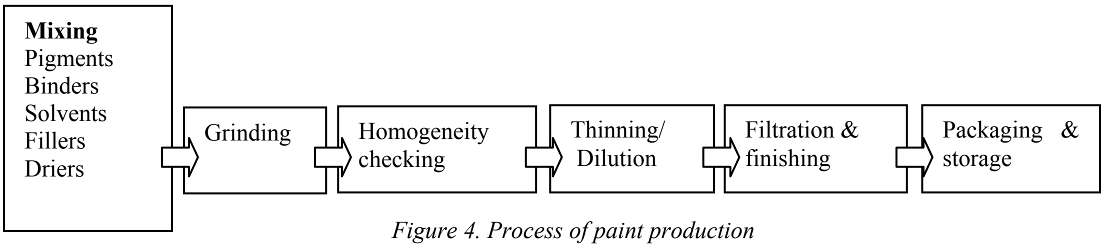


Figure 4. Process of paint production

Company was facing more rejection in terms of spoilage, shrinkage, and packaging. Management people felt that improper training, team work, lack of coordination among workers may be the possible reasons for quality loss. By introducing the proposed framework, a pilot study was conducted. Various human characteristics considered for analysis are:

SM: Self management,
PC: Participation,
FL: Flexibility,
TR: Training,
MS: Managerial support,
C&C: Communication and cooperation,
F&R: Feedback and reward,
LS: Leadership,
IS: Information sharing and
PIO: Process improvement orientation.

To assess these characteristics, a questionnaire was developed (A sample of questions is shown in Table 3). The questionnaire consists of 10 questions related to team/group behavior. Each question has been assigned 100 points; behavioral characteristics of team/group were interviewed. By considering each member as an entity (with in 6σ teams i.e. Champion, Master Black belts, Black belts, Green belts, Yellow belts). They were asked about their perception of the level of business performance and customer satisfaction and are finally evaluated according to their view point. The data was analyzed and identified reliable by computing Cronbach's alpha, as the alpha comes out to the .82

(>0.70 is generally considered to be acceptable). The sigma level(within) and sigma (overall), yield, Cp and Cpk have been calculated to check the process capability and find out the scope for improvement with respect to SCM dimensions based upon team characteristics as shown in Table 4.

Table 3- Sample questions: **(100 points for each question)**

1. Top management actively participates in SCM activities.
2. Leadership on quality practices has an impact on organization performance.
3. Organization provides training opportunities to employees that enable the extension of skills, knowledge and ability.
4. Organization allows employees to share their knowledge through training and education method.
5. Flexibility in the organization increases the SCM performance and reduces waste.
6. Team work help in increasing the SCM performance.

Table 4.Yield and six-sigma of team characteristics

Team characteristics	Entity	Yield	Sigma (within)	Sigma (Overall)	Cp	Cpk
Self management (SM)	E1toE5	95.99	2.79	3.23	1.19	0.67
Participation (PC)	E1toE5	80.92	2.37	2.31	1.40	1.13
Flexibility (FL)	E1toE5	84.13	2.19	2.43	1.52	1.17
Training (TR)	E1toE5	96.96	2.23	3.32	1.49	1.18
Managerial support (MS)	E1toE5	98.71	1.95	3.53	1.70	1.62
Communication and Co-operation (C&C)	E1toE5	97.73	2.33	3.48	1.43	1.21
Feedback and reward (F&R)	E1toE5	80.92	1.86	2.3	1.70	.60
Leadership (LS)	E1toE5	84.13	1.86	2.50	1.79	1.70
Information sharing (IS)	E1toE5	84.13	1.72	2.51	1.93	1.68
Process improvement orientation (PIO)	E1toE5	73.40	1.91	2.13	1.74	1.02

7. ANALYSIS

Table 4, presents the yield, Six-sigma (within) and Six-sigma (overall) Cp and Cpk, of team characteristics comprising of all entities (Team of 6σ). The higher the sigma level is, the more contributive and effective the team is. Graphically, the results are shown in Figure 5 (a-j).

The Figure 5 (a-j) shows some important information including process data i.e. (sample mean, sample size N, standard deviation(within) and Standard deviation (overall), potential (within) capability i.e. (process spread Cp, CPL, CPU and process capability Cpk) and overall capability (PP, PPL, PPU, Ppk) and PPM of the relevant performance. The top management can find scope for progress by comparing the within and overall performance values as shown in Table 4 and Figures 5 (a-j). The within performance value indicate the potential capability for improvement. Potential capability considers the variation within subgroups and overall performance value is for the current system performance. Cp calculates process spread using within subgroup variation.CPL is lower specification limit and CPU is upper specification limit. For calculating Cp and Pp, one must know both the upper and lower specification limits. Pp ignores subgroup and considers the overall variation of the entire process.

As shown in Figure 5(a). The Cpk of self management is .67 which is very low and needs improvement. For improving the self management at work, the principle of 5S can be used for self management.

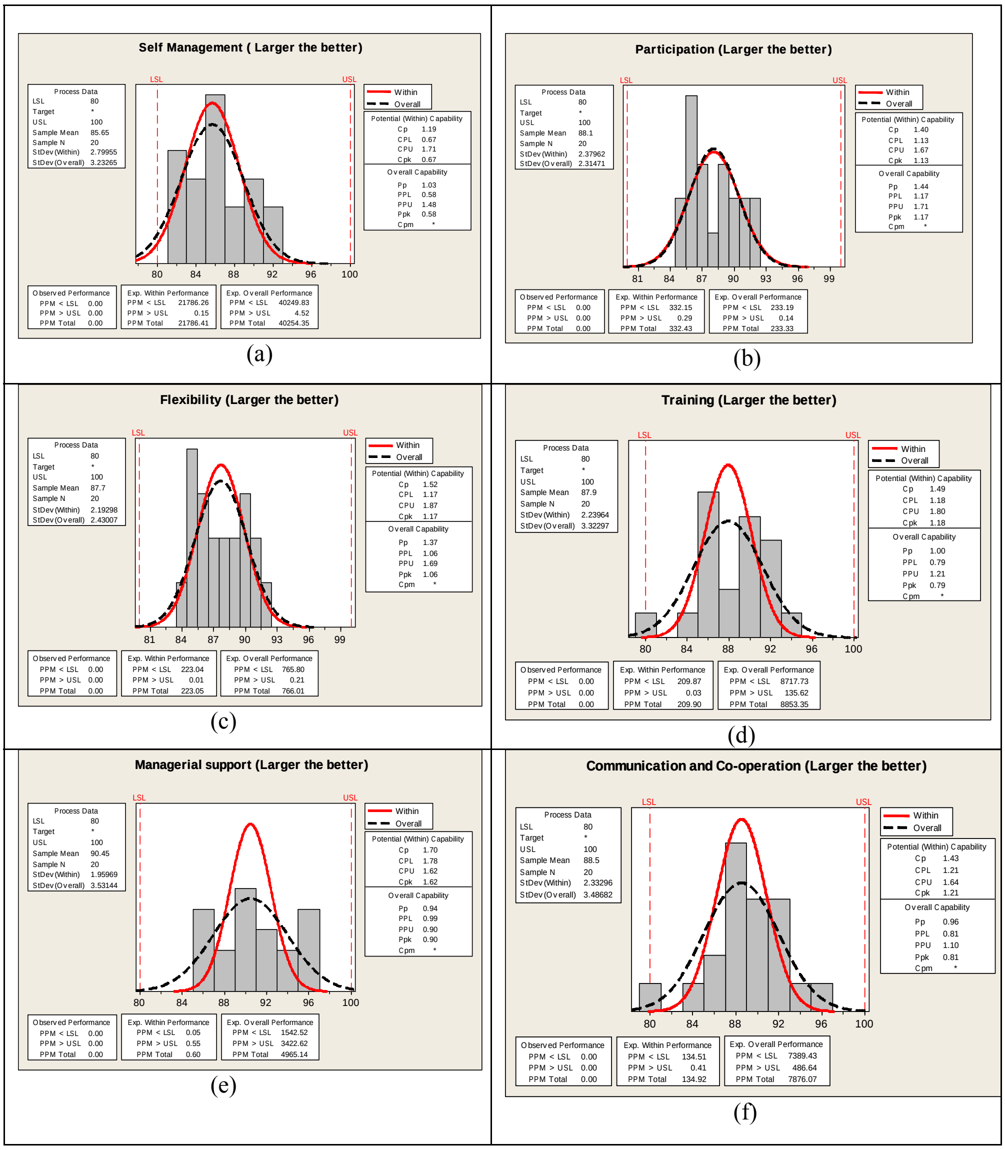
Sort (Seiri) – Separate the necessary things from the unnecessary and discard the unnecessary

Set in order (Seiton) - Neatly arrange and identify things to ease of use

Shine (Seiso) – To always clean up; to maintain tidiness and cleanliness in your workplace

Standardize (Shitsuke) – To have workers make a habit of always conforming to rules
Sustain (Seiketsu) - To constantly maintain the 4s above.

As shown in Figure 5 (e and f) and Table 4, the managerial support and communication and cooperation shows highest overall sigma level (3.53σ and 3.48σ) which support the improving of SCM performance but feedback and reward in Figure 5 (g), with lowest sigma level (2.3σ) means that is not well developed and contributes particularly towards system performance. As the management is supporting the team work culture but incorporation of proper feedback and reward system within the teams is required. So, the company should develop the feedback system.



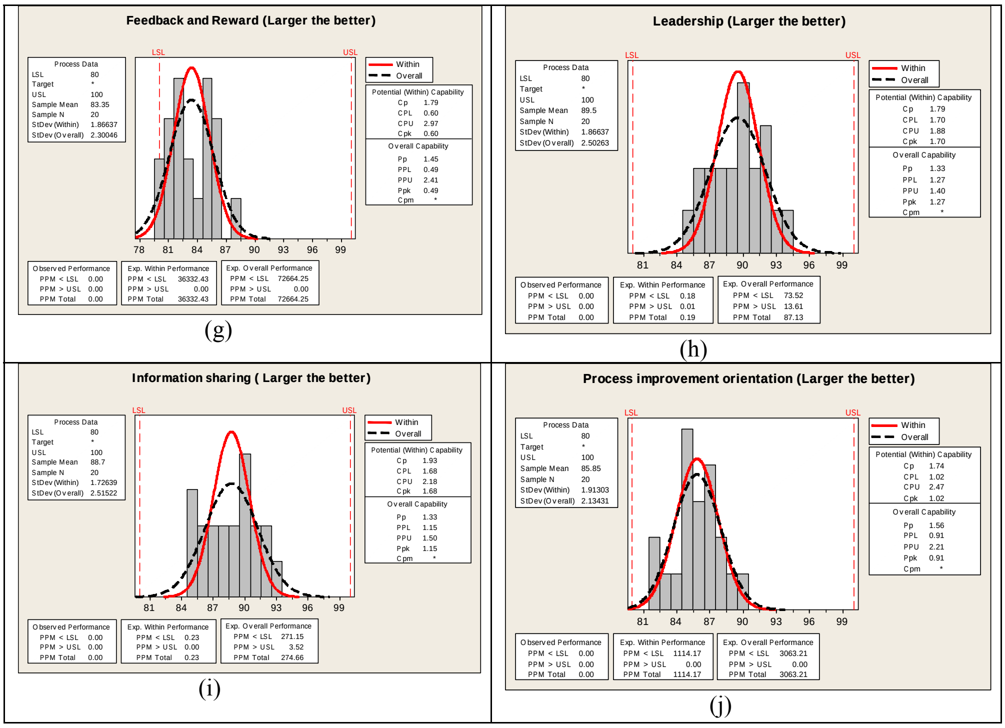


Figure 5 (a-j) - Process capability curve of Team characteristics

Leadership is one of the important factors that influence SCM implementation and a lack of leadership will be a barrier to SCM performance. Figure 5 (h) of leadership shows the maximum Cpk value i.e. 1.70 which is the ideal case. Leadership provided through Champions (senior, deployment, and project) at corporate unit and department level supported by team experts (Black Belts, Master Black belts, and Green belts) helps in successful implementation of framework.

Top management needs to support and as well as establishing the SCM strategies based upon leadership that organization need to become successful. For leadership other metrics are: The overall sigma - 2.50 and within sigma - 1.86 and yield - 84.13.

Process Improvement (Kaizen) is a method to introduce process changes to improve quality, reduce costs, or accelerate schedules. In other word process improvement is a series of actions taken to identify, analyze and improve existing processes within an organization to meet new goals and objectives. Figure 4 (j) of process improvement shows the Cpk value 1.02.

For improving the process, all the entities (Teams) of six- sigma has to participate and to help in the mobilization of all the resources timely and properly. Deming's Plan-Do-Check-Act or P-D-C-A cycle can be applied to improve the process.

In order to implement continuous improvement (P-D-C-A) more effectively, participation and information sharing among the team members is very important as evident from the Cpk values 1.13, 1.68 respectively to measure and monitor the sigma value of all dimensions.

8. MANAGERIAL IMPLICATION AND CONCLUSION

Some of the managerial implications of the study are:

(1). Top management can pay more attentions to the SCM practices which include team characteristics such as leadership, self management, and training etc. to measure the supply chain performance.

(2). Management can implement the proposed framework (6σ + SCM) in their organization to improve the supply chain performance.

(3). Training is very important for achieving the sigma level and improvement of supply chain performance so employees must be trained with adequate knowledge of (DMAIC) process.

(4). By comparing the yield and sigma level of team characteristics the top management can take corrective action for improving the lower level yields and sigma level of team. Yield values also need to be monitored to find the weak areas for improvement.

The performance measurement framework proposed in this paper provides an insight vision for continuous improvement of organizational performance with the help of team dimensions.

Using the proposed framework the companies can measure and monitor their supply chain performance based upon human dimensions. The application of this framework helps the management to understand information regarding the strength and weaknesses of the human characteristics affecting the performance.

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