

**STUDY OF SELECT PRACTICES IN
ORGANISATIONAL PERFORMANCE RELATED
WITH LEAN SIX SIGMA AND EMERGING
INFORMATION TECHNOLOGIES**

by

NEERAJ YADAV

Submitted

in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

to the



**DEPARTMENT OF MANAGEMENT STUDIES
INDIAN INSTITUTE OF TECHNOLOGY DELHI
NEW DELHI-110016, INDIA
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CERTIFICATE

The thesis entitled “**Study of Select Practices in Organisational Performance Related with Lean Six Sigma and Emerging Information Technologies**” being submitted by **Mr. Neeraj Yadav** to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy (Ph.D.) is a record of bona fide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree from the Indian Institute of Technology Delhi. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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Neeraj Yadav

ABSTRACT

Lean Six Sigma (LSS) methodology revolutionised the way of doing business in last century. From transnational organisations such as General Electric (GE) and Motorola, to small enterprises; all used Lean Six Sigma to dramatically enhance business performance, shareholder value, and customer satisfaction.

The world is now witnessing fourth industrial revolution, popularly known as Industry 4.0. Emerging Information and Communication Technologies (ICT) are propelling its adoption across all business units. Increasing use of automation, information technology, artificial intelligence is raising doubts if Lean Six Sigma will remain as powerful as ever in improving organisational performance. This research explores this aspect from several perspectives.

Impact of Lean Six Sigma on key performance indicators of organisational performance is evaluated under several determinants such as type and size of organisation, LSS focus, business sectors etc. Influence of other quality improvement methodologies including different quality management systems, Industry 4.0, emerging Information and Communication Technologies (ICT) is also assessed and found significant. Critical success factors for Lean Six Sigma when implemented using Industry 4.0 and other emerging technologies are investigated and their hierarchy established. A methodology to compare customer satisfaction - one of the most prominent indicators of business performance, is prescribed.

The research has many theoretical and social implications and brings out several revelations of significant value for practicing quality professionals as well as for organisations planning implementation of Lean Six Sigma and emerging technologies such as Industry 4.0

सार

उद्योग जगत के लिए 'लीन-सिक्स-सिग्मा' विगत सदी में एक क्रान्तिकारी पद्धति सिद्ध हुई। बहुराष्ट्रीय कंपनियों यथा जनरल इलेक्ट्रिक व मोटोरोला से ले कर सूक्ष्म व लघु इकाइयों तक सभी ने इस पद्धति का इस्तेमाल प्रमुखता से अपनी व्यापारिक उपलब्धियों, अंशधारकों के लाभ, तथा ग्राहक संतुष्टि में अभूतपूर्व सुधार लाने हेतु किया। अब जबकि समूचा विश्व चतुर्थ औद्योगिक क्रांति (जिसे इंडस्ट्री 4.0 भी कहा जाता है) के दौर से गुजर रहा है, और नवीन सूचना व प्रौद्योगिकी तकनीकें इसे नयी रफ्तार दे रही हैं, लीन सिक्स सिग्मा को एक नए परिप्रेक्ष्य में देखने की आवश्यकता है। स्वचालित उपकरण, नयी संचार प्रणालियाँ, तथा कृत्रिम बुद्धिमत्ता के अभिनव प्रयोगों के मध्य लीन-सिक्स-सिग्मा की प्रासंगिकता, उपयोगिता, तथा क्षमता में परिवर्तन अनुसंधान का विषय है। यह अनुसंधान इसी आवश्यकता को ध्यान में रखते हुए निष्पादित किया गया है।

इस अनुसंधान में लीन-सिक्स-सिग्मा के प्रभाव का विभिन्न परिचालन संबंधी सूचकांकों पर, अनेक निर्धारकों जैसे संस्था के आकार, प्रकार, व्यापार क्षेत्र, आदि के अंतर्गत परीक्षण किया गया। अन्य गुणवत्ता सुधार तकनीक व पद्धति जिनमें ISO सिस्टम, इंडस्ट्री 4.0, तथा अन्य उभरती हुई सूचना व संचार प्रौद्योगिकी शामिल हैं; लीन-सिक्स-सिग्मा को किस प्रकार प्रभावित करेंगी, इस पर भी अनुसंधान किया गया व पाया गया कि इन तकनीकों का लीन-सिक्स-सिग्मा के साथ सम्मिलित रूप से प्रयोग अधिक लाभदायक है। अतः इंडस्ट्री 4.0 जैसी तकनीकें लीन-सिक्स-सिग्मा को भविष्य में और अधिक प्रभावी बना सकती हैं।

ग्राहक संतुष्टि सूचकांक, जो कि व्यापारिक उन्नति का सर्वाधिक महत्वपूर्ण पैमाना है, की तुलना हेतु भी एक नयी विधि प्रस्तावित की गयी है।

इस अनुसंधान के विभिन्न सैद्धांतिक, सामाजिक, तथा पेशेवर निहितार्थ हैं जो कि गुणवत्ता तंत्र के पेशेवरों, व्यापारिक संस्थाओं, और उनके प्रबंधकों के लिए अत्यंत लाभकारी सिद्ध होंगे; विशेष रूप से उनके लिए जो लीन-सिक्स-सिग्मा तथा इंडस्ट्री 4.0 जैसी उभरती तकनीकों व पद्धतियों को अपने संस्थानों में अमल में लाने का प्रयास कर रहे हैं।

Keywords and List of Abbreviations Used

Keywords: Lean Six Sigma (LSS), Information and Communication Technology (ICT), Critical Success Factors, Customer Satisfaction, Customer Satisfaction Index (CSI), National Customer Satisfaction Index, Organisational Performance, Performance Indicators, Quality Improvement, Industry 4.0, Smart Manufacturing, Internet of Things, Artificial Intelligence.

Table 0.1: List of Abbreviations

ACSI	American Customer Satisfaction Index
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
ANOVA	Analysis of Variance
ASQ	American Society for Quality
BB	Black Belt
CMMI	Capability Maturity Model – Integrated
C-SAT	Customer Satisfaction
CSF	Critical Success Factors
CSI	Customer Satisfaction Index
CTQ	Critical to Quality
DEMATEL	Decision Making Trial and Evaluation Laboratory
df	Degrees of Freedom
DFSS	Design for Six Sigma
DMADV	Define-Measure-Analyse-Design-Verify
DMAIC	Define-Measure-Analyse-Improve-Control
DOE	Design of Experiments
EFA	Exploratory Factor Analysis
EVOP	Evolutionary Operations
FMEA	Failure Mode and Effect Analysis
GB	Green Belt
IATF	International Automotive Task Force
ICT	Information and Communication Technology
IIOT	Industrial Internet of Things
IOE	Internet of Everything
IOT	Internet of Things
ISM	Interpretive Structural Modelling
ISO	International Organisation for Standardisation
JIT	Just in Time
KMO	Kaiser Meyer Olkin Test
KPI	Key Performance Indicator
KRA	Key Result Area

LSS	Lean Six Sigma
M2M	Machine to Machine
MBB	Master Black Belt
MICMAC	Cross-Impact Matrix Multiplication Applied to Classification
MSA	Measurement System Analysis
MSME	Ministry of Small and Medium Enterprises
NA	Not Applicable
NCSI	National Customer Satisfaction Index
NIST	National Institute of Science and Technology
NMIU	National Monitoring and Implementation Unit
P2M	Person to Machine
P2P	Person to Person
PCA	Principal Component Analysis
PFD	Process Flow Diagram
PI	Performance Indicator
QA	Quality Assurance
QC	Quality Control
QM	Quality Management
QMS	Quality Management System
RFID	Radio Frequency Identification
ROI	Return on Investment
RQ	Research Question
SCADA	Supervisory Control and Data Acquisition
SE	Standard Error
SME	Small and Medium Enterprise
SMED	Single Minute Exchange of Dies
SPC	Statistical Process Control
SQC	Statistical Quality Control
TISM	Total Interpretive Structural Modelling
TPM	Total Productive Maintenance
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TPS	Toyota Production System
TQM	Total Quality Management
TRIZ	Theory of Inventive Problem Solving
VOC	Voice of Customer
VSM	Value Stream Mapping
WSN	Wireless Sensing Network
ZED	Zero Defect - Zero Effect

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