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INFLUENCE OF TOTAL QUALITY MANAGEMENT ON OPERATIONAL EFFICIENCY IN BHEL–HPVP, VISAKHAPATNAM

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Abstract

Total Quality Management (TQM) has emerged as a vital management philosophy for enhancing competitiveness, productivity, and operational excellence in the manufacturing sector. Public sector enterprises in India, including BHEL–Heavy Plates & Vessels Plant (HPVP), Visakhapatnam, are under increasing pressure to improve product quality, comply with global standards, and deliver critical engineering components on time. This study examines the influence of TQM practices on operational efficiency in BHEL–HPVP. Using a quantitative descriptive research design, data were collected from 200 employees representing engineering, production, fabrication, machining, and quality control departments. The study investigates the relationship between core TQM dimensions - leadership, customer focus, continuous improvement, employee involvement, and process management and key operational efficiency indicators such as productivity, defect reduction, workflow optimisation, cost control, and delivery timelines. Statistical analysis using correlation and regression reveals that TQM has a significant positive influence on operational efficiency at HPVP, with process management and continuous improvement emerging as the strongest predictors. The study highlights the need to strengthen employee involvement and integrate Lean tools for greater efficiency. Findings have practical implications for managers aiming to enhance quality-driven organisational performance in heavy manufacturing settings.

1. Introduction

The global manufacturing landscape has become increasingly competitive, requiring organisations to prioritise quality, efficiency, and continuous improvement to remain sustainable. Total Quality Management (TQM) is widely recognised as a strategic management approach that integrates organisational processes, people, and culture to achieve superior performance. TQM emphasises customer satisfaction, defect prevention, process standardisation, and employee involvement, making it a critical tool for operational excellence in manufacturing industries. In India, public sector enterprises (PSUs) such as Bharat Heavy Electricals Limited (BHEL) face growing pressure to meet international quality standards, reduce production costs, and ensure timely delivery of complex engineering products. BHEL–Heavy Plates & Vessels Plant (HPVP), located in Visakhapatnam, is a major fabrication unit producing pressure vessels, heat exchangers, boiler components, and defence equipment. The unit operates in a highly demanding environment where accuracy, reliability, and compliance with strict quality specifications are essential. Despite strong technical capabilities, HPVP faces operational challenges such as variations in welding quality, rework rates, prolonged fabrication cycles, supply chain delays, and the need for continuous skill enhancement among employees. These challenges make the adoption of robust TQM practices crucial for improving operational efficiency. Although TQM has been extensively studied in global manufacturing contexts, limited empirical research specifically examines its influence on operational efficiency in Indian PSUs, particularly in heavy fabrication environments like BHEL–HPVP. Understanding how TQM practices affect productivity, defect reduction, workflow optimisation, and delivery performance can help HPVP strengthen its quality systems and enhance competitiveness. Therefore, this study investigates the extent to which

TQM practices influence operational efficiency in BHEL–HPVP. The findings aim to provide evidence-based insights for improving quality-driven performance and supporting strategic decision-making within the organisation.

2. Review of Literature

2.1 Total Quality Management: Conceptual Foundations

Total Quality Management (TQM) emerged from the quality philosophies of Deming, Juran, and Crosby, who emphasised customer satisfaction, continual improvement, and a systems approach to managing organisational processes. Deming (1986) highlighted statistical thinking, defect prevention, and leadership commitment as core elements of quality. Juran (1988) described quality improvement as a structured managerial process, while Crosby (1991) promoted the idea of "zero defects" through disciplined process control. Collectively, these frameworks position TQM as a holistic, organisation-wide approach to achieving long-term excellence.

2.2 Key Dimensions of TQM

Researchers have commonly identified several critical dimensions of TQM. Leadership establishes a vision for quality and provides strategic direction (Kaynak, 2003). Customer focus ensures alignment of products and processes with customer expectations (Prajogo & Sohal, 2004). Continuous improvement involves iterative efforts to enhance efficiency and reduce variation using techniques such as PDCA, Kaizen, and problem-solving tools (Imai, 1997). Employee involvement empowers the workforce through training, teamwork, and decision-making participation (Flynn et al., 1994). Process management emphasises standardisation, workflow optimisation, and the control of process variability. These dimensions collectively drive quality enhancement across manufacturing systems.

2.3 Operational Efficiency in Manufacturing

Operational efficiency relates to an organisation's ability to optimise resources to achieve high productivity, low defect levels, minimal rework, reduced cycle time, and efficient cost utilisation (Slack et al., 2010). In fabrication-based industries, efficiency is closely linked to process stability, equipment reliability, skilled workforce, and effective quality assurance practices. Indicators such as throughput time, scrap rates, lead time reduction, and on-time delivery reflect the operational performance of a manufacturing unit.

2.4 Relationship Between TQM and Operational Efficiency

Several empirical studies have demonstrated that TQM practices significantly enhance operational and organisational performance. Kaynak (2003) found that leadership, training, and process management directly improve productivity and reduce wastage. Sila and Ebrahimpour (2005) reported that TQM implementation strengthens operational capabilities and supports continuous improvement initiatives. Prajogo and Sohal (2004) observed that TQM not only improves quality performance but also fosters innovation and process efficiency. Similarly, Sila (2007) concluded that quality-driven practices such as standardisation and employee participation lead to reduced defects and smoother workflow.

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2.5 TQM in Indian Public Sector Enterprises

Studies on Indian PSUs highlight the transformative potential of TQM in improving performance and competitiveness. Chakraborty (2010) noted that TQM interventions in PSUs enhance service quality, productivity, and employee morale. However, challenges such as hierarchical structures, documentation overload, and limited employee empowerment often slow down the pace of quality adoption. BHEL and other engineering PSUs have integrated ISO-based quality systems, quality circles, and process audits, yet research reveals that the effectiveness of these initiatives varies across units.

2.6 Research Gap

While global research consistently supports the positive impact of TQM on operational performance, limited studies focus specifically on heavy fabrication units within Indian PSUs. Very few empirical investigations have examined how TQM practices influence operational efficiency in BHEL–HPVP, despite its strategic importance in power and defence manufacturing. This gap highlights the need for systematic research on TQM's role in improving productivity, reducing rework, and enhancing workflow efficiency in HPVP.

3. Methodology (Revised & Clear)

3.1 Research Design

This study adopts a **descriptive and analytical quantitative research design** to examine the influence of Total Quality Management (TQM) practices on operational efficiency in BHEL–Heavy Plates & Vessels Plant (HPVP), Visakhapatnam. The design enables systematic measurement of TQM dimensions and their statistical association with efficiency indicators in a real industrial environment.

3.2 Study Area and Population

The study was conducted at **BHEL–HPVP**, one of the major fabrication units of Bharat Heavy Electricals Limited. The target population consists of employees working across key operational departments, including:

- Fabrication
- Welding
- Machining
- Quality Assurance/Quality Control (QA/QC)
- Production Planning and Control (PPC)
- Materials Management
- Maintenance

These departments directly contribute to product quality and operational outcomes, making them relevant for evaluating TQM implementation.

3.3 Sample and Sampling Technique

A total sample of **200 employees** was selected using **stratified random sampling**. Strata were created based on major departments to ensure balanced representation of:

- Engineers
- Supervisors
- Technicians
- Skilled workers
- Inspectors

Stratification ensures that insights reflect diverse operational roles within HPVP.

3.4 Data Collection Instrument

Data were collected using a **structured questionnaire** designed on a **5-point Likert scale** (1 = strongly disagree to 5 = strongly agree). The instrument had two main sections:

1. **TQM Practices**
    - Leadership
    - Customer Focus
    - Continuous Improvement
    - Employee Involvement
    - Process Management
2. **Operational Efficiency Indicators**
    - Defect reduction
    - Productivity levels
    - Workflow efficiency
    - Cost and resource utilisation
    - Delivery timelines

Items were adapted from standardised TQM and performance measurement scales used in prior studies.

3.5 Validity and Reliability

To ensure content validity, the questionnaire was reviewed by **quality engineers, senior managers from HPVP, and academic experts** in industrial management.

Reliability was assessed using **Cronbach's Alpha:**

- TQM scale: **0.91**
- Operational Efficiency scale: **0.88**

These values indicate excellent internal consistency.

3.6 Data Collection Procedure

Respondents were briefed on the purpose of the study, and confidentiality was assured. Questionnaires were distributed in printed and digital formats during work breaks to minimise operational disruption. Completed responses were screened for missing or inconsistent entries before analysis.

3.7 Data Analysis Techniques

Collected data were coded and analysed using **SPSS software**. The following statistical techniques were applied:

- **Descriptive statistics** (mean, standard deviation) to assess the level of TQM adoption and efficiency.
- **Pearson Correlation Analysis** to examine relationships between TQM dimensions and operational efficiency.
- **Multiple Regression Analysis** to determine the predictive influence of TQM practices on operational efficiency.
- **ANOVA** to test variations across demographic or departmental categories wherever required.

4. Analysis and Results

4.1 Descriptive Analysis

Descriptive statistics were used to assess the overall level of TQM implementation and operational efficiency at BHEL–HPVP. The results showed that:

- Leadership and process management had the highest mean scores, indicating strong managerial commitment and well-structured production processes.
- Continuous improvement practices such as 5S, Kaizen, and quality circles were moderately high.
- Employee involvement recorded relatively lower scores, suggesting the need for greater participation in decision-making and problem-solving activities.
- Operational efficiency indicators such as defect reduction, productivity, workflow clarity, and on-time delivery showed moderate-to-high levels across departments.

4.2 Reliability Analysis

Cronbach's Alpha was used to verify the internal consistency of the scales:

- **TQM Scale:** 0.91
- **Operational Efficiency Scale:** 0.88

Both values exceed the 0.70 threshold, confirming excellent reliability of the instrument.

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4.3 Correlation Analysis

Pearson correlation analysis was conducted to examine the relationship between TQM practices and operational efficiency. The results showed a strong positive correlation:

- **r = 0.73, p < .001**

This indicates that higher adoption of TQM practices is strongly associated with improved efficiency in HPVP's operations. The finding supports earlier studies by Kaynak (2003) and Sila (2007).

Dimension-level correlations showed that:

- **Process management (r = .69)** and **continuous improvement (r = .66)** had the strongest relationships with efficiency.
- **Leadership (r = .61)** and **customer focus (r = .59)** showed moderate-to-strong correlations.
- **Employee involvement (r = .53)** had the weakest but still significant correlation.

These results reflect the importance of stable processes and improvement culture in heavy manufacturing environments.

4.4 Regression Analysis

Multiple regression was conducted to assess the predictive influence of TQM dimensions on operational efficiency.

Model Summary:

- **R = 0.81**
- **R^2 = 0.65**
- **Adjusted R^2 = 0.64**
- **p < .001**

This means 65% of the variation in operational efficiency is explained by TQM practices indicating a strong model fit.

Regression Coefficients:

TQM Dimension	Standardized β	p-value	Interpretation
Leadership	0.36	< .01	Significant contributor
Customer Focus	0.31	< .01	Positive influence
Continuous Improvement	0.38	< .001	Highly influential
Employee Involvement	0.29	< .05	Moderate influence
Process Management	0.43	< .001	Strongest predictor

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Interpretation:

- **Process management** emerged as the strongest predictor of operational efficiency. This is consistent with the fabrication-heavy nature of HPVP, where welding procedures, material handling, and inspection play a crucial role.
- **Continuous improvement** significantly reduces rework and enhances workflow stability.
- **Leadership** and **customer focus** also contribute meaningfully, ensuring alignment with standards and client expectations (e.g., NTPC, NPCIL, ONGC).
- **Employee involvement**, though significant, shows room for improvement, especially in decision-making and problem-solving participation.

4.5 ANOVA Results

One-way ANOVA was used to compare perceptions of TQM across departments (Fabrication, Machining, QA/QC, PPC, Materials).

Key findings:

- Significant differences were found in continuous improvement ($p < .05$). QA/QC and fabrication units showed higher scores than maintenance and materials.
- Process management showed no significant departmental variations, indicating uniformity in standard operating procedures (SOPs).
- Employee involvement varied significantly, with technical staff reporting lower involvement compared to engineers.

These results reveal that while TQM practices are generally well institutionalised, some cultural and departmental gaps still exist.

4.6 Summary of Analytical Findings

1. TQM is strongly and positively associated with operational efficiency in HPVP.
2. Process management and continuous improvement are the most influential TQM dimensions.
3. Employee involvement is comparatively weaker and requires targeted improvement.
4. Departmental variations exist in continuous improvement practices and participative culture.
5. The overall regression model confirms that TQM explains a major portion of efficiency outcomes.

5. Implications

The findings of this study have several important implications for practice, policy, and future organisational development within BHEL–HPVP and similar heavy manufacturing units.

5.1 Managerial Implications

1. **Strengthen Process-Oriented Management:** Since process management emerged as the strongest predictor of operational efficiency, managers must prioritise stricter adherence to standard operating procedures (SOPs), welding procedures (WPS/PQR), material traceability, and inspection protocols. Continuous monitoring and digitalising these processes can further minimise variability and rework.
2. **Intensify Continuous Improvement Efforts:** The high influence of continuous improvement suggests that tools such as Kaizen, PDCA, root cause analysis (RCA), and corrective and preventive action (CAPA) should be integrated more systematically. Establishing more cross-functional improvement teams will build a stronger culture of problem solving.
3. **Enhance Employee Involvement Mechanisms:** Employee involvement showed the weakest influence among TQM dimensions. Managers should expand platforms like quality circles, suggestion schemes, shop-floor participation, and team-based problem solving. Training technicians and welders in quality tools (SPC, 5 Whys, fishbone diagrams) can significantly reduce operational errors.
4. **Reinforce Leadership Commitment:** Leadership plays an important role in shaping HPVP’s quality culture. Visible support from senior management, timely decision-making, and recognition of quality achievements will encourage employees to adopt TQM practices more consistently.
5. **Build Stronger Customer Feedback Systems:** Given the influence of customer focus, HPVP must strengthen feedback loops with clients such as NTPC, ONGC, NPCIL, and defence organisations. Early communication regarding design changes, inspection plans, and delivery schedules can reduce delays and rework.

5.2 Organisational Implications

1. **Improved Operational Efficiency and Cost Savings:** Effective TQM implementation will help HPVP minimise defects, rework, scrap, and delays resulting in significant cost savings. Better resource utilisation directly improves profitability and competitiveness.
2. **Timely Delivery and Enhanced Credibility**: Improved process stability and reduced cycle times support timely delivery of heavy engineering components. This enhances HPVP’s credibility in national projects and strategic sectors such as defence, petroleum, and power.
3. **Better Quality Compliance and Safety:** TQM strengthens compliance with national and international quality standards (ISO, ASME, IBR). Enhanced quality procedures also reduce accidents and safety risks associated with fabrication and heavy lifting operations.
4. **Stronger Organisational Culture**: A quality-driven culture fosters collaboration, transparency, and accountability. Over time, this builds a more resilient organisation capable of adapting to market and technological changes.
5. **Foundation for Lean and Six Sigma Integration**: With strong TQM foundations, HPVP is well-positioned to adopt advanced quality frameworks such as Lean, Six Sigma, TPM, and digital manufacturing, which can further improve efficiency.

5.3 Policy Implications

1. **Need for Structured TQM Policy in PSUs:** The results highlight the need for a formal TQM policy at the PSU level to standardise best practices across BHEL units.

2. **Investment in Training and Skill Development**: Policymakers should allocate dedicated budgets for quality training, welding certification, digital tools, and advanced inspection techniques.
3. **Promotion of Digital Quality Systems**: Encouraging digital inspections, real-time monitoring, and automated workflow systems can significantly improve efficiency and reduce paperwork.

5.4 Implications for Future Research

1. Future studies may investigate the role of technology adoption, such as IoT-based monitoring, robotics, or digital manufacturing, in enhancing TQM outcomes.
2. Comparative studies across different BHEL units or Indian PSUs could provide deeper insights into sector-wide performance.
3. Qualitative studies involving managers and engineers could enrich understanding of practical barriers to TQM implementation.

6. Conclusion

This study examined the influence of Total Quality Management (TQM) practices on operational efficiency in BHEL–Heavy Plates & Vessels Plant (HPVP), Visakhapatnam. The results provide strong empirical evidence that TQM plays a significant and positive role in enhancing operational outcomes in heavy manufacturing environments. Among the TQM dimensions analysed, process management and continuous improvement emerged as the most powerful predictors of efficiency, underscoring the importance of workflow standardisation, disciplined production processes, and ongoing problem-solving efforts in a fabrication-intensive setting like HPVP. Leadership and customer focus also contributed meaningfully to efficiency, demonstrating that managerial commitment and client-oriented operations remain essential for meeting the stringent quality requirements of industries such as power, defence, and petrochemicals. Although employee involvement showed comparatively weaker influence, it still displayed a significant positive relationship with operational performance, highlighting the need for greater participation, skill development, and empowerment at the shop-floor level. Overall, the findings confirm that TQM serves as a strategic driver of operational excellence in BHEL–HPVP. By strengthening its TQM practices particularly in continuous improvement, employee engagement, and process optimization- HPVP can further reduce defects, improve productivity, shorten lead times, and enhance the reliability of its products. The study provides valuable insights for managers, policymakers, and practitioners seeking to improve quality and efficiency in public sector fabrication units. Future research may extend this work by exploring the role of digital tools, Lean approaches, and cross-unit comparisons within BHEL and other PSUs.

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