

IMPACT OF TOTAL QUALITY MANAGEMENT PRACTICES ON MANUFACTURING PROCESS INNOVATION IN MECHANICAL ENGINEERING FIRMS

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Abstract: This paper examines how systematic quality management practices impact manufacturing process innovation in mechanical engineering firms. Internal opposition to organizational innovation as well as ineffective linkages between existing quality management systems and current manufacturing systems, however, are critical factors limiting process innovation within such firms. To overcome these limitations, this paper introduces a Total Quality Management based model of process innovation that includes practices of employee involvement, continuous improvement, customer focus, process control and data-driven quality management. By applying this new model, firms should be able to increase productivity and efficiency, reduce defect rates and production costs, improve their manufacturing flexibility, increase the pace of innovation, and ultimately better compete in the global market.

Keywords: Process Innovation, Total Quality Management, Mechanical Engineering Companies, Efficiency Gains, Manufacturing Process Innovation, Quality Management Practices.

1. Introduction

Total Quality Management (TQM) is defined as a management system aiming at continuous improvement of organization's performance through customer satisfaction, involving employees, process control and systematic improvement [3]. TQM is considered to be a method or system in which problems in processes can be identified, process variation can be reduced, products can be made better and employees can be encouraged to get involved in the activities of their areas [1].

Many research papers have examined the interrelationships between total quality management (TQM) and innovation [5][6], as TQM increases organization's internal capabilities for innovations [6]. Prajogo and Sohal proposed the conceptual link between the two [8], and Perdomo-Ortiz [7] stated that TQM has the capacity to generate a firm's innovative capabilities. Additionally, a linkage has been demonstrated by Kaynak [4] that relationships between activities of quality management have an effect on operations performance in the manufacturing.

Mechanical engineering companies need process innovation because process requirements such as precision, productivity, and adaptability are typically higher than those needed by products in mechanical engineering companies. Improving production processes, better machine operating techniques, using automated systems, development of inspection systems or introducing new technologies fall under the purview of mechanical engineering process innovation. Beyond product innovation, some evidence indicate that the role of quality management also extends to production process. From this stream of thought, several researchers have been studying the link between quality management practices and innovation. For example, a link between quality-oriented practices and different types of process innovation have been identified by Kim et al. [7]. Camisón and Duverlies-Puig [2] on the other hand argue that simply quality management is enough to induce process innovation, so investigating the underlying mechanisms of the relationships between the two is essential for successful

applications of this stream of research to mechanical engineering process innovation. Yet still, there remain considerable obstacles preventing TQM and manufacturing process innovation from effectively linking: opposition to change, lack of employee participation, the poor articulation between quality practice and new technologies, and the lack of actual results from TQM initiatives to provide linkages to process innovation. While industrial engineering studies have shown that quality management provides a basis for technological innovation[4,5,6], the extent to which this contribution is realized varies among industries and organizational type.[3,7] The connection to innovation, according to Perdomo-Ortiz [8], appears to go through the presence of business innovation capacities; in the Brazil, a positive linkage between quality management and innovations was documented,[3], as has the role of ongoing processes related to continuous improvement as a precursor to innovation[17]. The exploration of the connections between TQM and manufacturing process innovation in mechanical engineering enterprise may thus provide insights into how principles of employee participation, continuous improvement, customer focus, process control and quality may be integrated into manufacturing processes to increase operational performance and innovation capacity.

2. Literature Review

Despite wide use in production to foster better products, stronger operations, and more effective organizations, Total Quality Management (TQM) has been analyzed for a long time by researchers trying to link it to firm performance, such as by Prajogo and Sohal [10] and their exploration of how TQM affects innovation. Other authors like Kayaka[4] also look into the consequences of TQM implementation on organizations' performance. Although quality initiatives may affect companies differently depending on a range of circumstances (Prajogo and Sohal

[12]), applications of TQM in certain contexts, such as the Portuguese footwear industry (Abrunhosa et al. [1]), show it enables not just quality gains but also innovation. These papers show TQM should be evaluated beyond defect reduction and quality performance, since it underpins certain competences essential for firms' ability to innovate.

Despite much debate, numerous later investigations confirmed that there are strong ties between quality management, technological, and process innovation (e.g. [8][9]). Quality management in particular has been considered as a determinant of business innovation capability; Perdomo-Ortiz et al. [8] observed that quality focused firms possess a strong predisposition towards innovation. The same authors supported a similar stance when analyzing the link between quality management, innovation capability and technological innovation [9]. Perdomo-Ortiz et al. [9] highlighted organizational capability as an intervening variable between TQM and technological innovation, therefore underlining that quality management boosts innovation through enhanced organizational capabilities. Similarly, Kim et al. [6] stressed that quality management promotes innovation while Sadikoglu and Zehir [13] concluded that TQM can be analyzed and explained in terms of the impact of the practice on employee performance and firm innovation (implying that employee performance and innovation performance mediate between TQM and performance outcomes). Finally, the above theories have supported that quality management may impact firm performance indirectly by influencing the level of firm innovativeness and therefore firm effectiveness (e.g., [14]).

In recent years much research has focused upon manufacturing process innovation, this is an extremely topical area for companies operating within the mechanical engineering sectors. Camisón and Puig-Planas [2] questioned whether quality management practices were truly enough to stimulate process innovation; to date the literature offers

few insight into the mechanisms that drive process innovation. Quality management practices have been empirically demonstrated to promote innovation for Brazilian manufacturers [3] and as such TQM has a number of contributions to make as to how innovation can be sustained in a manufacture sector [7]. This once more highlights TQM's crucial position within an organization focused on innovation. It was demonstrated that for ISO9001 certified manufacturing organizations, innovation acts as a mediating variable within the relationship between quality management practice and performance [5]. In addition, continuous improvement behaviors and how they lead to a positive impact on innovation, was demonstrated by Lizarelli et al. [17]; while Sun et al. [15] revealed the relationship between quality management practice and enterprise innovation performance. Quality management and its relationship to both innovation and competitive advantage within ISO9001 certified organizations is further discussed by Oliveira et al.[16]. Furthermore, process innovation, product innovation, quality management adoption and supplier buyer collaboration, which have all been shown to be important predictors of firm performance were examined by Gunawan et al. [18]. These findings, suggest that certain TQM practices, employee involvement, continuous improvement and process management, that have long been theorized to promote innovation, remain under-researched in the process innovation context within mechanical engineering companies. Therefore, the current research aims to explore TQM practices on manufacturing process innovation.

3. Current Approaches to TQM and Manufacturing Process Innovation

The evolution of manufacturing process innovations in mechanical engineering has shifted away from a focus primarily upon quality assurance toward a total quality management philosophy. A conventional quality management approach primarily involves inspection, or defect reduction, or

production efficiency; a TQM approach is more concerned with customer satisfaction, employee empowerment, continuous improvement, process control, suppliers and decision making based on facts. There are a large number of papers documenting relationships between organizational/process/product innovation and TQM [6, 8, 9, 11, 12, 15] and numerous manufacturing studies documenting how quality management can aid in fostering a productive environment and encouraging innovation performance and competitive advantage [3, 7, 16]. Nonetheless, a problem may still remain in the implementation of TQM in process innovations within the mechanical engineering industry, such as possible conflicts between TQM practices, organization contexts, and new process implementations. Interaction effects among individual TQM practice and organizational capability and manufacturing environmental conditions are significant.

3.1 Disadvantages

Two flaws in the current system are

3.1.1 Lack of Effective Integration of Quality Management and Process Innovation

Some firms apply TQM, yet do not integrate it directly to manufacturing process innovation; the benefits are largely accrued in higher product quality, reduced defects, standardization of production processes, and better manufacturing performance, instead of manufacturing process innovation. Although quality management practice has an association with innovation [6, 10], adoption of TQM does not necessarily lead to process innovation. Camisón and Puig-Navault [2] stressed the need for establishing whether quality management practice can induce process innovation and Perdomo-Ortiz et al. [8, 9] considered the innovation capability as a prerequisite for TQM to lead to technological innovations. The disconnection between quality improvement and innovation may hamper the adoption of advanced production technologies and processes, plant layout, and

production workflow in mechanical engineering firms. Employees in general must therefore be engaged continuously in innovation activities.

3.1.2 Limited Employee Involvement and Continuous Improvement for Innovation

Employee involvement and continuous improvement are both important aspects of a TQM approach, yet they are put into practice in various ways. Prajogo and Sohal [12] highlighted that different elements of TQM may have a greater or lesser impact on firm performance for quality and innovation performance, while Lizarelli et al. [17] established that continuous improvement activities could effect technological innovation; thus a culture of improvement is necessary. Sadikoglu and Zehir [13] investigated the link between TQM practices and performance measures. In the absence of staff involvement in problem identification, solution generation and change, there is no gain for the firm in terms of process innovation in all the areas mentioned. Without this staff engagement processes cannot be optimized, productivity improved or new technologies implemented, which hampers potential innovation in the mechanical engineering context.

3.2 Input Data

Data set of twenty respondent observations, denoted R01 through R20, have 16 attributes collected for the goal of understanding the links between process innovation in mechanical engineering manufacturing and TQM practices. Eight of the TQM variables, denoted TQM1–TQM8, correspond to management commitment, employee involvement, customer focus, continuous improvement, process management, quality control, supplier quality management, and training and education. Likewise, eight of the PI variables, denoted PI1–PI8, correspond to improved manufacturing methods, automation, efficiency, defect reduction, cost reduction, flexibility, new technologies, and overall process innovation, where each attribute can take on a value from 1 (least ability or

implementation) to 5 (greatest ability or implementation). While the record simulated instead of being from actual data, the analysis may be thought of in terms of how the ideas described in this chapter would be applied. The results provided here should be viewed as only an example of this method, not as information concerning the true nature of mechanical engineering manufacturing processes. It lends itself well to descriptive analysis, reliability and validity assessment, correlation analysis, and regression analysis of the links between TQM practices and process innovation.

Respondent	Total Quality Management (TQM) Practices								Manufacturing Process Innovation (PI)							
	TQM1	TQM2	TQM3	TQM4	TQM5	TQM6	TQM7	TQM8	PI1	PI2	PI3	PI4	PI5	PI6	PI7	PI8
R01	5	4	5	5	4	5	5	5	5	4	5	5	4	5	5	5
R02	4	4	4	5	4	4	4	4	4	4	5	4	4	4	4	5
R03	3	4	3	3	4	3	3	4	3	3	4	3	3	4	3	4
R04	5	5	4	5	5	5	4	5	5	5	5	5	5	4	5	5
R05	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3	4
R06	2	3	3	2	3	3	2	3	2	3	3	2	3	3	2	3
R07	5	4	5	4	5	5	5	5	4	5	5	4	5	5	5	5
R08	3	3	4	3	3	4	3	3	3	3	4	3	3	3	3	4
R09	4	5	4	5	4	4	5	4	4	5	5	4	4	5	5	5
R10	5	5	5	4	5	5	4	5	4	5	4	5	4	5	4	5
R11	3	4	3	4	3	3	4	3	3	4	3	3	4	3	3	4
R12	4	4	5	4	5	4	4	5	4	5	4	5	4	4	4	5
R13	2	2	3	3	2	3	2	3	2	2	3	3	2	3	2	3
R14	5	4	5	5	5	4	5	5	5	5	5	4	5	5	5	5
R15	4	3	4	4	3	4	4	3	4	3	4	4	3	4	4	4
R16	3	4	4	3	4	4	3	4	3	4	4	3	4	4	3	4
R17	5	5	4	5	4	5	5	5	5	5	5	5	4	5	5	5
R18	4	4	3	4	4	3	4	4	4	3	4	4	3	4	4	4
R19	3	3	3	4	3	4	3	3	3	3	4	3	3	3	4	3
R20	5	4	5	5	5	5	4	5	5	5	5	5	5	4	5	5

5-Point Likert Scale: Responses were coded from 1 (Strongly Disagree) through 2 (Disagree), 3 (Neutral) and 4 (Agree) to 5 (Strongly Agree).

4. Experimental Results

Overall, the relationship between manufacturing process innovation and TQM practices over the 20 records appears highly positive in general. Overall TQM means are very high, and the means of process innovation indicators are also relatively high. On the record-level, TQM practice records with higher TQM scores tend to have higher scores for manufacturing process innovation. The scatter plot provides very strong evidence that overall levels of TQM are strongly and linearly related to overall levels of process innovation and that individual level associations between most TQM and process innovation scores are positive. Essentially in this data, where quality management practices are implemented in a more consistent way (quality control, employee involvement, process improvement, continuous

improvement, and quality management, customer focus, and training), reports of manufacturing process innovation are more positive.

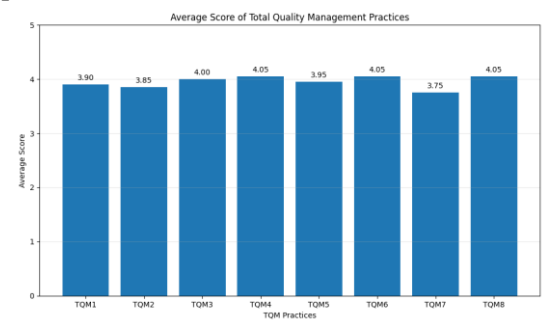


Figure 1. Mean Scores of the Eight TQM Practices

The eight TQM scores are means across five-point scales (Figure 1). Management commitment, employee involvement, customer focus, customer focus, continuous improvement, process management, quality control, and training and education are scored across a 5-point scale. The means are very high (and clustered very closely together around 4), meaning companies reported implementing the highest numbers of quality management practices on the highest of the five levels. Training and education, continuous improvement, quality control were scored at the top 4.05, while the lowest of the group was on training and education at number 3.75.

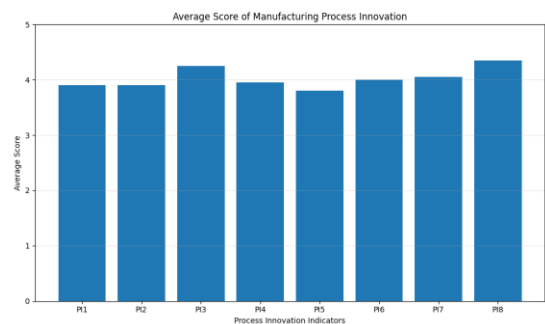


Figure 2. Mean Scores of the Process Innovation Indicators

Figure 2 presents the means for the 8 PI elements. The scores are on a 5 point scale. New manufacturing techniques, process automation, manufacturing efficiency, defect reduction, cost reduction, manufacturing flexibility, technology adoption and process improvement, the indicators, average

responses near and above a 4. PI8 and PI3 have the highest means. PI5 had the lowest.

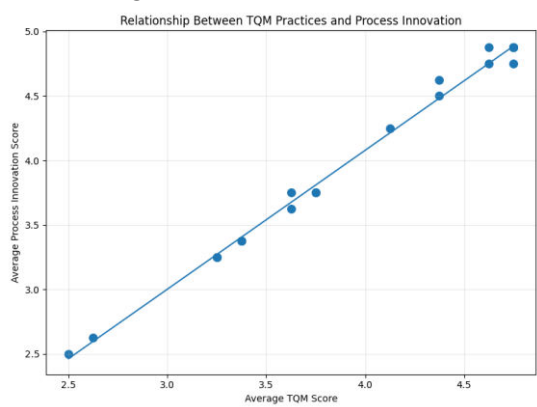


Figure 3. Overall TQM Score Versus Overall Process Innovation Score

The respondent level data is plotted in figure 3, each respondents overall TQM score against their overall process innovation score. Points increase steadily with TQM score and a regression line, fitted through the data, follows the trend closely and indicates a positive relationship between TQM and process innovation.

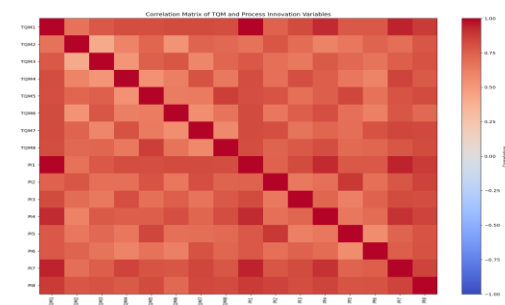


Figure 4. Correlation Matrix of TQM and Process Innovation Variables

The correlation between the 8 TQM variables and the 8 PI variables is presented in Figure 4. Colour shading indicates the level and direction of the correlation. Overall an positive correlation can be observed, with TQM high and PI scores high together, as well as the majority of the correlations positive.

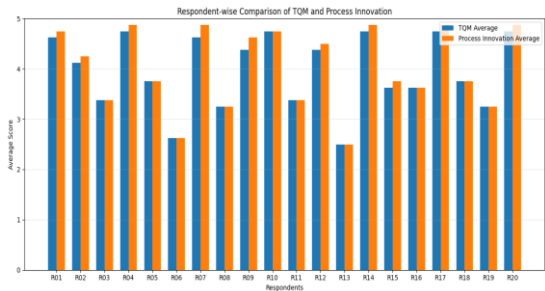


Figure 5. Respondent-Wise Comparison of TQM and Process Innovation

The figure shows the means of each respondent's TQM scores and PI scores. Paired bars of different heights for each case show the frequency of each different combinations of values. For example, high TQM and high PI. Overall a strong positive correlation is observed between the two variables. A number of individual scores deviate from this overall trend however.

5.1 Methodology

This study uses mechanical engineering and manufacturing process innovation as a case and attempt to verify the potential of implementing systematic quality management (QMs) on the improvement of manufacturing processes. A quantitative method with predefined five-point scale items has been applied for the data collection. Artificial data is provided instead of field data and analyzed on the basis of how the model would analyze real survey data. 8 dimensions of TQM (top management commitment, employee involvement, customer focus, continuous improvement, process management, quality control, supplier quality management and training and education) and 8 indicators of process innovation were analyzed by use of descriptive statistics, mean score analysis, correlation analysis, scatter plot and regression analysis, and the results graphically presented for analysis.

The architecture proposed in this research for TQM MPI in mechanical engineering firms consists of 5 phases, namely, data collection, pre-processing, TQM analysis, process innovation analysis and relationship evaluation. Phase1 involves, employees and managers filling questionnaires including

items regarding TQM and process innovation, on a 5-point rating scale. Phase 2 includes cleaning, validation, coding and computation of average score. The TQM analysis module examines management commitment, employee involvement, customer focus, continuous improvement, process management, quality control, supplier quality management and training, while the process innovation module examines new manufacturing techniques, automation, production efficiency, defect reduction, cost reduction, flexibility, technology adoption and process improvement. Finally, correlation and regression analyses determine the relationships between TQM practices and process innovation, and the resulting graphs and statistics support interpretation and decision making.

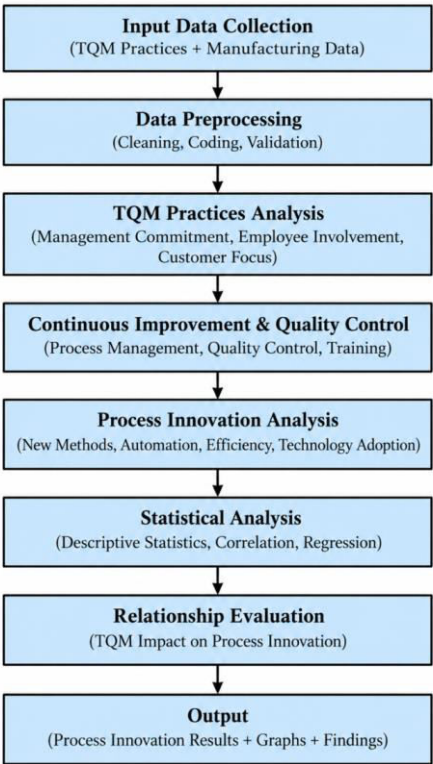


Figure 5.1 Proposed TQM-Based Manufacturing Process Innovation Architecture

As shown in Figure 5.1, the proposed architecture is the architecture for sequential process analysis for investigating TQM practice impact upon design and innovation in the manufacturing process in mechanical

engineering firms. It begins by collecting data on the TQM practices and the manufacturing processes. These data were scrubbed, coded and validated to make sure they were suitable for the required analysis. It continued with the analysis of TQM practice itself with an analysis from top level commitment and employee involvement and customer focus to continuous improvement and quality control. The architecture then analyzed the results of the TQM practice (process innovation) ranging from the development of a new manufacturing process, increased use of automation and increased efficiency to increasing adoption of technology. Finally, it involves statistical analysis to establish and test the relationship between TQM practice and the process innovation, providing the results, charts and conclusions.

5.2 Advantages

The two major advantages of the proposed model are:

1. Better Manufacturing Process Innovation
The model introduces some basic principles of TQM like quality management, employee involvement, quality control and process management that will allow companies to spot those areas in the manufacturing process where improvement is best undertaken and will result in manufacturing process innovation, increase process efficiency, increase automation and better utilization of technology, in an effective way.
2. Better Quality and Process Performance:
The model introduces a systematic analysis of TQM practices and linkages with manufacturing process innovation and will assist firms like that of mechanical engineering to maintain zero defect, better operational efficiency and process performance and more continuous improvement in its operation.

6. Discussions of Results

It was observed that there is significant positive correlation exists between the various TQM practice and manufacturing process innovation from sample data. From the sample mean scores, correlation co-efficient matrix, scatter diagrams and from the individual

response analysis, it can be clearly noted that on increasing level of TQM practice the process innovation have a positive increase. Processes like continuous improvement, employee participation, process control, training and quality control can give the structural arrangement to the manufacturing processes where problems such as production problem are first detected and then solved, which supports the earlier observation of the positive relationship between quality management and innovation[2][6][8][10][12] though it should be taken in a cautious manner since data is not very large and synthetic one.

In relation to these findings, it is proposed that mechanical engineering firms should implement enhanced continuous improvement, employee participation, quality control system, management commitment, technical training and supplier quality in order to promote innovation within their manufacturing. Quality data provides the raw material to identify opportunities for process improvement. It is recommended that regular team meetings should be held where personnel are encouraged to highlight any difficulties that exist during manufacturing and put forward possible solutions. This can lead towards the implementation of TQM activity along with advanced technology and enhanced process monitoring and control systems that would promote manufacturing innovation. Supplier quality control should also receive attention since it affects the efficiency and stability of the manufacturing process. Periodic reviews of the implementation of TQM within an organization as well as the resultant innovation would help promote a sustainable integration between quality and manufacturing innovation and promote long-term development.

7. Conclusion

The findings from this work indicate that Top Management's commitment to Total Quality Management (TQM) has an important role to play in supporting manufacturing process innovation in mechanical engineering firms. This is supported by high mean scores, the strong positive correlation between the TQM

practices and manufacturing process innovation a positive scatterplot and the comparison of individual respondents' data. Top management commitment, employee participation, employee training, customer focus, process management, supplier quality management quality control and continuous improvement all contribute to a systematic approach to innovation of manufacturing processes. An architecture to investigate the relationship between TQM practices and manufacturing process innovation has been described. It analyses top management commitment employee participation employee training customer focus process management supplier quality management quality control continuous improvement and process innovation to identify opportunities to enhance design, automation, efficiency, defect reduction and cost reduction, to improve process flexibility and to increase the adoption of new technologies. Testing this approach using a small real dataset is the next stage.

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