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# Influence of total quality management practices on new product development performance in mechanical engineering manufacturing firms

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**Abstract**
The approach of Total Quality Management (TQM) to involve all employees in an organisation to achieve and sustain customer satisfaction and improving the performance of the organisation is briefly described. It includes employee involvement, process control, continuous improvement, customer satisfaction, design for quality, supplier development, employee training and a data driven culture. However, with mechanical engineering manufacturing organisation, this approach is difficult to implement in the New Product Development (NPD) process. With NPD, design changes, new quality attributes and longer leadtimes present difficulties in implementing TQM in the organization. A model has been proposed on how to implement TQM practices in NPD to improve its performance based on the key principles of TQM.

**Keywords:** Total quality management, new product development, mechanical engineering manufacturing, product development performance, quality management practices, continuous improvement, manufacturing innovation, customer focus

## Introduction

TQM or Total Quality Management is a holistic quality management system centered on processes improvement, employee involvement and quality-based decision making, customer satisfaction, process control and so forth. Due to interdependency of tasks in development of a new product, well established practices of quality would be more applicable on mechanical engineering and manufacturing disciplines. Existing literature supports that organizational performance would be affected by quality management. Good established practices of quality in turn support NPD process [9, 16]. Quality principles based on engineering have now also been institutionalized into product development processes to enhance speed and effectiveness.

NPD performance is a multiple criteria concept that includes the speed at which the new product development process takes, the quality of the developed product, the cost associated with the production, technical performance and if the requirements of the customers are satisfied. Previous studies have analyzed the linkage between quality management and rapid new product development [1, 2]. Quality management practices are also effective to promote successful implementation of NPD by inspiring workers to take part and acquiring organizational knowledge and abilities. Quality in the new product, which is related to good development performance, also has significant linkage to cooperation between design and development department and production department. Along with theses, successful implementation of quality management in NPD should necessarily involve engineering and quality assurance engineers in the new product development process for developing reliable products that satisfy both engineering and customer needs. Overall, the existing literature seems to suggest that TQM can be a useful organizational support for NPD in mechanical engineering companies.

Linking TQM to NPD for mechanical engineering producers might be more important, since product design is closely related with production processes, engineering resources, and coordination with suppliers as well as customer needs. Literature provides studies that shows the relationship between product development practices and firm performance [12], relationship between product development and manufacturing practices and firm performance [13, 14], and also quality function deployment as a customer driven approach [11]. However, study about quality management and innovation output within the manufacturing sector can be traced in literature [16, 18, 19]. Though this literature, overall does not focuses on mechanical engineering producers, but rather manufacturing and technology-oriented sectors. In the meantime, this study attempts to bridge this gap by analyzing the impact of TQM practices on NPD performance in mechanical engineering manufacturing organizations for quality improvement, productivity, customer requirements and results.

## Literature Review

Quality methods continue to shape how companies build better products and run smoother operations, notes a paper by Kaynak (2003), who shows links between TQM techniques and stronger performance results. A different path emerges when looking at new product design: Yau and Cheng (2009) draw on established theory to examine whether flawless processes hurry launches along - they argue correct techniques do indeed expedite progress. Support arrives later when Sun and Zhao analyze real-world cases; their findings confirm a clear alignment between solid quality controls and faster product introduction flows. While some question whether focus on precision blocks creativity, Sethi and Sethi (2009) investigate whether high-quality oriented businesses can still generate groundbreaking releases. Evidence builds slowly, yet it appears broadly consistent: robust quality frameworks appear to support effective launch processes across different contexts.

High achievers often possess more than one strong skill within their organization. From a capability's perspective, people-focused quality efforts play a significant role according to findings by Gutierrez-Gutierrez and colleagues (2018). When production teams work closely with research units, results tend to improve across both aspects, per conclusions drawn by Kang and Um in 2022. When tasks demand precision and durability, placing extra emphasis on reliability makes sense - an observation highlighted by Sivaram in 2013. Quality management has also been shown to act as a bridge linking broader operational adaptability to success in launching new offerings, something highlighted through analysis conducted jointly by Kumar and others in 2020. At the same time, data linking quality actions directly to advanced product design abilities and resulting achievements comes from Song and Su's overlapping examination launched in 2016. Recent insights from technology-driven factories suggest ties remain between structured quality work and stronger output measures, as revealed by Chung's group in 2024.

customer needs design production engineering customer driven design of products production integrated customer needs benefits of customer value integration manufacturing engineering coordinated operations development marketing processes process design development manufacturing manufacturing manufacturing engineering integrated manufacturing structured product design and manufacturing processes product manufacturing product design practices quality design improvements TQM concurrent engineering manufacturing performance TQM product development quality development manufacturing engineering manufacturing engineering and quality development manufacturing TQM quality and engineering TQM and manufacturing quality and engineering TQM and quality product design product development manufacturing development development quality quality management development.

**Existing Systems for New Product Development in Mechanical Engineering Manufacturing Firms**

New product development (NPD) has experienced the attempts of several mechanical engineering manufacturing firms to move off the traditional NPD process to integrated quality management and cross-functional teams and towards an innovation led process. The literature is dominated by studies on product design, manufacturing requirements, quality control, although more recent research has started to focus on customer requirements, TQM, R&D, organizational capabilities, and manufacturing. Quality management practices have been shown to affect the speed and success of NPD [1, 2] and TQM practices and human resource management practices are also effective in influencing NPD performance [3, 6] although some current approaches do not systematically incorporate quality practices into engineering design, manufacturing, and the processes of customer requirements and innovation. Many studies have mapped total quality to manufacturing, innovation and NPD performance but an existing framework for a mechanical engineering manufacturing enterprise does not exist.

## 1. Issues

TWO shortcomings of the current system are

### 1.1 Weak Linkages between Quality Management and New Product Development.

As a result of this, although many companies operate a quality management system, few have addressed NPD in this. Indeed, many existing approaches still view quality management and NPD as non-overlapping 'domains of interest'. The TQM tools and techniques of continual improvement, a focus on customer requirements, empowerment of employees, process management and decision-making on quality are in many situations, not systematically applied in engineering design and development. Research has investigated the impact on NPD, highlighting a link between quality management and its relationship with shorter NPD cycles [1, 2]. It has also highlighted the crucial role of the 'manufacturer R D interface' [4] and in the absence of this a range of problems including increased time taken for development, re design, defects and extra development costs occur. This can particularly be said of mechanical engineering companies where the design and manufacturing processes are closely coupled throughout NPD.

### 1.2 Weak or non-existent focus on Mechanical Engineering-specific NPD performance measures.

The existing literature provides the bulk of studies relating to TQM, NPD and innovation in general manufacturing, electronics, high-technology or other industry-related sectors [6, 8, 16, 18, 19]. Studies relating to these general industries and sectors are partially relevant to mechanical engineering manufacturing company performance. Engineering design, material choice, prototyping, machining and assembly are integral to mechanical product development, in addition to factors like reliability, dimensions, process capability and product testing. In an engineering manufacturing environment, these features are inevitably linked to company-specific quality management and co-ordination between engineering and manufacturing. Research in product development and manufacturing practices [13, 14], quality, reliability, and concurrent engineering [5, 15] also generally align with these findings. In terms of TQM, there is very limited and somewhat disjointed work focusing on the linkages between individual TQM practices and NPD performance for a mechanical engineering-manufacturing setting.

## 2. Input Data

Data contains 20 observations on respondents employed by firms operating in the field of mechanical engineering manufacturing about their TQM adoption and NPD performance of their firm consisting of 14 measures grouped under six dimensions; Top Management Commitment (TM1TM3), Customer Focus (CF1, CF2), Continuous Improvement (CI1, CI2), Supplier Quality Management (SQ1), Process Management (PM1) and New Product Development Performance (NPD1NPD5) with each measure recorded on a scale of 1 (Very unlikely or 1 Strongly Disagree) through to 5 (Very likely or 1 Strongly Agree). These observations will be applied to explain the pre-processing, descriptive statistic, reliability analysis, correlation, regression and SEM techniques applied to assess the relationship between firm-level TQM practices and NPD performance.

| Respondent | TM1 | TM2 | TM3 | CF1 | CF2 | CI1 | CI2 | SQ1 | PM1 | NPD1 | NPD2 | NPD3 | NPD4 | NPD5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R001 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 4 |
| R002 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 4 |
| R003 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 |
| R004 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 4 |
| R005 | 2 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 |
| R006 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 |
| R007 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| R008 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 3 |
| R009 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| R010 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| R011 | 3 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 |
| R012 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| R013 | 4 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 5 |
| R014 | 2 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 2 |
| R015 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 |
| R016 | 5 | 4 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 4 | 5 |
| R017 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 3 |
| R018 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 5 |
| R019 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 |
| R020 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 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).

**Experimental Results**

To examine the relationship between quality management practices and the effectiveness of new product development (NPD) this paper provides empirical results for a sample of mechanical engineering firms in Singapore. The quality management practices examined were top management commitment (1), customer focus (2), continuous improvement (3), supplier quality management (4) and process management (5). The mean ratings for all five practices are all significantly high ($\bar{x} \geq 4$), implying that these dimensions of quality management are well adopted within the firms. Also, the NPD indicators have mean ratings all of which fall in the positive direction ($\bar{x} > 3.5$), indicating relatively high levels of development efforts within the respondent firms. In the regression analysis, it can be seen that there is a significant positive linear relationship between the TQM practices and NPD performance. Further, a plot indicates an upward sloping line that signifies a positive relationship between NPD performance and TQM.

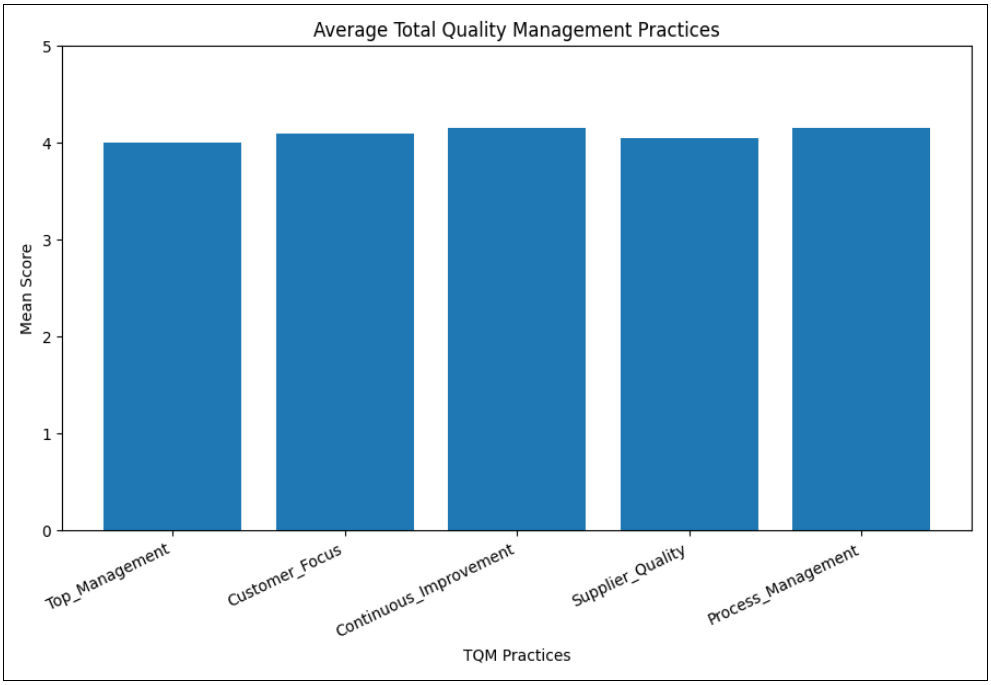



**Fig 1:** Mean Scores of the Five TQM Dimensions

Figure 1 Average score for each of the 5 dimensions. Strong average ratings were found for all 5 on the 5-point scale. Continuous Improvement and Process Management mean were highest, the highest of any of the variables and thus, the best indicated in research. Customer Focus and Supplier Quality Management mean was positive, both being a somewhat positive representation of both these variables. The mean for Top Management Commitment was, the lowest of any of the variables but was, still higher than the midpoint of the scale. Overall, a positive representation was found for all of the dimensions.

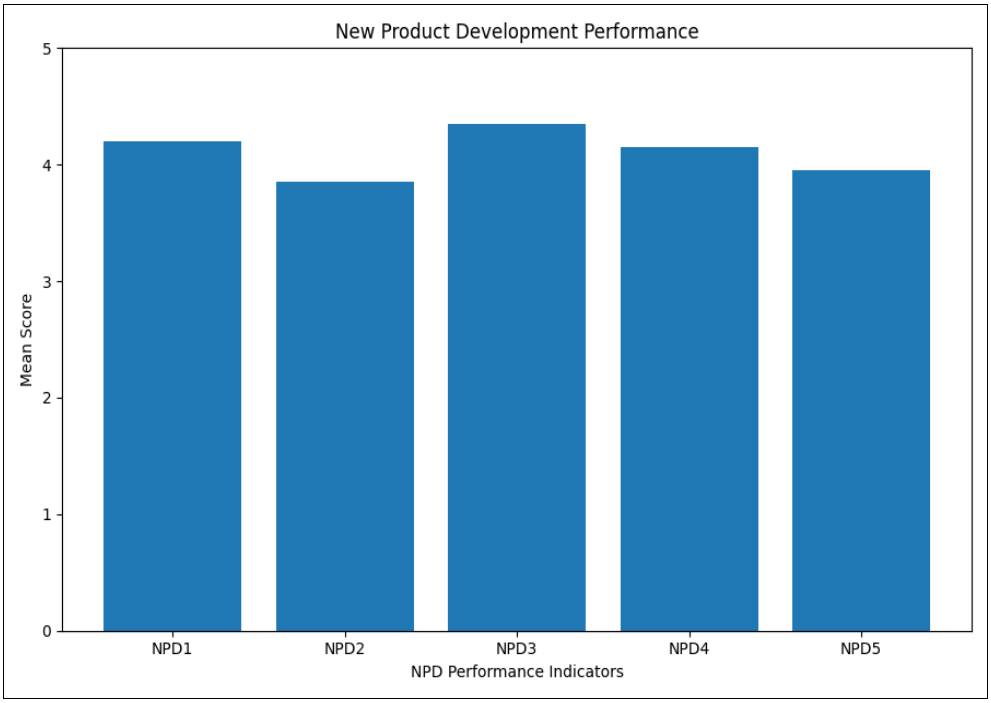



**Fig 2:** Mean Scores of the NPD Performance Indicators

Mean score for each NPD performance indicator (figure 2) is higher than the neutral point, indicating relatively good NPD performance. NPD3 has the highest mean followed by NPD1 and NPD4, while NPD2 is the lowest followed by NPD5.

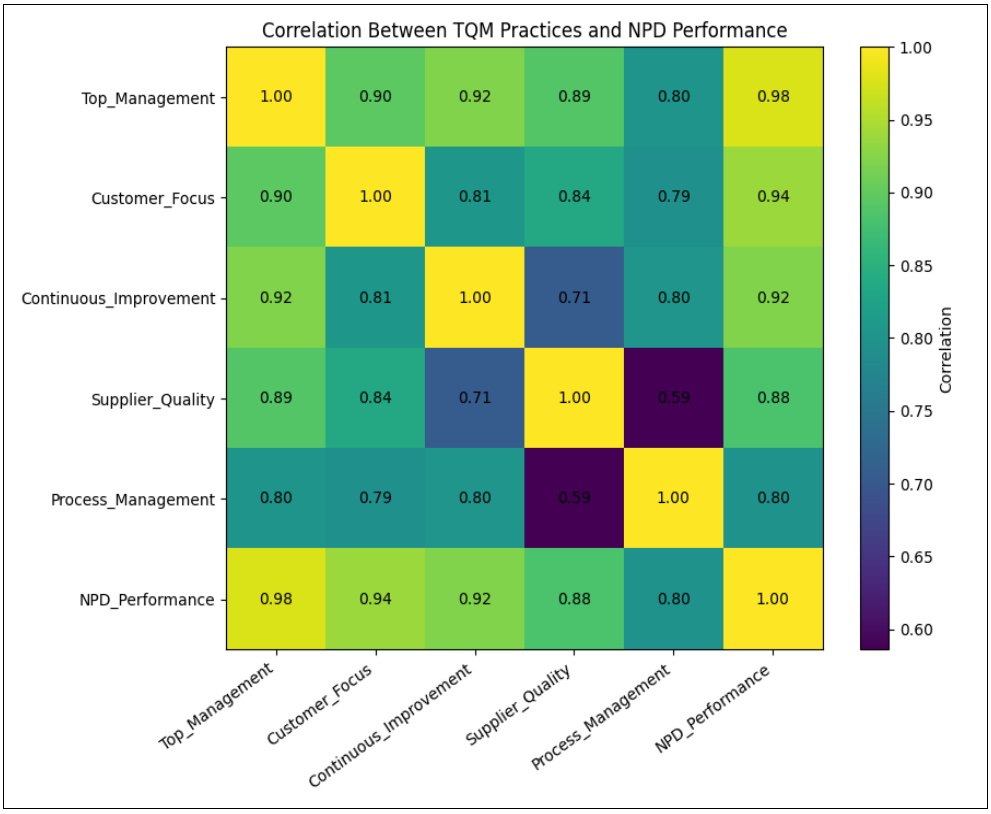



**Fig 3:** Correlation Matrix of TQM Dimensions and NPD Performance

The correlation between TQM and NPD is displayed in Figure 3. All TQM measures are positively correlated with NPD performance. Top Management Commitment has the highest correlation coefficient, at 0.98, closely followed by Customer Focus with 0.94, and then Continuous Improvement at 0.92, and then Supplier Quality Management and Process Management both at 0.88 and 0.80 respectively. The correlations suggest that respondents who reported high ratings for their TQM practices also report high NPD performance; preliminary evidence supporting a positive link between these two concepts, but not establishing any cause and effect.

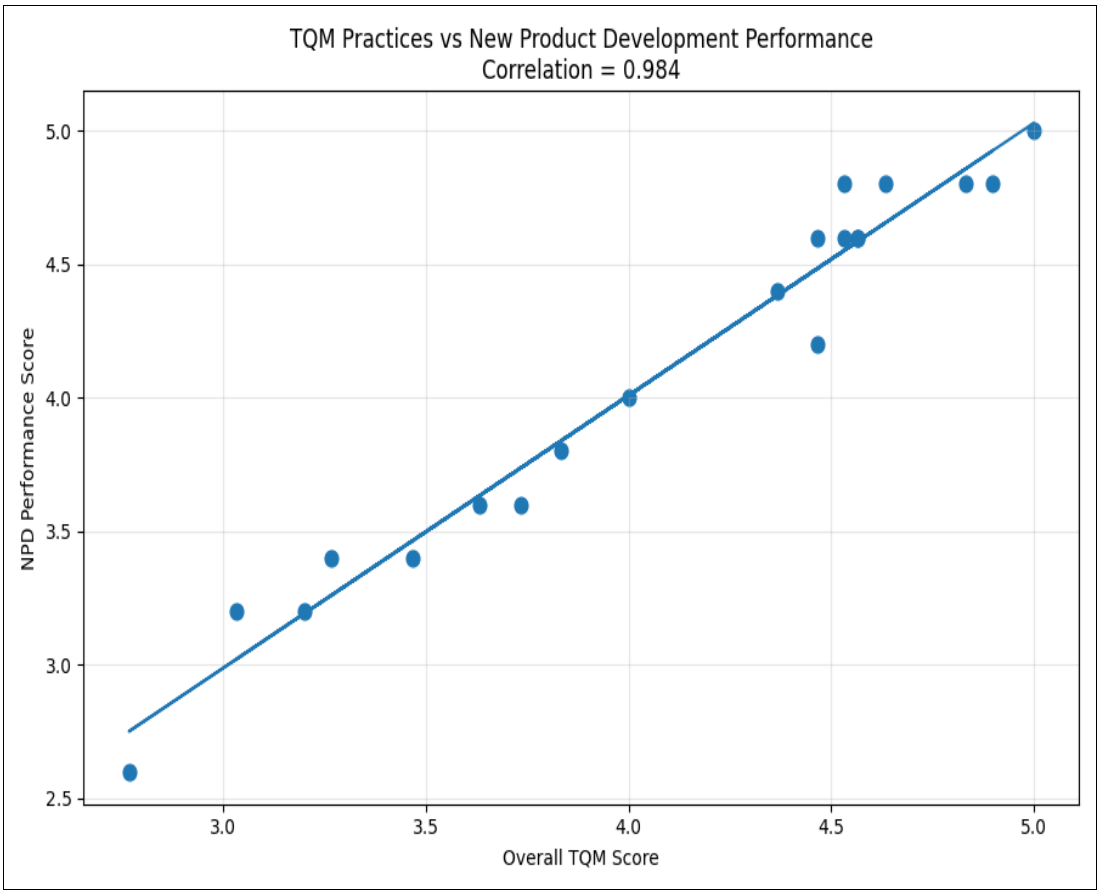



**Fig 4:** Overall TQM Score Plotted Against NPD Performance

The overall TQM score was plotted against NPD performance along with a fitted regression line and shown in fig 4. Observations are sorted to reflect a positive order: that is, the overall TQM level is greater with the level of NPD performance. The correlation coefficient is 0.98 meaning that there is very strong positive correlation in the data set. This is further endorsed by the regression line. It suggests that a respondent reporting very high usage of TQM should have correspondingly high level of success with their NPD, quantification of TQM effects on NPD that can be studied further with other analytical techniques.

**Methodology**

This study explores the relationship between total quality management (TQM) and the new product development process in mechanical engineering manufacturing. The role of TQM dimension which consist of 5 key elements: support by top management, customer focus, continuous improvement, supplier quality and process management, in enhancing new product development effectiveness, i. e., the development process with respect to product quality, effectiveness of development, performance, and fulfillment of consumer requirements is of specific interest. Engineering design, processing and inspection activities would benefit most by using this methodology in industry.

A quantitative design is adopted using data from a structured questionnaire survey. The items for TQM practices and NPD indicators were evaluated on a five-point Likert scale of Strongly Disagree through to Strongly Agree. The data were presented descriptively, coupled with paired correlation and regression analysis to establish the relationships between TQM practices and NPD performance, prior to pre-processing. The reliability and validity of the measures can be tested in order to verify their consistency and suitability as measurement tools. In combination, these approaches show how the application of TQM practice will affect NPD performance in mechanical engineering manufacturing companies.

The framework allows for investigating the effects of TQM on NPD performance, targeted at the mechanical engineering manufacturing firms. TQM dimensions like top management commitment, customer focus, continuous improvement, supplier quality and process management are used as inputs in the NPD process. Engineering design, defining customer needs, building models, prototyping and testing, quality assurance, production planning, etc. are considered as the process activities for NPD performance. The data collected from the questionnaires were pre-processed and then analyzed by employing descriptive statistics, correlation and regression analysis to see how they relate to the TQM practices. The expected outcome is to develop a performance evaluation framework on new product development concerning quality, effectiveness, performance and fulfillment.

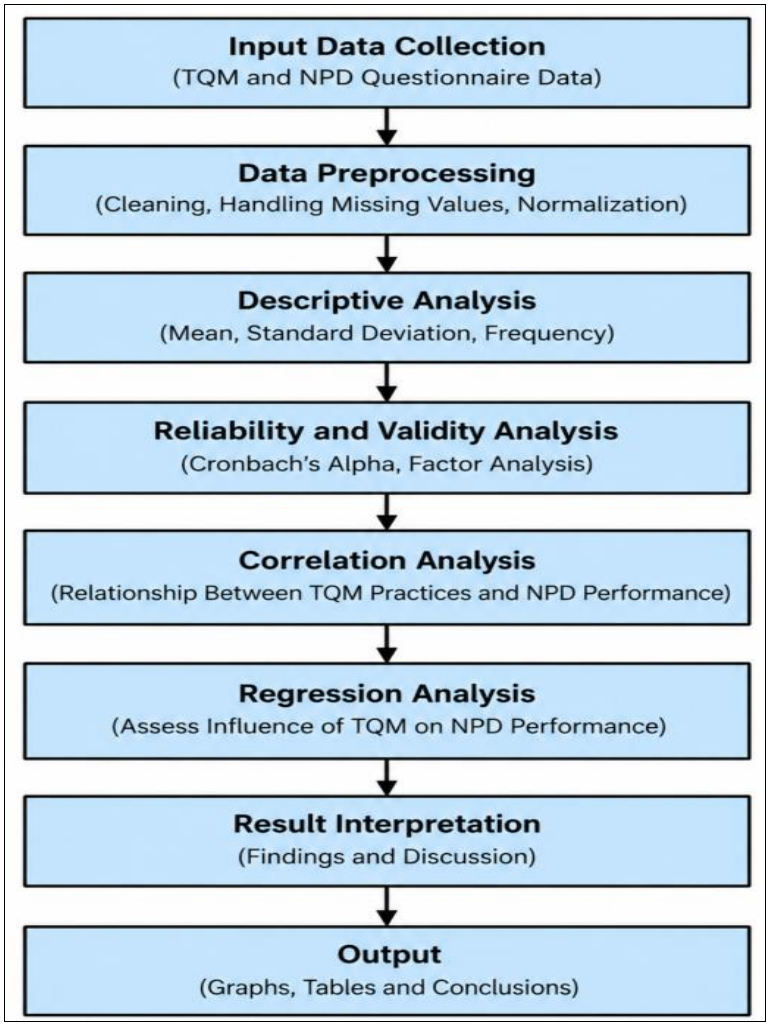



**Fig 5:** Proposed TQM-Based New Product Development Architecture

The Figure 5. illustrates the structure of the proposed framework and how it can be used for improving NPD performance in the context of mechanical engineering manufacturer. The different phases are data collection from TQM practices and NPD performance, cleaning, imputation, normalization of response data to an appropriate scale for analysis; descriptive statisticq will tell about the nature of data and will help in the application of reliability and validity tests for measuring variable. Correlation analysis is applied to see if the TQM practices are interrelated to NPD performance; regression analysis to estimate the contributions of TQM practice. Ultimately this results in a number of Output in form of statistical output, figure, table, conclusion and recommendations.

**Benefits**

The proposed model benefits in two folds.

1. Through employing techniques of continuous improvement and customer focus, TQM elements improved design specification, process control, quality supplier will lead to product quality. This results in more efficient new product development process meeting the needs of customer effectively.

2. The proposed model utilizes statistical analysis, for determining relationships between TQM practice and NPD performance, enabling decision makers to objectively make decisions and also enabling identification of the potential areas of improvement in thisregards.

TQM-based new product development performance evaluation model comprises the following 10 stages.

**Step 1: Data Collection**

structured questionnaire in the gathering of TQM practices and New Product Development performance data from mechanical engineering manufacturing companies.

**Step 2: Data Preprocessing**

Data cleansing by missing value imputation, duplicate respondent removal and outlier detection

**Step 3: Data Encoding**

translate the response of questionnaire using 1–5 scale into numeric values (from "Strongly Disagree" to "Strongly Agree").

**Step 4: TQM Practice Assessment**

Evaluation of the five TQM components top management commitment, customer focus, continuous improvement, supplier quality management and process management

**Step 5: NPD Performance Assessment**

NPD performance measurement in product quality, development efficiency, technical performance, degree of fulfilled customer requirement and NPD outcomes

**Step 6: Descriptive Statistical Analysis**
calculation of mean, range, mode and standard deviation for data description

**Step 7: Reliability and Validity Testing**
analysis of validity and reliability for items of questionnaire items using Cronbach's alpha and factor analysis.

**Step 8: Correlation Analysis**
determine how closely practices of TQM relate to NPD performance, and which direction these associations are taking.

**Step 9: Regression Analysis**
determining effects on NPD performance by individual practice of TQM practice and identifying the TQM practices, which are most effective in product development performance.

**Step 10: Result Interpretation and Output**
interpretation of statistics to present graphs, tables, conclusions and recommended TQM practices for enhancing NPD performance

**Discussion**
The results illustrate that implementing TQM is related to NPD success for mechanical engineering manufacturing companies. All five TQM elements are found at a relatively high level within the sample, as are the NPD variables. Correlation shows that each TQM practice is associated positively with the NPD success variables, as well as overall TQM, which is associated positively with overall NPD success. These findings suggest that adopting systematic quality managing approaches will have several benefits such as improved product quality, faster product introduction, better meeting of customer needs and improved NPD overall performance.

To sum up, the research results imply that mechanical engineering firms should enhance top management involvement in NPD activities, customer-oriented product development practices, continuous product/service improvement, customer-focused and supplier-oriented activities and quality-oriented process practices over their product life cycle. To resolve potential design and quality problems on time, design, production, quality control, purchasing and R&D departments should work more closely than before. Moreover, firms should monitor the progress of their NPD projects more effectively and in real time by means of statistical methods using data regarding quality, lead time, quality defects, customer requirements and technical performance. Firms should also follow up the employee training activities and employee proposal projects in the company in addition to all these. It seems that all these activities can be carried out in the context of total quality and by adopting these principles systematically, it is possible to raise NPD activities' success.

**Conclusion**
According to this study, evidence supports that TQM implementation can improve NPD performance. TQM practices such as commitment of top management levels, customer focus, continuing improvement, quality management of suppliers, process management showed a positive association with NPD performance. These quality practice correlated and regressed with NPD performances. Therefore, product quality can be enhanced by implementing total quality management with respect to customers' needs. This has an impact on product development efficiency, technical performance and success. This study introduces a TQM-based approach toward sustained improvements of the NPD process.

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