LITERATURE SURVEY

2.1. Introduction

In this chapter, the literatures surveyed during this research work are narrated from three different views. First, the status reports of TPM and QFD have been appraised from the literature perspective. Second, the intrusion of TPM into QFD and vice versa is examined by citing relevant papers. Third, the impact of TPM and QFD in engineering education has been presented. These narrations reveal the gaps existing in research arena with respect to the integration of TPM and QFD.

2.2. QFD: A perspective from literature

The origin of QFD is traced to the quality tables that were developed in Kobo Shipyard, Japan in the year 1960. The formal appearance of QFD as the TQM technique was made possible through the works of Yoji Akao in the year 1972 (Akao and Mazur 2003). Thereafter the popularity of QFD spread across the world. Also a large number of case studies reporting QFD's successful implementation and its benefits appeared in literature (Chan and Wu 2002). A few researchers have brought out different definitions (Zairi and Youssef 1995) leading to the proposition that QFD is a technique used for converting customers' vague languages into technical languages. Therefore QFD facilitates deployment of customers' voices into practising environment. In this era of increasing competition, QFD is supposed to reveal the hidden and open voices of customers and support the organizational managers in meeting market requirements.

The implementation of QFD progresses through the development of a composite matrix known as House of Quality (HoQ). The conceptual features of HoQ are shown in Figure 2.1. As shown, HoQ consists of six main sub-matrices (Kumar and Midha 2002, Han et.al, 2001). The construction of HoQ begins by developing customer language matrix whose inputs are vague customer voices. Consequently, the second matrix titled 'ranking of customer
languages' is developed. The values indicating the ranks of the customer languages are determined by considering the competitors’ performance and companys’ affordability in fulfilling the customer languages. The third matrix consisting of the technical languages corresponding to the customer languages is developed. The fourth matrix is constructed by entering values to represent the degree of relationships between customers and technical languages. The fifth matrix consisting of values representing the ranking of technical languages is then formed. The sixth and last major sub-matrix of HoQ is the correlation matrix, which is constructed by entering the values to represent the correlation among the technical languages. All these matrices developed are joined to construct HoQ.

The construction of HoQ requires the involvement of personnel with adequate theoretical and practical knowledge about the customers’ voices that are under consideration. Followed by the development of HoQ, the engineers and production managers are required to study the completed QFD’s contents and develop target values and process plans. Thus the customer voices are translated into technical languages through the development of HoQ, which penetrates into the field of practice.

![Figure 2.1. Format of HoQ Matrix](image-url)
During the earlier days of its birth, QFD was used as a product development (Lokmay and Khurana, 1995) technique. However during the recent times, it is proved to be a feasible technique for several applications where customer voices are required to be translated into technical languages (Han and Wu, 2002; Sahney et al. 2003; Sahney et al. 2004).

2.3. TPM: A perspective from literature

The origin of TPM is traced to 1970 and as in the case of QFD, its place of birth is Japan (Cooke 2002, Ireland and Dale 2001). Before the evolution of TPM, the field of maintenance engineering was adopting technology oriented approaches like condition monitoring, preventive maintenance and reliability centered maintenance. Presumably on realizing the absence of totality and human elements, the principles of TPM were promoted by Japanese Institute of Plant Maintenance (JIPM) (Bamper et al. 1999). Later it spread to different parts of the world including western countries.

Fundamentally TPM encompasses various elements of TQM and maintenance engineering. In fact there have been researches linking TPM with quality (Ben-Daya and Duffuaa, 1999). Because of the shadowing of TQM, TPM envisages the total involvement of employees towards enhancing
maintenance quality with equipments (Cooke 2000, Ireland and Dale, 2001). Several definitions of TPM have been brought out (Bamber et.al, 1999). Several approaches of implementing TPM have also been brought out. A bird’s eye view of literature would indicate that eight pillar approach of implementing TPM is the most exhaustive one (Yamashina, 2000; Cigolini and Turco, 1997). The conceptual features of this approach are depicted in Figure 2.2. As shown, maintenance engineering and total quality control form the foundation of TPM programme. After laying this foundation, TPM programme is developed by constructing the following eight pillars (Ahmed et.al, 2005). The conceptual features of these pillars briefly describe in the following eight sections. Simultaneous review of articles by Ahmed et.al (2005), Cigolini and Turco (1997), Ireland and Dale (2001), Bamber et.al (1999), and Patra et.al (2005) would reveal that the pillar numbers from five to eight have grown from the earlier days of TPM to the contemporary days.

2.3.1. Autonomous Maintenance (A M)

According to this pillar, the sense of ownership over the equipment operated by the workers shall have to be developed. In other words, the worker should consider the equipment that he/she operates as his/her own child and in case of its failure, the worker should react immediately to restore its status quo. This is a contradiction to the traditional maintenance engineering approach in which even minor maintenance problems are attended by the employees working in maintenance engineering department (Cooke, 2000).

2.3.2. Individual Improvement (I I)

According to this pillar, the worker has to improve himself/herself to the extent of attending to maintenance failures. He/she must also learn to analyze the cause of maintenance failures using tools like why-why analysis and performance measurement analysis. This is a contradiction to the conventional maintenance engineering approach in which, a separate team consisting of maintenance engineering professionals carries out the analysis and finds out the causes of maintenance failures. The solution provided through this conventional
approach often would fail to penetrate into the field conditions because of its incompatibility.

2.3.3. Planned Maintenance (P M)

This pillar is a shadowed form of conventional preventive maintenance approach (Ireland and Dale 2001). In order to build this pillar, the maintenance schedule must be drawn in advance. Besides, provision should be made to allot sufficient resources to meet the planned schedule. Another aspect of this pillar is the control of maintenance costs and elimination of equipment losses. Six big losses identified in TPM field are (Chan et.al,2005),

a. Breakdown losses
b. Set-up and adjustment losses
c. Minor/ Idling stoppage losses
d. Reduced speed losses
e. Defect/ Rework losses
f. Start-up losses

2.3.4. Quality Maintenance (Q M)

In order to construct this pillar, the organization has to inculcate the culture of zero defect philosophy and use of all resources including equipments for attaining continuous quality improvement. In the absence of TPM, the equipment is never a focus for achieving quality of operations.

2.3.5. Office TPM (O TPM)

In order to construct this pillar, the smart methods and administrative activities shall have to be promoted to support TPM activities. Further cost reduction in maintenance of equipments shall have to be supported by office administration. This is a unique emphasis of TPM since no other model on continuous improvement has envisaged the supporting role of office administration in organisations.
2.3.6. Education and Training (E & T)

According to this pillar, the employees of different levels must be imparted education and training on TPM. Such programmes may deal with the TPM tools and techniques. Although training is imparted to employees even in conventional maintenance approach, its scope is restricted to a section of workers working in maintenance engineering department.

2.3.7. Safety Health and Environment (S H E)

This pillar encompasses the humane approach. According to this pillar, the TPM programme has to evolve a policy on environment, health and safety, which has to be strictly enforced with the commitment and support of the management. Further the awareness on environment, health and safety among the employees shall be effected through the adoption of top down approach, installation of relevant facilities and imparting education and training.

2.3.8. Initial control/ Development Management (I C/ D M)

In order to construct this pillar, the TPM programme shall allow the review of designs for preventing further mistakes, use of manufacturing process data and establishment of equipments start up times. These principles are not followed in conventional maintenance engineering approaches.

In a nutshell, the implementation of TPM is marked by the construction of the eight pillars and prevention of equipment losses. After constructing these pillars to different heights, the TPM programme is liable to contribute higher degree of maintenance quality. In order to assess the level of maintenance quality, the literature on TPM envisages the usage of the parameter known as Overall Equipment Effectiveness (OEE). The computation of OEE is carried out using the following mathematical formulae (Nakaajima, 1993).

\[
OEE = \text{Availability} \times \text{Performance Efficiency} \times \text{Rate of Quality of Products}
\]

Some authors claim that OEE is the only parameter that has got the capability to indicate the maintenance quality of equipments in organization
(Kwon and Lee, 2004). However, some authors have claimed that OEE alone cannot be considered as performance indicator of TPM programmes (Blanchard 1997). Hence it is recommended that the parameters namely Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Performance Quality, Mean Down Time (MDT) and Availability, which require only simple computations, shall also be used for assessing maintenance quality level. According to the management policy, any one of the above performance measurement parameters or group of them shall be chosen to measure the maintenance quality level of the equipments.

Today literature is available to indicate the application of TPM to various extent in different countries (Eti et.al,2004, Tsang and Chan 2000, Ahmed et.al 2004, Cigolilini and Turco, 1997). To cap it all, TPM is considered to be one of the world class manufacturing strategies (Yamashina, 2000, Bamber et.al, 1999). These developments indicate the prowess of TPM which has played a phenomenal role in revolutionizing maintenance management and engineering approaches and thus have gained a heritage position in world class manufacturing principles. However like any other managerial and technological models, TPM also suffers from certain drawbacks. Particularly its scope is restricted to enhancing maintenance quality of equipments only. Its scope does not extent to enhancing maintenance quality of products and services offered by the organizations. Presumably, due to this limitation, TPM models have not been incorporated with customer voice adoption techniques like QFD.

2.4. QFD in TPM and vice versa: a literature perspective

After studying the characteristics of TPM and QFD, the author developed an impression that QFD adoption in TPM projects would be a synergizing contribution to TPM professionals. Hence the author aspired to locate any work that reports the adoption of QFD in TPM projects and vice versa. At this juncture, it was very encouraging to see an article by Chan and Wu (2002). They have reviewed as many as 650 publications, which is considered to be relatively an exhaustive literature on QFD. They have dealt with QFD right
from its birth to its dissemination to various countries and fields. They have listed the popular application fields of QFD, which include product development, quality management and customer need analysis. They have also identified the industrial sectors in which QFD is applied. Some of them are transportation, communication, software systems and manufacturing. In addition to that, they have listed articles, which report the linking of QFD with simultaneous engineering, knowledge intensive engineering, quality engineering, rehabilitation engineering, requirement engineering, and so on. However this list does not include TPM. On the whole, the review of this paper clearly indicated the absence of any work linking QFD with TPM. In order to further confirm the absence of QFD application in TPM field, some more papers were reviewed in this direction. The details of reviewing these articles are briefly described in this section.

Terziovski, and Sohal, (2000) have collected responses from approximately 400 Managers. They have discussed the use of seven new quality tools, namely, Failure Mode and Effect Analysis, QFD, Creativity tools, Standardization tools and “SS” for achieving continuous improvement. They have cited that some companies use TPM as a tool for Kaizen. However they have not indicated any work involving the application of QFD in TPM and vice versa. Rho et.al (2001) concentrated on various studies designed to investigate the relationship between manufacturing strategies, practices, and performance. They have compared the results from three different nations namely Korea, U.S and Japan. They have included TPM and QFD in their studies but have not attempted to integrate them. Negri and Galli (1997) have worked on the quality improvement strategies in Italy and have cited that TPM influences process control on preventive basis and minimizes down time. They have identified QFD as one of the most effective and reliable approaches. However they have not mingled QFD and TPM with each other in their studies.

Voss and Blackmon (1998) studied the differences in manufacturing strategies between Japanese and Western manufacturing companies. Cultural differences caused difference in attitude towards the duration of
Implementation, which led to the adoption of long term and short term strategies. They have analyzed the data that have been drawn from 600 companies situated in 20 countries. They have mentioned that Japanese considered TPM as one of the long-term strategies. They have reported a higher level of adoption of QFD than TPM in Japan. They have also reported higher payoff of TPM than QFD, whereas this trend is reversed in western countries. However the difference in these quantified parameters is very less and hence, we inferred that TPM and QFD are dominating both Western and Japanese companies. However, this study reveals no integration between TPM and QFD principles.

After realizing the absence of any article regarding the integration of QFD and TPM, the author developed curiosity to check whether any attempts have been made to link any other manufacturing strategies with them. It was quiet surprising to see few articles, which have emerged in this direction. Those linking efforts exerted by TPM and QFD researchers and practitioners are presented in Tables 2.1 and 2.2. As seen, these articles indicate the feasibility of linking both TPM and QFD with other similar approaches with different combinations. Hence it was inferred that the synergizing of QFD and TPM principles would also be a feasible proposition.

<table>
<thead>
<tr>
<th>Articles</th>
<th>Contribution</th>
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<tbody>
<tr>
<td>McKone et. al. (2001)</td>
<td>Have presented a framework for linking TPM with JIT and manufacturing performance.</td>
</tr>
<tr>
<td>McKone et. al. (1999)</td>
<td>Have presented a framework for linking TPM with environment, organisational and managerial contexts.</td>
</tr>
<tr>
<td>Cua et. Al. (2001)</td>
<td>Have presented a framework for linking TPM with JIT</td>
</tr>
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Table 2.2. Articles reporting the linking of QFD with other manufacturing strategies and principles

<table>
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<th>Articles</th>
<th>Contribution</th>
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<tbody>
<tr>
<td>Olhager and West (2002)</td>
<td>An improved version of HoQ called House of Flexibility has been presented. (QFD and Manufacturing Flexibility principles are linked.)</td>
</tr>
<tr>
<td>Witter et.al. (1995)</td>
<td>A model called 'enhanced QFD has been presented. The Concept of reusability has been linked with QFD.</td>
</tr>
<tr>
<td>Ginn et. al. (1998)</td>
<td>A model interfacing QFD and FMEA has been proposed.</td>
</tr>
</tbody>
</table>

2.5. TPM and QFD In Engineering Education

The ever-rising global competitive waves keep invading all fields and geographical regions. This phenomenon has been pressing mankind to infuse higher degree of quality in all spheres of products, processes and services (Prendergast et.al, 2001, Chong and Rundus, 2004). The knowledge required for attaining higher degree of quality originates from the brains of human resources. Hence a society will be enjoying higher degree of quality of life, if its human resources are effectively groomed and developed. The responsibility for contributing highly useful human resources for the welfare of the society of all regions is lying with educational institutions. Today globalization process progresses at a faster pace making the humans face common challenges irrespective of the societies and countries to which they belong (Irandoust And Sjoberg, 2001). In most of the societies these challenges are largely tackled by engineering professionals (Paten et.al, 2005). Hence, a large portion of social contribution originates from engineering educational institutions (Johnston, 2001). Needless to mention, the engineering educational institutions have to contribute high quality human resources who are not only technocrats but also society-friendly individuals (Perez-Foguet et.al, 2005). While the business world has been reporting the adoption of different continuous quality improvement models (Kaye and Anderson, 1999), the examination of their...
application feasibility for infusing higher degree of quality in engineering education will lead to useful contribution to all kinds of societies over the globe (Johnston, 2001).

Total quality management (TQM) models have revolutionized the organizations of all types (Chong and Rundus, 2004, Hoque, 2003, Montes et al., 2003). Presumably due to this reason, during the recent years, some engineering educationalists and researchers have been striving to apply TQM and its techniques in engineering education (Sahney et al., 2004). Some engineering educational institutions have started practising TQM (Jaraiedi and Ritz, 1994, Prendergast et al., 2001, Swift, J. A., 1996). These efforts are getting focused on attaining specific strategies. For example, the engineering educational institutions are becoming quality system conscious since many of them have implemented ISO 9001: 2000 quality system standard. Likewise Hwarng and Teo, (2001) and Lam and Zhao, (1998) have reported the pilot implementation of QFD in engineering education. These efforts have yielded in achieving higher degree of quality in administering engineering educational institutions, testing the students’ capabilities to meet the requirements of their employer and building excellence in the learning of engineering advancements (Ferrer-Balas et al., 2004). These favourable results indicate that, on application of well-proven quality engineering and management models, the quality level of engineering education would rise. In this context, during this research work, it was foreseen that the synergising effect of implementing TPM and QFD together would trigger significant stride in attaining higher degree of quality in engineering education. However, it appears that no researcher and practitioner has so far attempted to link these two techniques and apply them in the engineering educational scenario.

2.6. Conclusion

The world community began to realize the importance of quality when competitive war invaded the globe after the Second World War (Cooke, 2003). Various Total Quality Management (TQM) techniques and tools were almost immediately implemented in different organizational cultures as a sequel to the
competitive war (Irani et al., 2004, Kaynak, 2003, Hoque, 2003, Jung and Wang, 2004, Sahney et al., 2004, and Montes et al., 2003). Amidst this visible and pompous trend, a humble revolution has been taking place in the field of maintenance engineering (Tsang and Chan, 2000). This revolution is today addressed under the name TPM. Before the evolution of TPM, the maintenance engineering community was exposed largely to technologically oriented approaches (Deshpande and Modak, 2002, Eti et al., 2004, Murthy et al., 2002). These approaches segregated maintenance activities from the mainstream operations of the organizations. The emanation of TPM was a strategic change in the maintenance engineering arena because, unlike the previous approaches, TPM linked maintenance engineering with human elements like operator empowerment and involvement (Nakajima, 1993).

Today in parallel with the TQM implementation, a significant number of organizations have been adopting TPM (Mc Kone et al., 1999, Cua et al., 2001, Mc Kone et al., 2001). The objective of this effort is to achieve high degree of competitiveness through the enhancement of maintenance quality. The age of TPM is little more than three decades and its adoption has resulted in various benefits including the reduction in rejections, reworks and stoppages of equipments (Chan et al., 2005). Of late, the researchers have been trying to establish the link between TPM and TQM (Miyake and Enkawa, 1999). This is presumably due to the reason that both principles dominate world-class organizational cultures and offer benefits in various forms and magnitudes (Mitchel et al., 2002; Cua et al., 2001; McKone et al., 1999; McKone et al., 2001; Yamashina, 2000). These researchers’ findings indicate the imperativeness of interlinking TQM strategies with TPM. However, the literature overview would indicate that both research and practice in the direction of interlinking specific TQM strategies with TPM have been dismally low. Particularly both TQM and TPM envisage the customer satisfaction (Jostes and Helms, 1994). In TQM field, customer satisfaction is given significant thrust whereas in TPM field, the thrust on customer satisfaction has been given only indirect and minimum thrust.
In TQM field, the customer satisfaction is achieved through customer voice adoption (Hwarng and Teo, 2001). In order to achieve this strategy, the technique, QFD technique is being dominantly employed in TQM field (Fung et al., 1999, Zairi and Yousef, 1996, Kathawala, and Motwani, 1994, Bouchereau, and Rowalds, 2000, Masui, et al., 2003). However, no specific technique is envisaged in TPM field to achieve customer satisfaction. Considering the power of customer satisfaction in improving quality, it is imperative that both TPM and QFD have to be interlinked.

Besides achieving higher degree of quality levels, recent researchers have been appraising the need for sustaining engineering education (Ashford, 2004, Ferrer-Balas et al., 2004). The sustainability of engineering education is ensured by maintaining the quality of engineering education. TPM provides a way for bringing out such kind of changed scenario in engineering education. Another requirement of engineering education is to react according to its customers. In practical application, the technique QFD is found to meet this requirement. Hence the application feasibility of QFD in engineering educational scenario has to be studied. However both TPM and QFD cannot be applied in their present forms in engineering education since they are compatible with applications only in manufacturing and service organizations. In order to accomplish this process, both QFD and TPM have to be remoulded in a systematic way, so that they are made suitable for application in engineering educational scenario.