Benchmarking for strategic maintenance quality improvement

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Abstract *Points out that the concepts of total productive maintenance (TPM) were formulated by combining the principles of total quality control (TQC) and maintenance engineering. Claims that the theory of TPM is not yet exhaustive. Proposes a model called "strategic maintenance quality engineering" (SMQE) to make the theory of TPM exhaustive. Deals with the last phase of SMQE which envisages the evaluation of each cycle of SMQE performance. Applies benchmarking with suitable modifications to carry out the last phase of SMQE. Presents the salient features of pilot implementation study conducted in two companies. Suggests that the use of information technology (IT) for benchmarking SMQE would aid in improving strategic maintenance quality more effectively.*

Introduction

One of the most popular topics currently being discussed among the manufacturing community is total productive maintenance (TPM). Although TPM was formulated during the 1970s (Seiji, 1992), it became popular among manufacturing professionals only after the late 1980s. TPM emanated from the realisation that maintenance activities should not only be technologically improved but also blended with managerial concepts (Blanchard, 1997). In particular, the importance of applying total quality for enhancing the quality of maintenance activities facilitated the evolution of TPM concepts (Nikkan, 1995). The fast rate of acceptance of TPM indicates the thirst of today's practitioners for improving maintenance quality. However, a critical analysis of the theory indicates that TPM concepts are not yet exhaustive in producing continuous maintenance quality improvement. For this reason, presumably, articles introducing many new tools, techniques and approaches are being written to improve TPM concepts (Geraghty, 1996; Blanchard, 1997; Lawrence, 1999; Bamber *et al.*, 1999). Meanwhile, it is observed that the total quality management (TQM) philosophy itself has been appended with various new approaches. Of late, the strategic quality management (SQM) (Ricardo, 1994) approach has become popular among both theorists and practitioners. Hence, we thought that it would be prudent to append and integrate TPM concepts

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with an appropriate SQM model. Considering this development, in this article, we propose a model called strategic maintenance quality engineering (SMQE) which has been developed by integrating a theoretical SQM model (Aravindan *et al.*, 1996) with TPM concepts.

Even though the proposed SMQE model has not been subjected to an empirical study, a perusal of the literature indicates that many of its activities have been tried by a few organisations as part of TPM implementation (Coetzee, 1996; Deweese, 1999). However, it appears that no company has ever attempted to implement the last phase of each cycle of the SMQE model which envisages the evaluation of the progress of SMQE in comparison to competitors' progress (Nikkan, 1995). On realizing this gap, research was carried out and its details are presented in this paper. During the initial stage of the study, it was noted that the "benchmarking" technique, which has contributed significantly to both SQM and TQM programs, could also be exploited in the SMQE program. Hence, the benchmarking technique was suitably modified to evaluate the performance of maintenance quality in the SMQE program. Following this, an attempt was made to implement benchmarking in two manufacturing organizations. Due to the absence of adequate funding, the study was restricted to benchmarking only the internal competitors. The details of this work are briefly presented in this article.

SMQE model

The gurus of TPM admit that TPM has been augmented by integrating TQC concepts with those of maintenance engineering (Naakajima, 1993). A detailed study into the fundamental concepts of TPM indicates that not all TQC concepts have yet been absorbed by maintenance engineering. In other words the theory of TPM has not yet been fully developed. Presumably for this reason, a section of TPM researchers have started to develop certain concepts under the title "quality in maintenance engineering" (Seiji, 1992). There is even a journal (*Journal of Quality in Maintenance Engineering*) dealing exclusively with the topics and issues related to maintenance quality, published by MCB University Press, Bradford, UK. This trend indicates that the latest developments concerning quality improvement efforts should incorporate maintenance engineering concepts to ensure that maintenance quality projects are made compatible in modern manufacturing enterprises.

During the early phases of the research, it was realised that a suitable contemporary quality improvement model had to incorporate maintenance engineering concepts. For this purpose the development trends of quality improvement models were studied in the literature (Anonymous, 1994; Godfrey, 1995). It was realized that, in today's context, the adoption of SQM models in maintenance engineering projects would be a prudent proposition. Even though SQM is still in its development stage, many researchers have developed models for the SQM process (Ricardo, 1994; Kaye and Dyason, 1995; Aravindan *et al.*, 1996; Juran and Gryna, 1997). While all of them share the same fundamental concepts, the details of the quality strategies differ. Of these models, the model proposed by Aravindan *et al.* (1996) contains as many as nine quality strategies. Other models contain less than nine strategies and hence this model was adopted to create the theoretical foundation for enhancing maintenance quality in today's manufacturing enterprises. Also, one more strategy, "maintenance quality through counseling", was added. After integrating the principles of this SQM model with that of maintenance engineering, the conceptual elements of the SMQE model were formulated. Its features are shown in Figures 1 and 2.

Though an in-depth discussion on SMQE is beyond the scope of this article, its salient features are described here to enable the readers to understand and appreciate the background of this research. As shown in Figure 1, SMQE

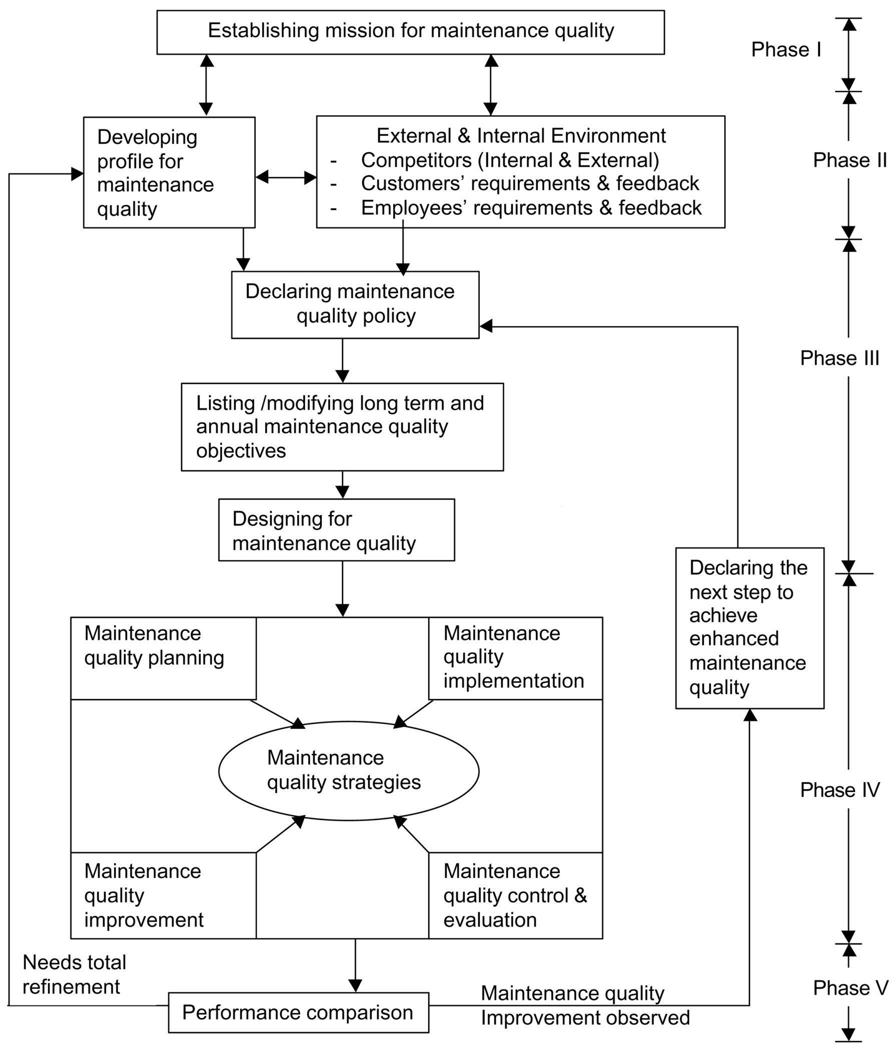

Figure 1.
Strategic maintenance quality engineering model

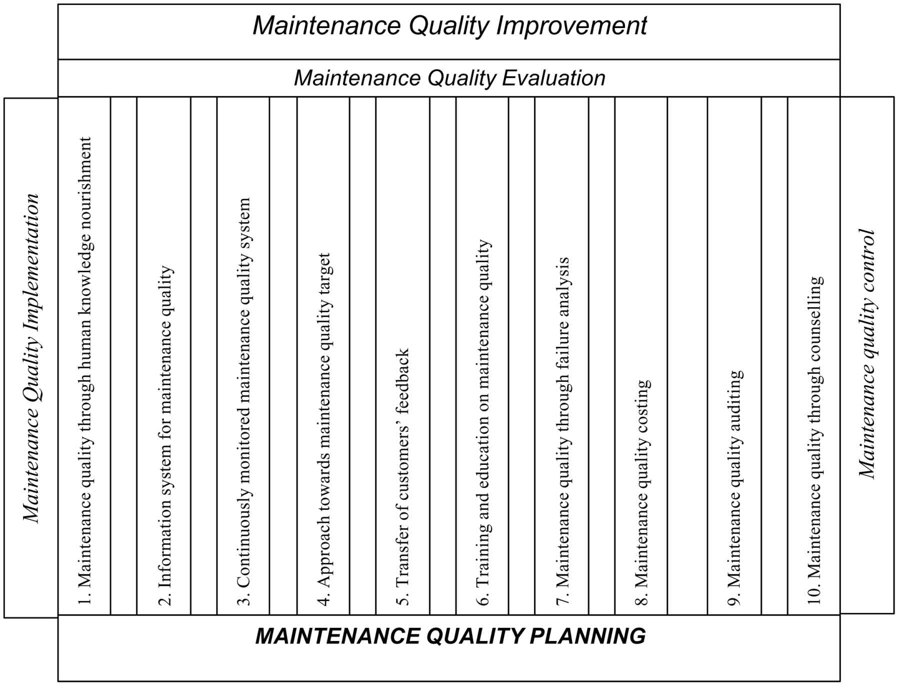

Figure 2. Maintenance quality strategies

progresses through five phases. During the first phase, the management's mission to achieve maintenance quality should be established. For example, management may have a mission to produce maintenance-free products. The coordinator of the SMQE program is required to interview the management personnel and identify their maintenance quality mission. Following this, a maintenance quality mission statement should be developed which should be endorsed by the management. During the second phase, steps towards developing a maintenance quality profile should be undertaken. A maintenance quality profile refers to the major milestones that must be achieved within different periods in the company. For example, a newly-established company will have a difficult period during the first five years while it develops. This may be considered as the first profile period and a maintenance quality profile to suit this period should be developed. This quality profile must be made realistic and feasible by comparing it with both external and internal environments. Based on the approved quality policy, the maintenance quality profile for a specific period should be declared. The difference between maintenance quality mission and policy is that the former refers to a dream which appears to be an impossible task and the latter refers to an ambition which can be achieved within the specified period provided appropriate and necessary steps are taken.

Once the maintenance quality policy is approved, the objectives must be declared. Some of the objectives can be achieved within a very short period, say one or two months. For example, fixing a maintenance activity chart in front of a set of machines takes a few weeks at the most. This can be considered as the short-term objective. On the other hand, the objectives that demand more time, e.g. many months or years, can be classified as long-range objectives. For example, identifying the cause of a set of chronic maintenance problems and taking remedial actions may take many months. This can be considered as an example of a long-range objective. Adequate care should be taken to ensure that the objectives set exactly fulfil the requirements of the maintenance quality policy. In other words, the objectives set should be neither inadequate nor superfluous in meeting the requirements of the maintenance quality policy. According to the objectives, product, process and system designs are carried out. The design activities should facilitate the achievement of both short- and long-range objectives. For example, if a number of objectives require incompatible facilities, then a new design is needed so that common facilities are utilised to achieve all the interrelated objectives.

Following the fourth phase, the fifth phase, which is the heart of the entire SMQE process, should be carried out. Figure 2 shows the expanded view of this phase. During this phase, maintenance quality strategies are developed. So far, as shown in Figure 2, ten maintenance quality strategies have been recognised. A detailed description of each strategy is beyond the scope of this article. The techniques, tools and methodologies available in the SQM field (Aravindan *et al.*, 1996) may be properly modified and applied to develop the maintenance quality strategies. It is encouraging to note that TPM concepts themselves incorporate a few of these strategies without identifying them by any of the names specified in SMQE model. For example, the strategy known as "maintenance quality through human knowledge nourishment" in SMQE is achieved in the present form of TPM implementation by employing "small group activities" (SGAs). However, many of the other maintenance quality strategies are not explicitly addressed in TPM.

The final phase of SMQE calls for holistic performance evaluation of one cycle of implementation. As the name suggests, this phase calls for a performance level comparison by considering various factors. First, it calls for its performance within the organisation itself to be evaluated in terms of the time factor, i.e. the performance of each new maintenance quality strategy should be compared with the earlier ones. Following this, the progress of the SMQE process should be compared with various departments or units in the company. In addition to this, the overall performance of SMQE should be compared with external competitors. This phase is designed not only with the purpose of rejuvenating SMQE process, but also of ensuring balance, unbiased implementation and growth of the SMQE process. Hence this phase assumes special importance and a literature review indicates that, so far, no work has been undertaken in this direction (Nikkan, 1995). Hence this was considered as the research gap and attempts were made to fill this gap by applying the "benchmarking" technique.

Benchmarking in SMQE

Benchmarking has been the only technique that has so far been applied in evaluating the quality improvement projects. Presumably due to the absence of any compelling reasons, benchmarking is not widely used in companies (Hinton *et al.*, 2000). In fact, benchmarking is a governing cum accelerating device to further develop the quality improvement projects (Watson, 1994; Fisher *et al.*, 1995). When TQM was rapidly developed during the early 1980s, benchmarking attained its highest level of recognition. As companies failed to recognize its importance in TQM projects, the popularity of benchmarking started to wane. It can be inferred that SMQE projects will also fail if each cycle of its implementation is not subjected to benchmarking. Hence it is imperative to adopt benchmarking for holistic performance evaluation of SMQE projects.

In the literature, different types of benchmarking are identified (Lema and Price, 1995). The most suitable type of benchmarking that can be adopted in SMQE is strategic benchmarking. As SMQE progresses by developing maintenance quality strategies, benchmarking should be carried out to cover maintenance quality strategies. For each maintenance quality strategy, measurement parameters should be identified for benchmarking purposes. Initially, the benchmarking of maintenance quality strategies (MQSs) in one department should be carried out by comparison with other departments. This enables the department to know, after one cycle of SMQE implementation, which MQS has been successfully developed and which has performed poorly. This enables poorly performing departments to concentrate on their MQS. Following this, all the departments can be benchmarked with reference to each MQS. For example, if the MQS entitled “maintenance quality through human knowledge nourishment” is benchmarked by considering all the departments, then it will reveal which department has excelled in implementing this strategy and which is trailing behind in implementing this strategy. If the company is maintaining partnerships with other companies, then these companies may also be subjected to benchmarking covering the MQSs.

The benchmarking for SMQE may be a difficult task when its scope is expanded to competitors which have been implementing SMQE or TPM. In this case, the competitors may not be cooperative, fearing that some of their business secrets may be leaked during the benchmarking process. However, benchmarking between companies which are not in direct competition may not face this problem. For example, a pump manufacturing company and a software developing company which have been implementing either SMQE or TPM may not have any reservations about revealing the details concerning the performance of MQSs. Hence, in order to execute a successful benchmarking program among companies, it is suggested that benchmarking should be carried out between non-competitors. This will ensure the free exchange of ideas which is vital for the improvement of the knowledge concerning SMQE implementation. Another issue that is considered as most important for benchmarking MQSs is the method used. Though the benchmarking professionals and practitioners have suggested a number of methods such as interviews, questionnaire-based surveys, personnel evaluations, etc., the method of asking questions supported by Likert's scale is the most appropriate device for benchmarking MQSs. This allows the near-perfect quantification of the performance of each MQS. Another aspect worth consideration here concerns the reporting of the benchmarking results. As benchmarking aims, basically, to improve the performance of the next cycle of the SMQE process, its report should be precise, legible, clear, and accompanied with simple statistical tools such as pie charts, bar charts, scatter diagrams, etc., so that not much time is wasted understanding and clarifying before its approval.

Case study

The pilot implementation study for checking the practical feasibility and validity of applying benchmarking for strategic maintenance quality improvement was conducted in two Indian companies. In one company, TPM is currently being implemented while, in the other, TPM has not been formally implemented. First, an Indian cement producing company was approached. In this company, TPM has been implemented since 1994. Because SMQE is a new model, the management was initially briefed about it. After negotiations, the management agreed to permit the use of their premises and facilities for an implementation study. The company is, in fact, one unit of a major Indian cement producing company. It is estimated that all the 11 units of this company combined produce about 45 percent of the cement requirements of India. In all the units, the TPM program is being implemented. This case study was restricted to Coimbatore-based unit (Coimbatore is a small city located in the Tamil Nadu state of India). In this unit, there are 741 regular employees. There are also about 300 casual laborers, but this number varies depending on the quantum of production. As in almost any mechanical engineering-based company, in this unit there are eight functioning departments.

The raw material is quarried from nearby in the form of limestone, which is subsequently processed through five major operations. Though the main policies are formulated at the company's main office located at Mumbai, the Coimbatore unit enjoys autonomy while carrying out production activities. In this unit, TPM is being implemented with the support of both employees and managerial personnel. This unit is ISO 9002 accredited. All these factors imply that the work culture and the management's interest in enhancing quality in maintenance engineering were suitable for conducting a test implementation study of benchmarking the SMQE process. As far as TPM implementation is concerned, the major activities that have been carried out in this direction are SGAs, poster campaign, slogan raising, gate meeting, frequent communication through daily meetings, and committee formations to rectify specific maintenance problems. Apart from these activities, quality engineering techniques such as quality circles, 5S, house-keeping, etc. are also being exploited in the TPM program. It was also pleasing to find out that benchmarking had once been attempted, though only on a small scale. These observations further confirmed that the theoretical development of the benchmarking of SMQE could be well tested in this unit. However, benchmarking principles were not familiar among many of the employees. An inquiry revealed that benchmarking principles have been mainly used to rank the units of the company with regard to their monthly production. Hence it was thought that if benchmarking SMQE were carried out in this unit, it would be a useful contribution and would reveal interesting research findings.

Initially an informal proposal was made to the management. On interviewing and inquiring, it was revealed that the benchmarking of maintenance quality strategies had to be restricted to the internal environment as it would be too difficult to get permission to conduct test implementation studies at other units. Hence, in order to carry out the internal benchmarking of maintenance quality strategies, questionnaires were developed. The questionnaire developed for assessing the depth of implementing the maintenance quality strategy "maintenance quality through human knowledge nourishment" is shown in Table I.

It was anticipated that the respondents would not be patient enough to respond to all the questions due to their routine work assignments. Hence the questionnaires were taken to different sections and responders were interviewed and requested to orally respond to the questions. A Likert-type scale with the range of 0 to 5 was used for each question with "0" representing the "nil" state and "5" representing the 100 percent perfect state. Middle values represented proportional values. The nature of responses varied widely. In some cases, the responders took personal interest and chose appropriate scales for each question. In many other cases, the responders did not show interest in using the Likert's scale. Since the literacy levels among low-level employees was low, in each section the head of the section was interviewed and asked to respond to the questions. Later on, in each section the lower-level employees were interviewed informally to check whether the response

Question number	To what extent are:
A1	Suggestion schemes employed?
A2	Members' ideas recognized and implemented effectively?
A3	Contributed members rewarded?
A4	Frequency of meetings balanced? (i.e. the frequency of conduct of meetings should be such that it should not affect work assignments of members, but should help them to contribute effectively)
A5	Suggestions, projects and ideas contributed by the members on the basis of requirements?
A6	Quality circle programmes conducted?
A7	SGAs conducted?
A8	Efforts made to motivate the members towards attaining this strategy?
A9	Ideas formally recorded and analysed?

Table I. Questionnaire used to obtain ratings regarding "maintenance quality through human knowledge nourishment" ratings given by the head of that section were the same. In most of the cases, the response rates pronounced by lower level employees and section heads coincided. In very few cases, the most senior employees, who felt that their suggestions were frequently ignored, responded skeptically about TPM activities. Finally, for each strategy, the response rates were collected from all sections. Table II shows the response rates for the "maintenance quality through human knowledge nourishment" strategy. Similar Tables were developed pertaining to response rates for other maintenance quality strategies.

After entering the response data into the Tables, the mean percentage performance against each maintenance quality strategy was computed. The details of mean percentage ratings for each maintenance quality strategy are shown in bottom row of Table III. Further, percentage ratings corresponding to all maintenance quality strategies were computed for all sections. The details are shown in the last column of Table III.

As shown, these computation details reveal that the instrumentation section exceeds all other sections in implementing maintenance quality strategies, whereas the crusher section lags behind all sections in overall implementation

Table II. Response ratings recorded in Coimbatore-based unit of cement company regarding "maintenance quality through human knowledge nourishment"

Responding department	Question number[a]									Average
	A1	A2	A3	A4	A5	A6	A7	A8	A9	response (%)
Crusher	2	4	3	3	3	3	4	3	3	62.2
Flotation	2	2	1	5	1	4	4	4	3	57.7
Kiln	5	5	4	4	5	5	4	5	4	91.1
Electrical maintenance	3	4	2	2	4	4	4	3	4	66.7
Instrumentation	3	5	3	5	5	0	4	4	5	85.0
Garage	3	5	1	3	4	5	4	5	3	73.3
Maintenance work shop	4	4	2	2	3	0	2	0	3	50.0
DG set	3	5	5	4	5	5	5	4	4	88.8

Note: [a] Likert-type rating scale: "0" = "nil" to "5" = 100 percent perfect

Table III. Consolidated percentage response ratings for all strategies and departments collected from the cement manufacturing unit

Responding department	Strategy number										Department
	1	2	3	4	5	6	7	8	9	10	rating
Crusher	62.2	71.1	70.0	71.4	60.0	68.5	66.7	60.0	65.9	50.0	64.6
Flotation	57.7	60.0	78.0	65.7	86.7	45.7	66.7	45.5	91.6	80.0	67.8
Kiln	91.1	86.7	83.6	85.5	80.0	75.0	100.0	71.1	63.5	25.0	76.2
Electrical maintenance	66.7	66.7	86.1	72.4	76.7	77.1	73.3	65.5	70.6	70.0	72.5
Instrumentation	85.0	91.1	94.3	88.6	100.0	87.1	100.0	82.2	96.5	60.0	88.5
Garage	73.3	77.3	70.0	76.2	83.0	80.0	66.7	60.0	71.8	80.0	73.8
Maintenance workshop	50.0	64.4	76.4	76.2	93.3	81.5	80.0	93.3	83.5	75.0	77.4
DG set	88.9	87.5	94.6	69.4	80.0	72.9	80.0	88.6	77.5	80.0	81.9
Strategical average	71.9	75.6	81.6	75.7	82.5	73.5	79.2	70.8	77.6	65.0	75.3

Note: All figures are percentages

of maintenance quality strategies. In-depth analyses were made by referring to all other Tables containing the response data. The results of the analyses were discussed with the managerial personnel who claimed that these results were helpful in identifying the main areas for future implementation to make the TPM program more effective.

On sensing the positive response of the test implementation study in this company, the same procedure was adopted for collecting data from the machine tool sections of a manufacturing company in which TPM is not being currently implemented. Since it is a small section, only two departments are functioning. The data for each maintenance quality strategy collected from the departments are shown in Table IV.

A bar chart shown in Figure 3 was developed to compare the performance of each maintenance quality strategy in both companies.

As shown, since no formal TPM or SMQE efforts have been undertaken, the machine tool section lags behind the cement company in implementing all the maintenance quality strategies. On realising the quantum of analyses, it was thought that, if statistical tools such as pie charts, bar charts, etc., are developed, then it will be of immense use to analyse and interpret the results. It was realised that manual developments of these tools would not only be extremely time-consuming, but would also be a cumbersome practice. Hence software was developed to ease the analyses and provide interpretations to ensure easy and quick decision making. However, due to lack of space, the details of the developed software are not illustrated in this article.

Table IV. Consolidated percentage response ratings for all strategies and departments collected from the machine tool section

Responding department	Strategy number 1	2	3	4	5	6	7	8	9	10	Department rating
HED Production	17.5	71.1	41.6	30.0	50.0	44.3	33.3	32.7	8.2	25.0	35.4
HED maintenance	8.8	31.1	30.8	27.4	50.0	32.8	46.7	35.0	0.0	25.0	28.8
Strategic average	13.2	51.1	36.2	28.7	50.0	38.6	40.0	33.9	4.1	25.0	32.1

Note: All figures are percentages

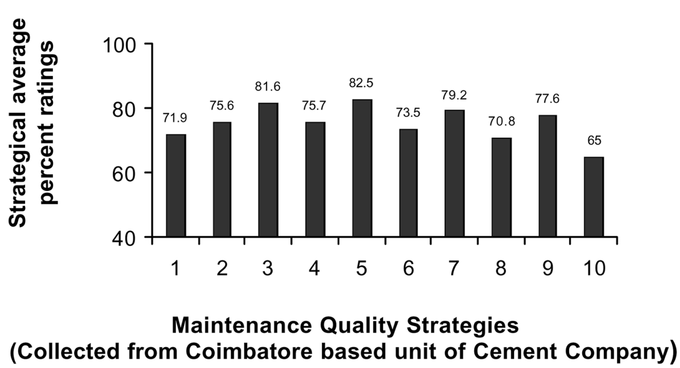

Figure 3. Graphical output

Conclusion and future scope

The reason for this research was the importance attributed to TPM concepts in the industrial world. On exploring its details, it was found out that the ultimate aim of TPM concepts is to integrate the concepts of TQC and maintenance engineering. Further analysis indicated that the scope of TPM could be enlarged and made more powerful by integrating it with the contemporary continuous quality improvement model called SQM. Hence, we designed a conceptual model, SMQE, by integrating the SQM model with maintenance engineering principles. SMQE envisages the evaluation of its progress after the completion of each cycle of its implementation. In this context we developed an interest in exploring the feasibility of exploiting the benchmarking technique in the SMQE process. As addressed in this paper, benchmarking was initially attempted in a manufacturing enterprise in which TPM concepts have been applied vigorously for the past five years. Later, the same practice was tried in a machine tool manufacturing section of a company in which TPM is not implemented. Due to the upper management's lack of influence, we could not install the benchmarking system in the company. However, the implementation experiences gave us confidence that it would be a useful contribution if companies employ benchmarking of maintenance quality strategies. An important point to consider is the increased and efficient use of information technology (IT) for benchmarking maintenance quality strategies. The experience of developing software and using it successfully for analysing and interpreting the benchmarking data revealed that, if the modern advances in the IT field are exploited, then the process could be made more efficient. To begin with, it is suggested that the benchmarking of maintenance quality strategies can be done using the developed software in a networked environment. For this, an intranet may be utilised. In addition to this, Web sites may be created exclusively for this purpose which might be useful in evolving globally benchmarked results of maintenance quality strategies. This would enable the companies to improve themselves in attaining maintenance quality strategies at global level.

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