International Journal for Quality Research 9(2) 185–196
ISSN 1800-6450

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Article info:
Received 06.10.2014
Accepted 05.05.2015

UDC – 54.061

AN ANALYTIC HIERARCHY PROCESS ANALYSIS FOR SMALL AND MEDIUM-SIZED ENTERPRISES: PRIORITIZING THE PRACTICES OF TOTAL QUALITY MANAGEMENT IN BRAZIL

Abstract: *Effectiveness of quality management in the effort to satisfy customers' expectations has been questioned both by academicians and practitioners. In the course of the evolution of quality, very important theories have been developed in the field but failed to satisfy customers' expectation. The aim of this paper is to examine the challenge and develop a new method to address it. Following a literature review on the evolution of the concept of quality, confusions and limitations in the present paradigm are clarified. Then the future quality paradigm is proposed, and two practical cases are presented to substantiate the new approach. Quality management evolved from product inspection at the final stages of the production process. Basically, manufacturers take care of quality up to the point where a product is delivered to a customer. Product failure occurs due to various reasons after purchase. However, this happened or discovered during operational phase of the product which subsequently result in dissatisfaction for the users after purchase. To address this misalignment, all inclusive approach called Lifecycle Quality came into being as the future generation's paradigm. Misalignment between the manufacturer and the customer's desire in the operational phases of a product life-time leads to market loss to the former and dissatisfaction to the latter. Considering lifecycle quality of the product will definitely resolve the occurrence of such undesired outcomes affecting the two parties.*

Keywords: *Total Quality Management, ISO 9001, Small and Medium-sized Enterprises, AHP*

1. Introduction

TQM can be considered a managerial process, performed by many activities and practices. These practices demand time and resources for their execution. The purpose of this paper is to present the application of the Analytic Hierarchy Process (AHP) to prioritize practices of TQM for Small and Medium-sized Enterprises.

Mathematical Modeling (Bertrand and

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Fransoo, 2002) was the research method adopted. Specifically, the problem was modeled using Multi-Criteria Decision Making (MCDM). AHP, the MCDM method with the greatest number of scientific publications (Wallenius *et al.*, 2008), was applied to this modeling. The choice of AHP was also based on the need of acquiring knowledge from different companies and an advantage of this method is to overcome decisions of managers which are often based on experiences or feelings. This method is especially helpful in situations with several dependent variables (decision alternatives) and independent variables (decision criteria) and thus might be a potent tool in the context of this research. So, concepts of Group Decision Making (GDM) were considered. The use of the AHP software facilitated the GDM.

A literature review on TQM practices indicated that much has been written about TQM practices and their implementation in different sectors but little attention has been given to prioritizing these practices (Talib *et al.*, 2011). However, there is a pressing need to identify the criteria for determining implementation priority of TQM practices for their successful implementation in small and medium industries.

To define what small and medium-sized enterprise is, some researchers like Hoffmann and Schlosser (2001) and Kaminski *et al.* (2008) take into account the number of employees. Thus, values vary, respectively, for small and medium-sized enterprises, from one to 10 and from 11 to 500, respectively. According to Almus and Nerlinger (1999), Bade and Nerlinger (2000), Ullah and Taylor (2007), Salgado *et al.* (2014), small and medium-sized enterprises, have attracted growing interest from academics and politicians, especially when many traditional industries faced serious problems, thus some new fast-growing industries, began to emerge. For Millward and Lewis (2005), Koufteros *et al.* (2005), Millward *et al.* (2006) and Mu *et al.* (2007), small and medium sized enterprises represent a key element in national economies around the world.

Furthermore, according to Bayazita and Karpak (2007), a considerable number of organizations have tried to implement these practices and have failed to achieve much, while many others have implemented TQM with great success, justifying researches in this area.

In order to bridge this gap, the present study uses an analytic hierarchy process (AHP) approach to determine the relative importance of TQM practices in small and medium-sized industries.

For this purpose, the main objective of the AHP application is to help managers prioritize TQM practices, because it can be very difficult to perform all the practices with the same attention. This way, TQM can be more effective, better controlling the higher-priority practices.

2. Total quality management

Total quality management (TQM) is a management philosophy aimed at improving the quality of products and processes, continuously, to achieve customer satisfaction through a quality-driven strategy. Its implementation remains an important issue for service and manufacturing organizations all around the world for improving their competitiveness. It defines the quality with emphasis on top management commitment and customer satisfaction (Lewis *et al.*, 2005; Khanna *et al.*, 2011; Kumar *et al.*, 2011; Lam *et al.*, 2011, Harrington *et al.*, 2012; Luburić, 2012).

Total quality management (TQM) is a compilation of various processes, systems, committed people, transparent communication and culture for customer satisfaction. TQM is infinitely variable and adaptable and can be defined as a managerial method both for improving an organization's core competitive ability and for gaining the maximization of market share within the

industry in which it belongs (Kumar *et al.*, 2011; Chen and Chen, 2009).

Much has been written about what constitutes the basic ingredients or the philosophical pillars of TQM. The number and priority of these elements vary from one author to another and their importance might vary as well from one organization to another. Also, most of the literature which addresses the elements of TQM is outdated (Harrington *et al.*, 2012). Recent literature addressing TQM does not emphasize the elements, since they have been exhaustively addressed in the literature that appeared when the TQM was in its introductory stage (Harrington *et al.*, 2012).

As can be seen, the benefits of adopting TQM practices are numerous and varied (Lam *et al.*, 2011). The various benefits of total quality management as stated by many researchers are (Lewis *et al.*, 2005, Kumar *et al.*, 2011): Improved competitive position, Increased profitability, Less scrap and reduced wastage, Successful new product launch, Increased productivity, Increased quality, Empowerment of employees, Employees feel confident, Gain in positive attitude, Increased teamwork, Cleanliness, proper use of space, Satisfied internal and external customers, Revenue improvement, Operational improvement, Continuous improvement, Trained work force, Reduced lead time, System approach to management, Self and mutual development, Reduced pollution, Culture change, Development of managerial ability of circle leaders.

In exploring the operating principles of TQM, the work of Alolayyan *et al.* (2011) identify eight critical practices: namely leadership, employee management, information analysis, training, customer focus, continuous improvement, process management, and supplier management. According to Vanichchinchai and Igel (2011), Talib *et al.* (2011) other critical practices are identified: quality culture, innovation, quality systems, benchmarking, strategic planning, employee involvement, product design, communication, employee incentive and teamwork.

3. Analytic hierarchy process

AHP can be recognized as a powerful method to solve problems of multi-criteria decision making in several areas and sectors for selection and hierarchy, according to researches of: Hsu *et al.* (2003); Ngai and Chan (2005); Wei *et al.* (2005); Melon *et al.*, (2006); Ayag and Özdemir (2006); Bozbura *et al.* (2007); Kang and Lee (2007); Partovi (2007); Huang *et al.* (2008); Nepal *et al.* (2010), Salgado *et al.* (2012), Taha and Rostam (2012).

According to Wang *et al.* (2007), AHP is the most popular method of multi-criteria decisions and allows the measurement of the decision judgment coherency. AHP is a systematic method of synthesizing priorities, structurally represented by a hierarchy (Saaty, 2010). Figure 1 presents a hierarchical structure composed by three levels: objective, criteria and alternatives. In practice, an AHP application may require more levels, for instance, with the inclusion of sub-criteria (Salgado *et al.*, 2012).

The Mathematical Modeling of a problem, with the application of an MCDM method, consists of three steps:

1) Identification of decision criteria and alternatives;
2) Designation of weights for the criteria and priorities for the alternatives;
3) Synthesis of the results.

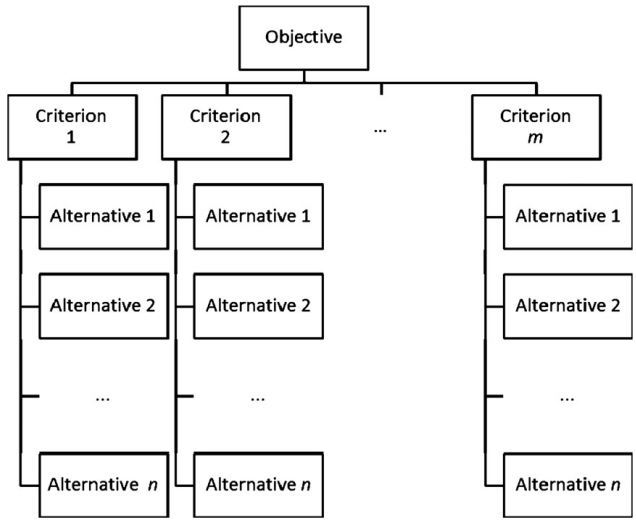

Figure 1. Hierarchical structure (Salgado *et al.*, 2012)

The prioritization of practices of total quality management in Brazil can be considered an MCDM problem. Because TQM are composed by so many practices, they are, for better understanding, grouped as in categories. This grouping facilitates the AHP application, since a "fundamental aspect of AHP is making paired comparisons of homogeneous activities" (Saaty, 2010). AHP can be applied to prioritize criteria, and then, to prioritize practices of total quality management inside the criteria.

However, the hierarchical structure for TQM practices prioritization will be a little different from the usual (Figure 1). As it can be seen in Figure 2, an alternative will only contribute to a single criterion, because in this model, a practice is performed during only one criterion.

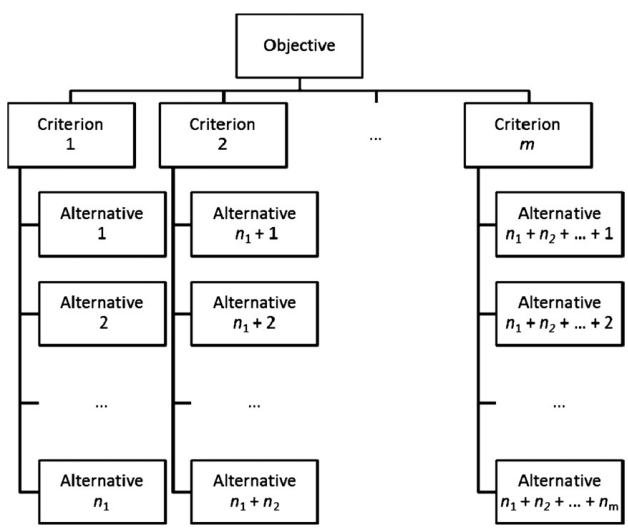

Figure 2. Hierarchical structure with alternatives contributing to a single criterion (Salgado *et al.*, 2012)

In an Excel, weights for the criteria and priorities for the alternatives are obtained with the judgments provided by experts. These judgments must be inserted in pair wise comparisons matrices, **A**. The weights, or priorities, for the compared objects (alternatives or criteria) are computed with the comparison matrix's right eigenvector, **w**, as in equation (1), where λ_{max} is the maximum eigenvalues.

$$\mathbf{A}\,\mathbf{w} = \lambda_{max}\,\mathbf{w} \quad (1)$$

The judgments, inserted in the comparisons matrices are often based on the Fundamental Scale of Absolute Numbers (Saaty, 2010). That is, a linear scale from 1 to 9. Value 1, from that scale, is used when it was judged that both objects have the same priority. One implication of the use of the Fundamental Scale is that the comparison matrix will be a positive reciprocal matrix.

Let A_1, A_2,…, A_n be the 'n' comparable alternatives or criterias with w_1, w_2, …, w_n as its weights. The matrix of ratios of all weights is given below.

$$W = \left[\frac{w_i}{w_j}\right] = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix}$$

$$where\ i, j = 1, 2, \ldots, n$$

The matrix of pair wise comparisons A = $[a_{ij}]$ represents in the intensities of the preference between individual pairs of alternatives (A_i versus A_j, for all i, j = 1, 2,…, n). Given n alternatives {A1, A2, …, An}, a decision maker compares pairs of alternatives for all the possible pairs and a comparison matrix A is obtained, where the element a_{ij} shows the preference weight of A_i obtained by comparison with A_j.

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ \frac{1}{a_{1j}} & \frac{1}{a_{2j}} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & \frac{1}{a_{in}} & \cdots & 1 \end{bmatrix}$$

However, in the AHP method, usually, the verification of the matrix comparisons consistency, takes as basis the consistency index, μ, according to Equation 2:

$$\mu = (\lambda - n) / (n - 1) \quad (2)$$

Thus, for a matrix of 100% consistent comparisons, we have m = 0, for λ = n. Saaty (2001) recommends that for values greater than 0.20 m, the comparisons should be revised. The review of comparisons is a systematic procedure for improving the multicriteria decision. The estimate of the largest λmax eigenvalues is performed by arithmetic average of consistency vector elements.

That is $a_{ij} = 1/a_{ji}$ and $a_{ij} > 0$, $\forall\ i, j = 1, 2 \ldots n$. Therefore, x, the number of comparisons required to fulfill a comparison matrix can be obtained by equation (3).

$$x = n\,(n - 1) / 2 \quad (3)$$

In the AHP application presented in this paper, the AHP software Excel was used.

4. AHP application to prioritize TQM practices

Talib *et al.* (2011) researched the prioritizing practices of total quality management using an analytic hierarchy process analysis for the service industries in India. The AHP use

served to prioritize categories and TQM practices. The AHP took into consideration the selected Talib *et al.* (2011), Khanna *et al.* (2011), Lewis *et al.* (2005), Kumar *et al.* (2011) and Souza Junior *et al.* (2014) researched. Figure 3 depicts the first three hierarchical levels.

Level 1 – Work objective, determination of implementation priorities of TQM practices for Brazilian SME.

Level 2 – Factor Categories or criteria for Brazilian SME.

Level 3 – Sub-Criteria or TQM practices for Brazilian SME.

In this case, there is no choice alternative since the idea is to order all TQM practices according to a hierarchy.

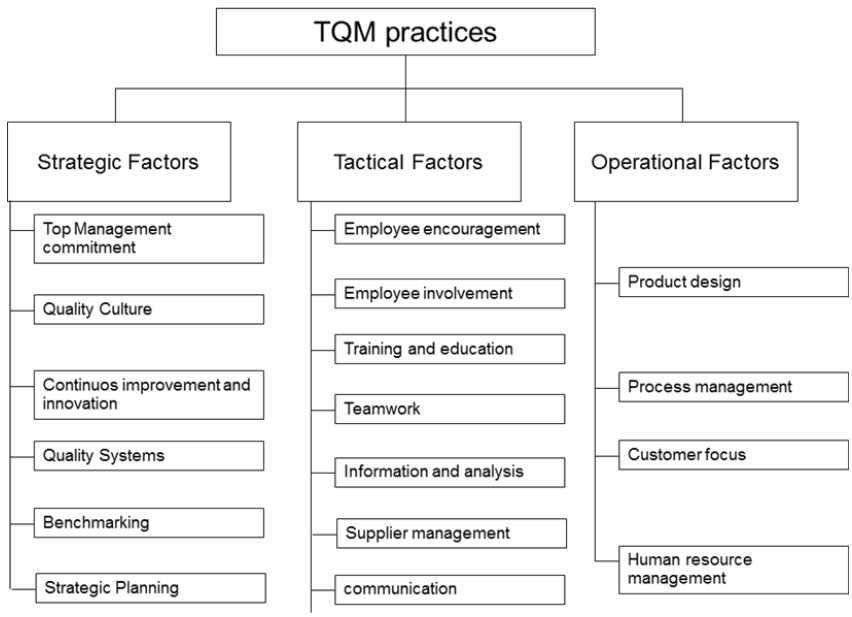

Figure 3. TQM implementation for SME's that is structured in the form of AHP (Talib *et al.*, 2011)

As for the preparation for applying the AHP method, two prior definitions were needed:

- The final choice objective;
- The evaluation criteria.

Firstly, the final choice objective may be described as the determination of priorities for implementing TQM practices for Brazilian SME. Secondly, it is the definition of criteria. This is the factor that will determine whether the other categories are best suited for enterprises concerned in this work. It is worth mentioning that the practices of low importance aggregate less value to TQM than the ones considered of great importance. Moreover, the categories and TQM practices with higher importance may have a greater attention from the responsible person for TQM.

For the application of the method, it was necessary the support of an expert in decision-making methods and of those responsible for TQM in the eight enterprises studied here. The support of the decision-making expert was necessary since he was responsible for telling the TQM staff how the judgments should be performed, how the program should be used and what maximum value should the inconsistency take.

Three evaluators were chosen from the academia with extensive experience in the field such as quality management and Small and Medium enterprises. Nine (9) evaluators were invited from organizations in eight industries namely:

- Manufacturing (IT and wire manufacturing);
- Service;
- Chemical;
- Aerospace.

All companies that participated in the judgments have ISO 9001:2008 certification, which allows a better understanding of the companies with the practice of total quality management.

After the entry of the hierarchy (Figure 3) in the Excel, the experts were defined as evaluators. Then, each expert was visited to perform the judgments. The experts were also personally contacted and informed on the research objectives.

Table 1 presents the comparisons among TQM practices for Brazilian SME, provided by Expert 1. The comparison matrix presented in Table 1 is consistent. Remarkably, all the comparison matrices provided by the experts were consistent. These are indications that the experts understood what they were judging.

Table 1. Pair-wise comparison of the three factor criteria with respect to the implementation of the TQM practices

TQM Criteria	SF	TF	OF	Priority
Strategic factors (SF)	1	**3**	**5**	65.2%
Tactical factors (TF)	1/3	1	**2**	22.3%
Operational factors (OF)	1/5	1/2	1	12.5%

The Aggregation of Individual Priorities (Saaty and Peniwati, 2007) was applied to aggregate their comparisons. The experts were considered as equally important. That is, their priorities had the same weight when aggregated. The whole data collection took less than two months. Table 2 presents the general result of the SME experts' evaluation.

Despite some divergences among the priorities for each expert, the Strategic factors were considered as the highest priority phase by all the experts. This is also according to recent researches (Talib *et al.*, 2011).

By performing a comprehensive analysis, unlike these researchers, the value obtained for the strategic factors is 56.14%. This probably happened by the fact of having more than one type of industry involved and the greater amount of respondents.

Just as the research of Talib and Rahman Qureshi (2011), the operational factors (17.90%) were considered of lesser importance to the practices of TQM compared to tactical factors (22.35%). The values are close, however this was mainly due the fact that SME's experts and academics focus on product design practices (Global - 3.82%) and, especially, in the customer focus practice (Global - 8.33%). These sub-criteria increased the scores of operational factors.

The sub-criteria with the lowest overall values are: Employee incentive (17), teamwork (16), employee engagement (15), process management (14), information and analysis (13), HRM (12) and supplier management (11). This fact distances from the 8 principles of quality management (Mellon *et al.*, 2010) and from the research by Talib *et al.* (2011).

Analyzing the strategic factors, locally, it is found that the practice of Benchmarking (Local - 6.58%) is often unknown by the companies and it is not used by vast majority. With more relevance, quality culture (Local - 12.03%) is known within the organization, but it is not a priority for small and medium-sized enterprises according to the research conducted by Lewis *et al.* (2005).

Table 2 - General result

Level	Criteria and TQM practices	Local weights	Rank	Geral weight	Rank
Criteria	Strategic factors	59.75%		59.75 %	
practices or sub-criteria	Top Management commitment	25.67%	1	15.34 %	1
	Quality Culture	12.03%	5	7.19%	6
	Continuos improvement and innovation	15.46%	4	9.24%	4
	Quality Systems	23.48%	2	14.03 %	2
	Benchmarking	6.58%	6	3.93%	8
	Strategic Planning	16.78%	3	10.02 %	3
Criteria	Tactical factors	22.35%		22.35 %	
practices or sub-criteria	Employee encouragement	8.27%	7	1.85%	17
	Employee involvement	12.17%	5	2.72%	15
	Training and education	23.71%	1	5.30%	7
	Information and analysis	12.56%	4	2.81%	13
	Supplier management	14.03%	3	3.14%	11
	Teamwork	11.99%	6	2.68%	16
	Communication	17.26%	2	3.86%	10
Criteria	Operational factors	17.90%		17.90 %	
practices or sub-criteria	Product design	21.37%	2	3.82%	9
	Process management	15.30%	4	2.74%	14
	Customer focus	46.56%	1	8.33%	5
	Human resource management	16.76%	3	3.00%	12

But the commitment of the leadership (local- 25.67% and Global - 15.34%) is seen as the most important for the strategic factor, the same way that other researchers like Talib *et al.* (2011) and Khanna *et al.* (2011).

Overall, the tactical factors had the lowest levels in the practice of TQM in SME's. By performing a local analysis of the practices related to this factor, it is clear that the SME focus mainly on training and education (local - 23.71%) and communication (local - 17.26%), which differs from the research conducted by Kumar *et al.* (2010) and Khanna *et al.* (2011), who found that these practices are less significant. But these results are similar to the results achieved by Talib *et al.* (2011) and Chen and Chen (2009) that consider these practices important among the tactical factors. However, this may be due the fact that the research conducted by Kumar *et al.* (2010) used a smaller number of practices, which could lead to such conclusions.

Thus, performing a comparison of the overall results of these practices, the data obtained by this research, compared to the survey conducted by Kumar *et al.* (2010), converge by the fact that training and education, and communication are ranked as the 7th and 10th practices. As in other

studies (Talib *et al.*, 2011; Khanna *et al.*, 2011), management of suppliers is not a practice that is a priority in TQM.

Still analyzing the tactical factor, the values obtained for the other practices were very close between them, with employee incentive (local - 8.27%) and teamwork (local - 11.99%) the practices with the lowest scores, approximating to the results obtained by Talib *et al.* (2011). This may have happened by the fact that SME do not have human resources in large quantities and for not using the incentive practice for implementation of systems.

Analyzing the operational factors, it is perceived that unlike the research conducted by Talib *et al.* (2011), but converging on the research of Chen and Chen (2009) and Khanna *et al.* (2011), customer focus (local - 46.56%) was the most important practice, locally, among all the sub-criteria. For this research, process management (local - 15.30%) had an intermediate result and is not considered a practice of high relevance to TQM.

5. Conclusions

Small and medium-sized enterprises are essential to the development of a country. The main difficulty in the conduction of this work was in the data collection. The contacted TQM experts did not know, previously, the AHP. Perhaps, also for this reason, some companies refused answering the judgments. However, it is important to state that our sample can be considered as significant, since 11 Brazilian representatives of SME were objects of study.

In this research, it was found that strategic factors are considered of greater importance for TQM. The operational factors are considered of lesser importance when compared to the tactical and strategic factors, but the customer focus sub criterion is considered a major. In the overall analysis of the results it is perceived that commitment of management, quality system, strategic planning, continuous improvement and innovation, and customer focus are the most influential practices.

Another limitation of the prioritization presented here came from the selection of the AHP, as the MCDM method applied. The sub criteria were considered as independent from each other. However, interactions may occur among several practices. Therefore, replication of the study presented with an ANP application may be the subject of future research. The results of the AHP application were welcomed by the companies' TQM experts.

But, the final approval of these results, in each company, shall be carefully studied with action researches. Thus, the prioritization of TQM practices to large industries and others branches of industry are suggested for future works.

Acknowledgments: The authors would like to thank the CAPES Foundation, (Process PE024/2008), the FAPEMIG Foundation (Processes: APQ-00976-13, SHA-APQ-04589-10, TEC-PPM-00520/13 and TEC-PPM-00058-13) and the CNPq (Processes: 249160/2013-7, 310660/2012-2, 401082/2014-8, 304628/201 2-3 and 478509/2012-0) and UNIFAL-MG, that without their support, this work would be impossible. In addition, the authors thank the interviewees, by their information, patience and devoted time for this work.

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