A QUANTITATIVE APPROACH TO MEASURE QUALITY-BASED COMPETITIVENESS OF AN ORGANIZATION

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January, 1999

KEY WORDS: COMPETITIVENESS, QUALITY MEASUREMENT, INDEX

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ABSTRACT

The operations strategy literature has identified four primary dimensions on which a firm competes with another. These are: price, quality, flexibility, and delivery dependability. Of these, quality is perhaps the most critical dimension in terms of the influence a competitive dimension exercises on the competitiveness of a firm. In this paper, we propose a quantitative measure – Quality-Competitiveness Index (QCI) - to determine the degree to which a firm's quality practices and policies are instrumental in improving its competitiveness. The QCI can be effectively employed for benchmarking among competing firms. More importantly, however, the process involved in the determination of a QCI is itself an educative one. It brings weaknesses and strengths of a company with respect to its quality practices and policies to the surface with pinpoint accuracy and can, therefore, be usefully employed to improve its quality competitiveness in an effective manner.

1. INTRODUCTION

Throughout the eighties, the corporate strategy development process has been negotiating significant paradigm shifts. A series of articles that appeared in Interfaces (e.g., Fine & Hax 1985) argued effectively that it is not enough for a company to be simply highly productive or efficient in order to gain market share. On the contrary, foreign competition and globalization place emphasis on other dimensions of competition, such as quality, flexibility (of different types, scope, or variety of products), and agility. Numerous Japanese and German companies show that higher quality, richer customization, and/or faster delivery can result in attracting more customers. This can improve market share and the profitability of operations, despite a higher price for the product or service that these companies may charge. During the eighties, the operations strategists, however, generally believed that a company should choose only one of these four dimensions so as to maintain a "focus" in all of its structural and infrastructure decisions that flows logically from the competitive priority chosen (Skinner 1974, Fine and Hax 1985, Swamidass 1986). A new paradigm of operations strategy has refined this concept in deference to the significant strides that operations technologies have made in the nineties. According to the new paradigm (Skinner 1996a, Hayes and Pisano 1996, Clark 1996.), it is possible for a firm to use new manufacturing technologies and make simultaneous improvement in cost, quality, flexibility, and agility performance despite their mutually conflicting demand on resources.

This article focuses on the *quality* dimension of competitiveness. We develop a framework to determine an index, called the quality-competitiveness index (QCI), for a manufacturing or service company. The QCI is a fractional number between 0 and 1 that measures the degree of competitiveness of a company with respect to the quality of its: mission, strategy, policies, and infrastructure.

A QCI can be interpreted as the *quality efficiency* of a company, where input is the company's total quality effort and the output is its strategic advantage arising from its quality activities. The framework proposed here to determine a QCI is generic. To apply it to a specific company, tailoring may likely be needed. Nevertheless, the measure is a useful one, since it represents a composite impact of a company's quality activities on its competitiveness. The measure can also be usefully employed for benchmarking purposes. Studying and investigating the difference between the QCIs of similar companies can lead to significant information relating to the potential areas of improvement. Indeed, the components of this measure can be intrinsically related to internal processes of the company, and a comparison with similar measures of the horizontally competing companies can be very useful in identifying weaknesses in such internal processes.

Overall then, the development of a QCI index has two benefits. First, the index tells us how effective a company's quality activities are with respect to their potential for improving competitiveness. Second, the process of development of the index yields valuable information regarding the areas of weaknesses with respect to its competitors.

The plan of the paper is as follows. The relevant literature is reviewed in Section 2. In Section 3, a discussion on identification of variables influencing a QCI is provided. An algorithm for the determination of a QCI is described in Section 4. In Section 5, an illustrative application is shown. The process for using the QCI for quality improvement and benchmarking is explained in Section 6. A discussion of relevant issues is presented in Section 7 and conclusions follow in sections 8.

2. LITERATURE REVIEW

In terms of a quantitative measure that reflects the competitiveness of a company with regards to its quality activities, there is no relevant research to date. However, the QCI serves a function similar to that of a productivity index (e.g., a productivity index reflects how well a company uses its resources to produce a specified product), for which there is relevant literature. Unfortunately, the process of development of a QCI is quite different than that of a productivity index, since a QCI relates competitiveness, which is not a concrete output. Indeed, the process used here to develop a QCI is a generic/causal one.

We first identify some conceptual dimensions or factors of quality, based on previous research and theory. Through a judgmental process of grouping similar requirements of quality, we found that the organizational requirements can be classified into the following nine separate dimensions or factors: integration of quality, operations strategy, quality leadership, customer satisfaction, employee empowerment and organizational learning, quality cost system, problem solving, lean manufacturing, continuous improvement, and quality measurement. One or more authors has mentioned many of these dimensions or factors, although none has mentioned all of them (see Table 1).

Frameworks for attaining competitive advantages through quality management have been developed via Crosby's 14 steps (1979), Deming's 14 prescriptive points (1982), and Juran's trilogy (Juran and Gryna 1980). While insightful, these frameworks do not always provide sufficient specificity for corporate initiation of quality improvements or internal evaluation of progress (Cole 1993, Wilkinson et al. 1993). Berry's list of 11 quality values consisting of how to plan, organize, and staff an effective quality program in a large company is primarily prescriptive and managerial in context. This list can be found in Zeitz et al. (1997). The Malcolm Baldrige National Quality Award (1993) has a 7-dimensionsal scheme that examiners use in assessing a company's quality program.

Anderson et al. (1994) used the Delphi method to determine basic concepts underlying Deming's 14 points. Based on the inputs of experts, seven overall concepts were identified in this study. From an examination of the voluminous literature on quality, Dean and Bowen (1994) conclude that there are three core principles inherent throughout the various alternative quality frameworks. These are customer focus, continuous improvement, and teamwork. Saraph et al. (1989) reported one of the first empirical efforts to validate an instrument for integrated quality management. They developed and tested a 78-item quality management instrument to measure the extent to which some technical aspects of a quality system have been implemented in a plant or company. A factor analysis produced eight different factors that measure the quality practice of an organization. The Flynn et al. (1994) study built on the Saraph et al. study to focus on a plant rather than an organization as a unit of analysis and utilized the perceptions of both line and managerial level employees. Ahire et al. (1996) identified, validated, and tested 12 constructs of integrated quality management through an empirical survey of 371 manufacturing firms.

These factors, survey instruments, and frameworks have been designed to examine various aspects of quality management implementation. In general, they are designed to be administered to a general manager or a quality manager in order to measure their perceptions of the extent or degree of practice of quality in an organization. Basing the measures solely on perceptions of the general manager and the quality manager has the potential for bias. Also, they are more manufacturing specific. This can limit its usefulness to manufacturing organizations, since most of these factors and frameworks focus primarily on the theoretical work and not on the empirical evidence or actual use. Indeed, they are designed to deal with quality management rather than quality performance.

To our knowledge, there are no references that address the development of a quality index in the context of quality competitiveness. However, there are is some literature that computes an index to measure the productivity or quality level of an organization, industry, or country (Alexander 1996, Beaumont and Libiszewski 1993, Bergendahl and Wachtmeister 1993, Brecka 1994, Ennew et al. 1993, Ellis and Curtis 1995, Hudson 1995, and Low and Aw 1997).

Beaumont and Libiszewski (1993) describe the applications of a quality index model using various hospitals' pharmaceutical dispensing operations as examples. The authors claim that the technique can be applied to other aspects of the pharmaceutical industry as well as to other healthcare services. The proposed index model appears to be sensitive enough to indicate changes in and identify areas of concern, such as changes in government standards. However, the authors caution that the data-gathering procedure requires improvement as they are somewhat crude and may interfere with day to day working.

Bergendahl and Wachmeister (1993) explain the creation of a total quality index by Televerket, a Swedish telecom company. This index consists of 36 core performance indicators and includes both absolute and relative measures. Weights assigned to the indicators indicate how significantly each specific indicator contributes towards the achievement of the company's business-wide quality goals. This index created explicitly for the Swedish telecom industry can be modified only for other business units that are in similar markets.

Ennew et al. (1993) propose a series of indices and related scores for measuring the quality of financial services. These indices and scores make better use of survey data and perceptions than a simple comparison of mean scores or detailed statistical modeling that is generally done when operationalizing different measures. The disadvantages with these particular indexes are that their focus is very specific to the financial sector. Also, the dimensions of service quality are relatively narrow. However, they indicate areas that might be of concern to the banking sector as a whole as well as to individual banks.

Brecka (1994) explains how the American customer satisfaction index (ACSI) quantifies quality and customer satisfaction and relates them to firms' financial performances. The ACSI uses a tested, multi-equation, econometric model to produce a national customer satisfaction index based on a scale of 0 to 100. The ACSI measures seven sectors of the economy, which includes 40 industries and over 200 individual companies and agencies. This index includes consumer perceptions of the quality of goods and services from companies and government agencies that together produce about 50% of the gross domestic product, plus foreign companies that have substantial U.S. market share. Although ACSI is good for measuring customer satisfaction and quality, it is not a relevant comparison for the present study. This is because the focus of this study is not to measure the economic performance of a region or sector but rather to measures the degree to which a firm's quality practices and policies are instrumental in improving its competitiveness. According to Hudson (1995), the ACSI charts the quality of goods and services produced in the U.S. and other countries. The index measures overall satisfaction with what people buy, eat, drive, and otherwise consume.

Ellis and Curtis (1995) discuss a customer satisfaction index that incorporates three of eight sub-components of overall customer satisfaction—responsiveness, technology, and quality/reliability. However, this index does not consider cost competitiveness and other sub-components of a possible satisfaction.

Alexander (1996) discusses a service quality index recently approved by the Maine Public Utilities Commission for NYNEX. This index contains twelve items (three items measure customer service, five measure service reliability, and four measure customer satisfaction). Each item in the index is assigned 10 points. Future performance is then compared to a baseline value. There are two disadvantages associated with this index. First, this index was specially developed for the electric utility industry and therefore may have limited applicability. Second, it allows the organization to offset less-than-acceptable performance in one measurement with excellent performance in another category.

Low and Aw (1997) propose a human development index (HDI) that measures the quality of life of a country's citizens and indirectly, is an indicator of the productivity of its labor force. Although the HDI clearly fulfills a useful role, it also is not a relevant comparison for this study.

The quality competitiveness framework proposed in this study is significantly different from the indices mentioned earlier in terms of its depth and scope. The differences are as follows. First, our index aims to tell us how effective a company's quality policies and practices are with respect to their potential for improving both quality and competitiveness. The process of developing the index is much more than just obtaining perceptions. It includes developing a set of critical quality factors, obtaining perceptions and inputs from key internal departments and external sources through customer and market surveys, assigning weights, and computation of a score. Second, the index is applicable both to the manufacturing and service sectors. Each organization, whether manufacturing or service, can customize the process of identifying factors and weights to its organizational needs. Third, the index reports on the actual company practice and degree of implementation. The index can be used as an internal and external benchmark tool and is designed to deal with quality management, performance, and improvement. Lastly, the index presents a total and clear view of business operations, weighs together hard and soft measurements, as well as relative and absolute measurements.

3. IDENTIFICATION OF VARIABLES INFLUENCING A QCI

We now develop a quantifiable measure of a quality-competitiveness relationship for a manufacturing or service firm – the QCI. This is accomplished through the steps outlined below.

3.1 Variables That Influence Quality Competitiveness

We identify three classes of interrelated variables that can influence quality competitiveness significantly (see Table 2).

*3.1.1 **Quality Factors:*** Each quality activity or factor influences the competitiveness of a company either through the products or services it produces or through its customer-company interface.

3.1.2 Departments or Functional Units: The degree or magnitude of the influence of an quality factor on the quality competitiveness of a company is a function of the activities performed by a department or functional unit in which it is implemented.

3.1.3 Stages of Quality Consciousness: The degree or magnitude of the influence of a quality factor on the quality competitiveness of a company depends on the degree of quality consciousness in the functional unit or department in which it is implemented.

3.2 Determination of Specific Variables for a Company

We propose the following guidelines to determine the three sets of variables just described for a specific company.

3.2.1 Quality Factors: First, identify as exhaustively as possible all *activities* or *factors* that can potentially impact the company's competitiveness through the quality of its products or services. The term *activity* is used here in a generic sense to include all aspects of the production/operation system such as operations, procedures, and practices. From now on, we denote these as factors U_{ij}, $i = 1, \ldots, I$; $j = 1, \ldots, J_i$. The use of a double subscript for these factors is helpful in first creating a broad classification of the factors and then fine-tuning them at a sub-factor level. In the notation provided later in Section 4.1, the redundancy of subscripts is eliminated by assigning a single-subscript index to each subfactor regardless of its parent factor.

The list of quality factors and subfactors can be developed using the following steps.

a. Compile several separate lists of factors that impact a firm's competitiveness through quality using independent knowledgeable sources. Such lists could be created, for instance, using the factors propounded by quality gurus such as Juran, Deming, Taguchi, and Crosby, or may be developed using the experts in the area relevant to the company's products or services.
b. From the compiled list of factors, an integrated union of quality factors can be created that impacts a firm's competitiveness through quality. This step eliminates redundant factors appearing in different lists.

c. Eliminate factors that do not apply to the company under study. This eliminates factors that have insignificant or no impact on the competitiveness of the company even though they may be influencing the quality to some extent. This will need input from or brainstorming with customers, market surveys, and sales representatives as well as many middle and high level managers responsible for individual departments or functional units.

d. Augment this list by additional factors specific to the company or products in question using input from customers, market surveys, and sales representatives.

A sample list of potential quality factors and subfactors can be found in columns 1 and 2 of Table 3, respectively.

3.2.2 *Stages of Quality Consciousness:* While the degree of quality consciousness is a continuum that extends from zero to perfect, we insert artificial boundaries in this continuum to create a four- or five-point quality consciousness scale or categories for the purpose of developing a QCI. This is an important step since the impact of each quality-related activity on a firm's competitiveness depends on the degree to which that firm is quality conscious. Indeed, the procedure developed here is further fine-tuned to allow consideration of the degree of quality consciousness of each functional unit or department in the company.

While any set of logical categories characterized by ascending degree of quality consciousness can be used, we suggest using Crosby's five stages (crisis management, awareness, emergence, maturity, and sustenance, see Table 2, row 2) as a starting point for this set (Crosby 1979). Let the weights of these stages be denoted by Y_k, $k = 1, \ldots, K$.

The interpretation of these weights is as follows. The weights represent, in a relative sense, how effective a particular factor is in terms of improving the competitiveness of the company under study. Thus, when a specific factor or technique is used in a department or functional unit that has a lower degree of quality consciousness, it will have a lower impact on the firm's competitiveness. The logic of this is as follows. If, for instance, a motivational program such as zero defects is used in a production unit that is still in a crisis mode, it would scarcely be effective in accomplishing its goals. However, the same technique could be very effective if the production unit has eliminated its systemic problems and has an environment of higher quality consciousness.

3.2.3 Departments or Functional Units: Identify departments or functional units that play a significant role in affecting the quality competitiveness of a company. In theory, all functional units contribute to the products or services quality so this may be a long list. However, for practical reasons, only a limited number of departments (say 8 to 10) should be included in such a list that has substantial impact on a firm's competitiveness through quality.

The weights assigned to each functional unit are denoted as Z_m, m = 1, ... , M. See Table 2, column 1, which provides a sample list of functional units or departments. The weight assigned to any department or functional unit represents the degree to which a department can impact, in a relative sense, the quality competitiveness of a company.

The impact of functional units is different from that of the quality stages described in Section 3.2.2. The departments have their *inherent* capability of the degree to which they can influence competitiveness quality. For instance, an SPC tool, such as a p chart, can be used in a production department as well as in an accounting department to control human errors, but the use of SPC in production should have a greater impact on quality-competitiveness than it would in accounting. Thus, while a department's role in improving a firm's quality competitiveness lies essentially in what the department does, and as such, is static in nature, a quality stage in which a department is classified may change over time depending on the efforts expended in implementing quality improvement programs. Then the stages are snapshots of various functional units in time in terms of their propensity to influence competitiveness but the departments or functional units themselves are permanent and would not change unless and until a department changes its scope of functionalities. This allows us to fine-tune the QCI since different departments in a company may be at different stages of quality consciousness.

We suggest that the base set of departments to be used for the purpose of developing a QCI be production, marketing, and finance. Other departments may be included based on the company, e.g., a human resource department may be more important for a headhunting service company.

3.3 The Conceptual Framework for Developing a QCI

We require the following assumptions for the development of our methodology.

3.3.1 Additivity Assumption: The individual contributions of each quality factor or subfactor are additive. That is, the total QCI is a sum of the elements contributed by factor i and subfactor j, based on both the department as well as quality consciousness of that department. This is represented by the equation,

$$\mathrm{QCI} = \sum_{\text{all } i,j} \mathrm{QCI}_{ij}$$

This assumption subsumes a simple independence assumption, which stipulates the independence of contributions of quality factors or subfactors.

3.3.2 Exhaustiveness Assumption: The quality competitiveness contributed by each factor or subfactor is a function of the three variables and their interactions described in Section 3.1 and can be represented by the following equation:

$$QCI_{ij} = F_{ij}\left\{\overline{A},\overline{B},\overline{C},\overline{AB},\overline{BC},\overline{CA},\overline{ABC}\right\}.$$

where F_{ij} is a function that relates the three vector variables - $\overline{A}, \overline{B},$ and $\overline{C}$ - the set of factors, set of departments, and set of stages, and all their interactions to yield the quality competitiveness index of factor i, subfactor j.

The impact of an array variable, QCI_{ij}, can be viewed as a small elemental volume contributed by subfactor j of factor i towards the entire competitiveness space. The competitiveness space is a conceptual enclosed space bounded by the range of impact on the competitiveness of three array variables – subfactors, departments, and stages of quality consciousness – represented along the X, Y, and Z axes, respectively of Figure 1.

Quality Competitiveness Space

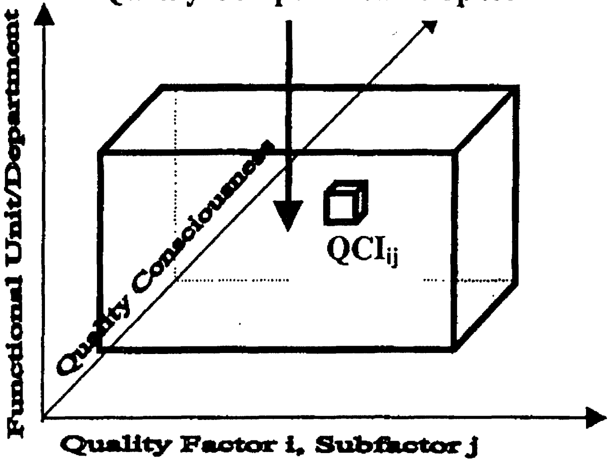

Figure 1. Three Dimensional Representation of QCI Influencing Variables

The purpose of this paper is to define the function F_{ij}, for computing QCI. Since this is complex, we present a methodology in Section 4 that develops QCI_{ij} using a series of logical interrelated linear relationships.

4. ALGORITHM FOR DETERMINATION OF A QCI

To develop these relationships, we introduce some notation in Section 4.1. First, as indicated in Section 3.2.1, we re-index the subfactors from 1 through $J_1+J_2, \ldots + J_I$, (recall that the i^{th} factor has J_i subfactors), since we are interested in the elemental influence of each subfactor on the competitiveness. Should it be necessary to evaluate the competitiveness contribution of any factor as a whole, we can add the contributions of the appropriate subfactors

4.1. Notation

The following notations are used in the development of the algorithm.

i = Index of quality subfactors, $i = 1, \ldots, J_1+J_2, \ldots +J_I$.

m = Index of departments or functional units in the company that impinge on quality competitiveness significantly, $m = 1, \ldots, M$.

k = Index of the states of quality consciousness, $k = 1, \ldots, K$.

U_i = Estimated weight of subfactor i to contribute to the quality competitiveness of the company on a scale of 1-10.

X_{mk} = Score that department m obtained in state k on a scale of 1 to 10. Note that

$$\sum_{k=1}^{k=K} X_{mk} = 10, \text{ m} = 1, \ldots, \text{M}.$$

Y_k = Weight of each state of quality consciousness based on its contribution potential to quality competitiveness on a scale of 0 to 1.

Z_m = Weight of department or functional unit m on a scale of 0-10, based on its potential to contribute to the quality competitiveness of a company of a company.

W_m = Revised normalized weight of department or functional unit on m a scale of 0 to 10 after its quality consciousness has been factored.

V_{im} = Actual performance of subfactor i in department m based on its impact on the quality competitiveness on a scale of 1 to 10.

V_i = Total weighted quality strength of factor i across all departments.

V_i^{max} = Maximum weighted quality strength of factor i across all departments.

4.2 Steps for Development of a QCI

The following steps are needed to develop a QCI.

Step 1. Create a Department-Consciousness Matrix

a. Identify all departments that play a significant role in building product or service quality or are involved in the customer-company interface.

b. Estimate and assign weights, $Z_1, Z_2, \ldots, Z_m$ to each of the m departments on a scale of 1 to 10 in proportion to the volume of quality-related activities they perform.

c. Identify stages of quality consciousness.

d. Estimate and assign weights, $Y_1, Y_2, \ldots Y_K$, to each stage on a scale of 1 to 10, that reflects the degree to which a stage can influence the quality competitiveness of a company.

e. Estimate and assign weights, X_{mk}, m =1, ..., M; k = 1, ..., K, to each cell in the department-consciousness matrix on a scale of 1-10, based on the "degree" of quality consciousness of that department within each stage. Weights must be assigned to a department in adjacent stages only. Furthermore, these weights should add up to 10 for each department to assure comparability between departments

Step 2. Compute the Weighted Quality Consciousness Level

a. Use Equation (1) to calculate each department's weighted quality consciousness level.

$$W_m = Z_m \sum_{k=1}^{k=M} X_{mk} Y_k, \qquad m = 1, 2, ..., M. \tag{1}$$

b. Normalize the *weighted quality consciousness levels* on a scale of 10 using the following substitution.

$$W_m \leftarrow \frac{10W_m}{Max\{W_m\}}, \quad m = 1, 2, ..., M. \tag{2}$$

Step 3. Create a Quality Competitiveness Matrix

a. Estimate and assign weights, U_i, i = $J_1 + J_2 + \ldots J_I$, for each quality factor or sub-factor on a scale of 1 to 10 based on its contribution to competitiveness of the company. This requires active involvement of top level personnel from marketing, sales, production, and quality departments; customers, and higher management personnel.

b. Estimate and assign weights V_{im} for i = 1, ..., I; m = 1, ..., M on a scale of 1 to 10 such that each assigned weight accurately reflects the effectiveness and completeness with which the subfactor in question has been applied to or implemented in department i.

Step 4. Compute the Quality Competitiveness Index

a. *Compute the Weighted Quality Competitiveness Strength.*

For each subfactor i, i = 1, ..., I, compute its weighted quality competitiveness strength using Equation (3).

$$V_i = U_i \sum_{m=1}^{m=M} V_{im} W_m, \ i = 1, 2, ..., I. \quad (3)$$

The expression for V_i contains a composite influence of all the departments in which subfactor i was present, the state of quality consciousness of each department, and the degree to which a subfactor contributes to the quality competitiveness of a company.

b. *Compute the Weighted Maximum Quality Competitiveness Strength.*

Set each entry in the matrix (V_{im}) equal to 10 and use equation (4) to compute the theoretical maximum quality competitiveness strength that each subfactor.

$$V_i^{max} = 10 U_i \sum_{m=1}^{m=M} W_m, \qquad m = 1, 2, ..., M \quad (4)$$

The interpretation of this term is that the contribution of subfactor i towards the total competitiveness would be V_i^{max} if the subfactor was implemented or applied in a manner that yields maximum possible strategic advantage.

c. Compute the quality competitiveness efficiency for subfactor i, i = 1, ..., I, as the ratio V_i/V_i^{max}.

d. Compute the relative contribution to quality competitiveness.

This is computed using equation (5).

$$QCI_i = \frac{V_i}{\sum_{i=1}^{i=I} V_i^{max}}, \quad m = 1, 2, ..., M. \quad (5)$$

QCI_i represents the relative (proportional) contribution of a quality subfactor to the total quality competitiveness of a company.

Step 5. Compute the Quality Competitiveness Index

The quality competitiveness index for a company is computed using equation (6).

$$QCI = \sum_{i=1}^{i=I} QCI_i. \quad (6)$$

A comment about the requirement of adjacency of quality consciousness weights stipulated in Step 1 (e) is in order. As a matter of practicality it is desirable that these weights are assigned either to any one cell or two adjacent cells. The stages of quality consciousness represent a chronological evolution of a department from the lowest stage of quality consciousness (crisis management) to the highest stage of quality consciousness (sustenance) as the quality improvement effort is expended. Any department, at any given time may be either in a given state of quality consciousness or in a state of transition from one state to the next higher state. Hence the adjacency of weights is dictated by reality. However, the presence of weights in non-adjacent columns or in more than one column is not a limitation of the QCI algorithm presented above. Indeed, our Table 2 contains several rows where the weights are assigned to more than two cells.

4.3 An Example

The following example shows how steps 1-5 of the algorithm presented in section 4.2 and equations (1)-(6) can be applied for a hypothetical Company A. The example further shows how the methodology is used for benchmarking and quality improvement.

Step 1. Create a Department-Consciousness Matrix

a. A list of departments that are relevant to QCI is placed for a company, called Company A, in Column 1, Table 2. Ten departments qualified to be on the list.

b. The weights assigned to these departments are placed in column 2, Table 2. These weights were assigned using the authors' own judgment.

c. The five stages of quality consciousness adapted from Cosby (1979) are placed in row 2, column 3-7 of Table 2.

d. The weights assigned to the stages of quality consciousness are placed in row 3, columns 3-7 of Table 2. These weights are assigned using the authors' judgment, consistent with the increasing impact of these stages on quality consciousness as one moves from the crisis management stage to sustenance.

e. Weights X_{mk}, m = 1, ...9; k = 1, ..., 5, were generated using a pseudo random number generator and placed in rows 4-13 and columns 3-7 of Table 2.

Step 2. Compute the Normalized Weighted Quality Consciousness Level

a. Using equation (1), compute the weighted quality consciousness level as follows. See column 8 in the production row (row 4), of Table 2.

$$W_l = (0*2.0 + 0*4.0 + 1*6.0 + 8*8.0 + 1*10.0)*10 = 800.$$

b. The Normalized weighted quality consciousness level for production department is calculated using equation (2). See column 9, row 4 of Table 2.

$$W_l = \frac{10*800}{800} = 10.$$

Step 3. Create a Quality Competitiveness Matrix (Table 3)[1]

a. Fifty-five weights, one for each subfactor, are generated using a pseudo random number generator and placed in column 3 of Table 3a and 3b.

b. The transposed weights from the last column (column 9) of Table 2 are placed in row 2 of Table 3.

c. A total of 55 x 9 (= 495) weights were randomly generated and placed in cells at the intersections of each subfactor and department of Table 3. For instance, a weight of 4 was assigned (through a random number generator) to the cell at the intersection of *production* (column 4 of Table 3a) *and quality assurance departments as part of the organizational planning* subfactor (row 3 of Table 3a).

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[1] Due to the large size of Table 3 (57 rows, 16 columns), it has been divided into four smaller tables – 3a, 3b, 3c, and 3d - to improve readability. Table 3a contains rows 1-27 and columns 1-9, Table 3b rows 28-57 and columns 1-9, Table 3c contains rows 1-27 and columns 10-16, and Table 3d contains rows 28-57 and columns 10-16. In addition, each of these four tables contains two header rows (rows 1-2) and three header columns (columns 1-3). Rows and column numbers are displayed in each table for easy reference.

Step 4. Compute the Quality Competitiveness Index

The following computations refer to the first subfactor, *quality assurance as part of quality planning,* row 3 of Tables 3a and 3c.

a. The weighted quality competitiveness strength is computed using equation (3) as follows.

   V_i = 2.0*(4*10+5*9.5+6*5.3+5*5.25+3*4.3+0*5.775+9*2.3+6*7.6+3*10.0) = 508.6.

   See column 13, row 3 of Table 3c.

b. The weighted maximum quality competitiveness strength is computed using equation (4) as follows.

   V_i^{max} = *2.0*10*(10+9.5+5.3+5.25+4.3+5.775+2.3+7.6+10.0)* = *1198.5.* See Table 3c, column 14, row 3.

c. The quality competitiveness efficiency for this subfactor is 508.6/1198.5 or 0.4244 (see row 3, column 15 of Table 3c). This number tells, given the quality consciousness of each department, how well a quality subfactor, activity, or technique has been implemented or applied. Thus, this number shows the quality performance and capability of management in terms of application of a specific subfactor. Thus, one can conclude that the management is only 42% effective in using quality assurance as part of organizational planning as a means of improving quality competitiveness.

d. The value of the relative contribution to quality competitiveness of the subfcator *quality assurance as part of quality planning* is 0.0028 as computed in accordance with equation (5). See Table 3c, column 16, row 3. This means that, given the current level of the company's quality competitiveness, 0.28% is contributed by this subfactor. The maximum possible contribution by this factor, if implemented ideally, would be 0.0028/0.4242 or 0.0066, provided that the quality consciousness of departments does not change.

Step 5. Compute the Quality Competitiveness Index.

The QCI for Company A is 0.5061 computed as the sum of all of the elements (QCI_i's) in column 16. The interpretation of this number is that Company A is only 50.61% effective in the performance of its quality function compared to the maximum quality competitiveness possible. Many other interpretations and uses of QCI are discussed in the following two sections.

5. AN APPLICATION OF THE QCI METHODOLOGY

To demonstrate the use of the methodology, we extend the previous example with data generated synthetically from a pseudo random number generator. The randomly generated data presents an opportunity to demonstrate many important points pertaining to the technique, a facility that sometimes is not available with real world data. The demonstration runs through 7 tables (Tables 2-8). Tables 2 and 3 contain the necessary information (factors, subfactors, stages of quality, departments, and weights) about a Company A. Tables 4 and 5 contain the same information about a Company B. Table 6, the variance table, contains the information on the quality-competitiveness differential between the two companies and is constructed from Tables 3 and 5. Note that Table 5, as presented, is also partitioned into 4 segments – Tables 5a, 5b. 5c, and 5d. The partitioning lines are identical to those of Table 3 as described in the footnote on P. 17. Tables 7 and 8 enunciate specific points that emerge from the analysis of information available in Tables 2-6. The data generation for various tables is now explained.

Table 2 is constructed as follows. All nine departments in the company are identified that can significantly impact the quality competitiveness of the company. These are listed in column 1. Column 2 contains the weights of these departments which are expected to accurately reflect their importance on a scale of 1 to 10 with respect to their ability to influence the quality competitiveness of the company. The weights are generated, for the purpose of this example, using a uniform random number generator. The next five columns contain information on the state of quality consciousness in each department. A particular department of the company could be in any of the five states of quality consciousness, from crisis management to sustenance (Table 2, row 2). The weights for these states are arbitrarily assigned as

2, 4, 6, 8, and 10, consistent with the fact that the increasing quality consciousness levels have increasing impact of subfactors on the quality competitiveness of any company. The numbers in these five columns are essentially scores on a scale of 1 to 10 that different departments of the company have obtained based on their actual state of quality consciousness. For instance, the production department has a quality weight of 10 (the maximum possible), and given its current state of quality consciousness, it scored 1 in emergence, 8 in maturity, and 1 in sustenance. In other words, on the continuum of quality consciousness, it attained 80% (8/10) maturity, it has still some parts (10% or 1/10) in an emergence state and some of its parts (10% or 1/10) have moved into the sustenance state. Notice that these numbers are in adjacent stages, as realism would dictate. Column 8 is the sum of each row element multiplied by the factor weight (equation 1). In column 9, these weights are normalized to a scale of 10, using the formula in equation (2). Thus, column 9 provides the net quality competitiveness weights of each of the nine departments in Company A, which also subsumes the information on quality consciousness.

Table 3 is constructed as follows. The first two columns represent the broad quality factors and their refined subfactors. The third column is the quality-weight of each subfactor. These weights are generated through a pseudo-random number generator based on a uniform (0,10) distribution. The next 9 columns are the departments that were identified in Table 2. Row 2 contains the normalized quality consciousness weights of each department that were developed in Table 2. The number in the cells in each department column (4-12) and each subfactor row (3-57) is what the department scores on a scale of 1 to 10 in that factor. For the purpose of this example, these numbers were generated using a uniform distribution with a range of (0, 10). Columns 13-14 are computed using equations (3) and (4), respectively. Column 15 is the ratio of column 13 to column 14 in each row. Column 16 is developed using equation (6). The last element in Table 3, column 16 is the QCI of company A, which is the sum of all the elements in that column. Tables 4 and 5 are the counterparts of Tables 2 and 3, respectively, for Company B. Table 5, as presented, is also segmented into tables 5a, b, c, and d exactly as Table 3 was.

The purpose of Table 6 is to facilitate a focused discussion of the variance between companies A and B. This table contains information from Tables 3 and 5, and is, in essence, condensed information needed for the comparison of the quality performance of two companies. Columns 1 and 2 are the same as those of Tables 3 or 5. Columns 3 and 4 of Table 6 are columns 15 and 16 of Table 3. Columns 5 and 6 of Table 6 are columns 15 and 16 of Table 5. Column 7 is computed as the difference between column 5 and 3 and Column 8 is computed as the difference between columns 6 and 4. Thus, columns 5 and 6 represent the differential between companies A and B on the issues of competitiveness efficiency and relative contribution to quality competitiveness for each subfactor. Consistent with the partitioning of Tables 3 and 5, Table 6 is partitioned into Table 6a and 6b for readability. Table 6a contains rows 1-27 and Table 6b contains rows 28-57 of Table 6 as well as the header rows 1 and 2 of Table 6.

6. USING THE QCI FOR QUALITY IMPROVEMENT AND BENCHMARKING

The QCI and the process of developing a QCI have diagnostic value insofar as the quality of an organization is concerned. Using the information developed in Section 4, we now demonstrate how the QCI development process can be used to improve the quality of a firm and determine where it stands relative to its competitors. We use Table 6a and b, because they contains the information of interest.

6.1 Quality Competitiveness Indices

From the last row of columns 4 and 6 of Table 6b, we see that the QCI for Company A is 0.5061 and for Company B, it is 0.3733. The QCI differential is 0.1329 (ignoring the small round-off error in the fourth place of the decimal, see column 8, last row of Table 6b). These numbers can be interpreted as follows: Company A's quality competitiveness is 50.61%. We can conclude that it has a way to go before it approaches the theoretical maximum of 100%. Similarly, Company B's quality competitiveness is 37.33%, and it has even more work to do before it approaches 100%. Thus, in comparing the current values of QCIs with the theoretical maximum of 1.0, we have essentially conducted a broad external benchmarking process with an ideal company. This illustration shows that the process of development of a QCI provides specific information as to the effectiveness of a company's quality efforts from the standpoint of competitiveness for each subfactor.

6.2 Quality Competitiveness Efficiency

From the last row, columns 3 and 5 of Table 6, notice that the average competitiveness efficiency of Companies A and B is, respectively, 0.5070 and 0.3771. This indicates that, on a macro levele Company A has done a better job of implementing quality-related techniques, obtaining higher levels of strategic advantage from its efforts. Furthermore, company A is able to get about 12.98% more competitiveness form its efforts compared to company B (see last row of column 7 of Table 6).

On a micro level, the same information can be analyzed for each subfactor. Consider, for instance, the subfactor *design for manufacturability* (row 4). The quality competitiveness efficiency of this factor is 0.4780 (column 3, row 4 of Table 6a) for company A, while it is only 0.2875 (column 5, row 4) for Company B. This means that, Company A is getting only 47.8% of the maximum possible contribution from this subfactor towards the firm's quality competitiveness. Company B is getting even less – only 28.75%. Thus, these numbers have both independent significance (i.e., where a company stands with respect to the ideal achievable performance on a factor) and also relative significance, i.e., how well a company is doing with respect to another in the same industry. The performance differential between Companies A and B is 19.05% (column 7, row 4). The variance here suggests the degree of efforts needed by Company B to be competitive with Company A on this specific factor. In the discussion in Section 6.4, we refine this difference even further. It can be tracked down to the department level.

6.3 Relative Contribution to Competitiveness

For the subfactor *design for manufacturability*, the relative contribution to competitiveness is 0.0124 and 0.0075, respectively, for Companies A and B (row 2, columns 4 and 6 in Table 6a). This means that out of the entire competitiveness index of 0.5061 of Company A, 0.0124 comes from *design for manufacturability*. Similarly, out of the entire competitiveness of 0.3733 of Company B, 0.0075 comes from design and manufacturability. These results indicate that Company A receives 2.1% contribution towards its total competitiveness from its implementation of *design for manufacturability* while Company B receives only 1.9%. This difference is obviously a composite resultant of many differences between the two companies. The actual quality consciousness state of the departments that employ this subfactor, the weights assigned by the two companies to this subfactor, the actual importance of the departments of the company, and finally, the performance of each company on this subfactor in each department - all have been factored into the calculation. Analyzing each of these items separately will provide further insights as to what needs to be specifically addressed in company B if it has to become competitive with A. We demonstrate how to do this in Section 6.4.

6.4 Internal Benchmarking

From Tables 3 and 5, the *design for manufacturability* related information (row 4) has been extracted and reproduced, along with the weights of the department-consciousness, in Table 7. It is clear that Company B's performance is poor on this subfactor in the production, PPC, and human resource departments compared to Company A. On a scale of 0 to 10, the scores are 4 and 1, 6 and 1, and 9 and 3, respectively for companies A and B, in the three departments. Given that these three departments subscribe most significantly (weights 10, 5.25, and 7.6 for Company A as compared to 10, 3.75, and 6.4 for company B), it follows that there is a clear need to improve Company B's performance on design for manufacturability-related activities in these three departments. Also, note that the competitiveness difference between Companies A and B is further accentuated because the weights of two of these three departments were significantly lower in Company B (5.3 for Company A and 3.75 for Company B in PPC, 7.6 for company A and 6.4 for company B in human resource). The reasons for these differences can be further tracked down in Table 8. Company B is better in service/staff type functions such as finance, accounting, and marketing on this subfactor, but these factors hardly impact *the design for manufacturability.* Hence, company B remains way behind company A in terms of gaining competitive advantage from its implementation of *design for manufacturability* as a quality subfactor.

We can even further pursue the differences arising from the three departments, production, PPC, and human resources. For tracking down these differences, we look at the degree of quality consciousness of these departments. Table 8 is excerpted from Tables 2 and 4 for this purpose. While the quality consciousness of Companies A and B is identical in the production department, Company B is in lower stages of consciousness in PPC and human resources. This indicates that the personnel handling the design for manufacturability aspect in PPC and human resource department must be retrained and re-educated. Further analysis may identify other reasons. These may include a need for a new jig or fixture or tooling, greater degree of fool-proofing of the equipment, or simply that the company needs to initiate a motivational program to harness the workers' self esteem to produce defect-free product.

This example serves to illustrate how the information on the QCI and the process of development can be effectively employed to track down deficient departments. Indeed, the entire exercise may be cathartic and could be used to pinpoint what exactly is the nature of improvement needed and where the efforts for remedial or preventive action may be directed.

We conclude the demonstration with two observations. First, since the numbers were randomly generated, the reader should not try to look for logical magnitudes or meanings of the weights. Second, the example just described pertains to just one subfactor, design for manufacturability. A similar analysis could be done for the remaining 54 subfactors.

7. DISCUSSION

The quantification of a company's performance on its quality activities as it relates to competitiveness opens up new opportunity to apply existing methodologies that improve decision-making. Two examples are provided in Sections 7.1 and 7.2.

7.1 Ranking of Priorities

The QCI methodology and the associated analyses present an opportunity to rank the priorities of a company in terms of where its effort should be expended in improving quality consciousness and implementing quality techniques. The QCI_i for each subfactor provides information as to the potential for improvement. The quality weight of the subfactor indicates how vital it is to pay attention to that factor in terms of its propensity to improve competitiveness. Indeed, this methodology lends easily to a Pareto type ranking methodology, thus guiding management effort towards a judicious course of competitiveness improvement.

7.2 Maximizing the Value of Resources Using Knapsack Formulations

With a limited budget for improvement, most companies face a decision as to where it's efforts or resources should be focused to maximize impact on competitiveness. To accomplish this, the methodology presented here lends to knapsack-type formulations. To see this, notice that each subfactor has a quality competitiveness weight (see, for example, column 3, table 3). These weights will constitute the objective function coefficients. The constraints may flow from the budgetary constraints in each department and the incremental cost of implementing the subfactors in each department. A detailed discussion of this formulation is outside the scope of this work which is confined to dealing with the development of QCI methodology.

On the other side, the quantification of subjective attributes such as competitiveness and the impact of quality efforts invariably leads to questions of validity and reliability. Some of these concerns are now outlined.

7.3 Validation Issues

According to Little 1970, Roberts 1977, Powers et al. (1983), and others, a model should be simple, transparent, and flexible. In our view, the framework presented here meets these criteria. The provided examples serve to improve the transparency of the framework. Flexibility is subjective to measure. We suggest that the model presented here is flexible enough to apply to any manufacturing or service organization and many types of quality systems. Toulmin et al. 1979 and McCloskey 1985 argue that in OR/MS, a *convincing argument* may help model validation. While the criteria for model validation discussed appear to support the case for validation of the framework presented here, we anticipate some problems in validating the model based on the subjectivity of the input in the matrices developed in Tables 2 and 4. However, it can be argued that most attempts to quantify performance is judgmental. These frameworks and models that seek subjective inputs to subjective criteria and being condensed into a number are difficult to validate.

This methodology has been validated based on two examples and appears to serve the objectives for which it has been developed. Not only were the estimates of a QCI developed accurately, we were also able to track down the culprit departments and factors effectively as prime candidates for improvement. However, this needs to be further tested over the course of several years, on real systems. Further work and insights are needed to fine-tune this work to serve the dual functions of internal and external benchmarking.

Finally, we believe that the validity and utility of this methodology is intimately dependent on the process of application, reliability of input, and training of personnel involved in the assessment of competitiveness. Furthermore, the QCI as a means of external benchmarking should be valid for the companies within an industry and must be used within the industry only.

7.4 Interpretation Issues

There are several issues relating to the interpretation of QCI that bear discussion. Hence, the interpretation of QCI should be done carefully, noting that a large amount of information is embedded, using a judgmental process, in a single number.

First, note that on its own, the QCI is expected to represent how effectively the quality policies of a company have contributed to the competitiveness of a company. However, this statement should be understood to have a large confidence interval around itself. There are a large number of subjective assessments and inputs that go into the determination of QCI. The margin of error in a QCI will be a result of all of those uncertainties. Hence, care must be taken in making specific inferences from a QCI.

Second, if a Company A has a larger QCI than a Company B, does it mean that Company A is strategically more successful than B? The answer is, not necessarily. For example, company B may have a strategic advantage in price or flexibility that may offset the quality advantage. Furthermore, the difference in QCIs may be within the margin of error.

Lastly, the QCIs of companies under different industries are not comparable qualities and as such all interpretations resulting from such comparisons would be invalid. This is because different industries will require vastly different weights for consciousness, departments, etc.

8. CONCLUDING REMARKS

A methodology is developed and presented that will allow companies to compute a quality competitiveness index that represents a composite value of the effectiveness with which a company has implemented its quality techniques, policies, and other activities. The index has some parallels with productivity efficiency in terms of the purpose of interpretation. Just as productivity efficiency indicates, on a scale of 0 to 1, how well a company's resources have been employed for production, a QCI indicates how well the company's quality activities are performed to gain strategic advantage.

The QCI development process allows evaluation of a company's performance on its quality-related activity as a stand-alone entity. The process also allows comparison with other companies in the industry. Perhaps a most useful outcome of the process of development of a QCI is that it allows tracking of factors and departments that are substantially impacting the quality competitiveness of a company adversely. An illustrative example is included to demonstrate the effectiveness of the process.

It is hoped that the framework presented here will constitute an important tool for companies seeking to improve their competitiveness through quality. The QCI developed here could help position them appropriately in a ranking on quality and provide insights as to the strengths and weaknesses of their system with respect to quality savviness. This in turn may provide a foundation for developing a blueprint to help successfully compete on quality.

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Table 1. Dimensions and Authors

Authors	Integration of Quality		Quality Leadership	Customer Satisfaction		Employee Empowerment	Quality Cost System		Problem Solving	Lean Manufacturing	Continuous Improvement	Quality Measurement
Ahire et al. (1990)	X	X		X			X	X			X	
Anderson et al. (1994)	X	X		X	X					X	X	
Berry (1991)			X	X		X	X			X	X	X
Black and Porter (1996)			X	X		X	X		X	X	X	X
Crosby (1979)			X	X			X		X		X	X
Dean and Bowen (1994)			X	X		X	X			X	X	X
Deming (1982)			X	X		X	X		X	X	X	X
Flynn et al. (1994)			X	X		X	X		X	X		X
Juran and Gryna (1990)			X	X			X		X	X	X	X
MBQA (1993)	X		X	X	X				X			
Saraph et al. (1989)			X		X	X	X		X	X		X
Wilkinson et al. (1993)			X	X	X		X				X	X

Table 2. Department-Consciousness Matrix for Company A

		State of Quality Consciousness						
		Crisis Manage-ment	Awareness	Emergence	Maturity	Sustenance	Weighted Quality Consciousness Level	Normalized Weighted Quality Consciousness Level
Department/Functional Unit	Weight	2.0	4.0	6.0	8.0	10.0		
Production	10	0	0	1	8	1	800.0	10.000
Quality Assurance	10	0	0	2	8	0	760.0	9.500
Production Planning and Control	6	0	0	5	5	0	420.0	5.250
Employee Empowerment and Organizational Learning	7	0	2	5	3	0	420.0	5.250
Finance	5	0	2	2	6	0	340.0	4.250
Marketing	7	1	2	1	5	1	462.0	5.775
Accounting	4	2	3	5	0	0	184.0	2.300
Human Resources	8	0	0	4	4	2	608.0	7.600
Engineering and R&D	10	1	1	1	1	6	800.0	10.000

Table 3a: Quality-Competitiveness Matrix for Company A

Row \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Production	Quality Assurance	PPC	Employee Empowerment & Learning	Finance	Marketing
2				10	9.5	5.25	5.25	4.25	5.775
3	Integration of Quality Into Operations Strategy	Quality Assurance As Part of Org. Planning	2	4	5	6	5	3	0
4		Design for Manufacturability	8	4	4	6	3	3	10
5		Motivational Programs	9	3	3	9	1	1	9
6		Quality As Part of Mission Statement	4	5	7	8	9	8	9
7		Quality As Distinctive Competency	7	10	8	2	6	2	5
8		ROQ Accounting	1	7	2	7	2	0	0
9		Quality Review Frequency and Level	1	2	10	4	5	5	0
10	Quality Leadership Organizational Learning	Top Management Commitment	9	7	1	0	3	3	6
11		Quality Training	5	1	10	1	3	3	10
12		Quality Circles	9	4	10	0		6	10
13		Development of Supportive Structures	6	3	10	9	0	1	0
14		Communication Efficacy	1	8	9	3	10	7	6
15		Change Management	1	3	5	9	2	8	0
16	Customer Satisfaction	Quality Function Deployment	1	5	4	5	3	1	5
17		Complaint Disposal Time	6	8	9	0	6	8	9
18		Guarantee & Warrantee	3	9	4	2	8	8	8
19		Product Liability Extinction System	7	9	9	10	5	8	0
20		Field Investigation	2	8	7	9	7	0	10
21		Complaint Management System	1	0	9	9	9	7	2
22		Customer Involvement in Policy Formulation	3	0	4	1	8	3	10
23		Frequency of Customer Surveys	5	10	3	4	4	7	4
24	Employee Empowerment and Organizational Learning	Work Teams	6	7	9	4	7	4	4
25		Quality Training	7	8	9	7	6	10	4
26		Quality Circles	1	10	0	6	1	8	5
27		Rewards and Incentive System	1	3	2	9	4	2	2

Table 3b: Quality-Competitiveness Matrix for Company A

Row \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Production	Quality Assurance	PPC	Employee Empowerment & Learning	Finance	Marketing
2				10	9.5	5.25	5.25	4.25	5.775
28	Quality Cost System	Data at Source and Integrity	8	3	3	3	6	2	9
29		Quality Cost Reduction Programs	5	6	2	5	4	0	6
30		External Failure cost	5	9		6	1	1	10
31		Internal Failure Cost	2	6	4	0	2	10	8
32		Prevention Cost	9	4	4	7	2	0	9
33		Appraisal Cost	10	4	9	10	5	6	8
34		Quality-Optimality at 1005 conformance	10	6	9	0	1	1	4
35	Problem Solving	Old seven tools	9	8	2	8	1	1	9
36		New Seven tools	10	10	0	9	0	6	9
37		Modern seven tools	2	7	5	3	2	5	2
38		Taguchi Methods for Process optimization	8	10	7	6	9	2	8
39		Prevention vs. Remedial philosophy	9	5	10	1	1	8	7
40	Lean Manufacturing	Emphasis on "Pull"	7	0	9	6	2	8	1
41		JIT/Kanban Philosophy	8	5	1	6	8	4	10
42		Waste Elimination	4	6	1	9	5	3	2
43		Value-Added Based Decisions	3	8	0	4	2	7	4
44	Continuous Improvement	Employee Suggestions Program	10	0	10	1	1	0	0
45		Process Control Through k-Sigma Measure	9	3	2	2	10	2	7
46		Lot Control	6	8	1	5	9	8	0
47		Taguchi Methods	1	9	6	1	10	5	10
48		Work Teams	5	7	3	3	0	3	9
49	Quality Measurement	Extent of Documentation	7	4	4	1	5	9	6
50		Non-conforming	3	7	5	1	3	10	0
51		Cost of Quality	10	1	6	7	3	2	9
52		Index of quality	9	2	4	7	1	6	9
53		Quality of Design	7	10	8	7	9	8	7
54		Reliability of Products	5	5	1	1	10	6	2
55		Gauge Maintenance and Repeatability	6	10	2	8	2	10	3
56		Degree of Conformance	5	2	2	5	10	0	2
57		Trends in Operational Performance, Supplier Quality	10	9	8	8	8	8	7
		Sum =	308.0	312.0	281.0	270.0	249.0	257.0	305.0

Table 3c: Quality-Competitiveness Matrix for Company A

Col. / Row	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Accounting	Human Resources	Engineering and R&D	Weighted Quality Competitiveness Strength	Weighted Maximum Quality Compet. Strength	Quality Competitiveness Efficiency of Subfcator	Relative Contribution of Subfactor to Competitiveness
2				2.3	7.6	10				
3	Integration of Quality Into Operations Strategy	Quality Assurance As Part of Org. Planning	2	9	6	3	508.6	1198.5	0.4244	0.0028
4		Design for Manufacturability	8	1	9	2	2291.6	4794.0	0.4780	0.0124
5		Motivational Programs	9	3	1	8	2355.5	5393.3	0.4368	0.0128
6		Quality As Part of Mission Statement	4	2	2	10	1646.1	2397.0	0.6867	0.0089
7		Quality As Distinctive Competency	7	6	8	2	2449.8	4194.8	0.5840	0.0133
8		ROQ Accounting	1	10	1	3	196.9	599.3	0.3285	0.0011
9		Quality Review Frequency and Level	1	10	6	2	272.1	599.3	0.4541	0.0015
10	Quality Leadership Organizational Learning	Top Management Commitment	9	10	7	5	2419.7	5393.3	0.4486	0.0131
11		Quality Training	5	8	9	5	1666.5	2996.3	0.5562	0.0090
12		Quality Circles	9	3	6	2	2616.8	5393.3	0.4852	0.0142
13		Development of Supportive Structures	6	8	8	3	1714.2	3595.5	0.4768	0.0093
14		Communication Efficacy	1	6	4	3	372.4	599.3	0.6214	0.0020
16		Change Management	1	2	6	10	319.5	599.3	0.5331	0.0017
16	Customer Satisfaction	Quality Function Deployment	1	7	3	1	212.0	599.3	0.3538	0.0011
17		Complaint Disposal Time	6	0	5	4	2165.9	3595.5	0.6024	0.0117
18		Guarantee & Warrantee	3	6	3	7	1101.9	1797.8	0.6129	0.0060
19		Product Liability Extinction System	7	2	2	4	2436.4	4194.8	0.5808	0.0132
20		Field Investigation	2	9	4	8	838.7	1198.5	0.6998	0.0045
21		Complaint Management System	1	7	6	9	373.0	599.3	0.6224	0.0020
22		Customer Involvement in Policy Formulation	3	5	1	6	704.6	1797.8	0.3919	0.0038
23		Frequency of Customer Surveys	5	9	4	2	1472.3	2996.3	0.4914	0.0080
21	Employee Empowerment and Organizational Learning	Work Teams	6	10	5	6	2246.1	3595.5	0.6247	0.0122
22		Quality Training	7	1	6	4	2710.8	4194.8	0.6462	0.0147
23		Quality Circles	1	5	9	10	379.5	599.3	0.6333	0.0021
24		Rewards and Incentive System	1	7	0	1	163.4	599.3	0.2727	0.0009

Table 3d: Quality-Competitiveness Matrix for Company B

Col. / Row	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Accounting	Human Resources	Engineering and R&D	Weighted Quality Competi-tiveness Strength	Weighted Maximum Quality Compet. Strength	Quality Competi-tiveness Efficiency of Subfcator	Relative Contribution of Subfactor to Competi-tiveness
2				2.3	7.6	10				
28	Quality Cost System	Data at Source and Integrity	8	6	10	10	2848.2	4794.0	0.5941	0.0154
29		Quality Cost Reduction Programs	5	0	2	9	1330.5	2996.3	0.4441	0.0072
30		External Failure cost	5	5	5	2	1291.3	2996.3	0.4310	0.0070
31		Internal Failure Cost	2	6	5	1	518.0	1198.5	0.4322	0.0028
32		Prevention Cost	9	5	2	0	1835.3	5393.3	0.3403	0.0099
33		Appraisal Cost	10	7	6	5	3876.5	5992.5	0.6469	0.0210
34		Quality-Optimality at 1005 conformance	10	7	0	3	2242.0	5992.5	0.3741	0.0121
35	Problem Solving	Old seven tools	9	10	3	0	2234.5	5393.3	0.4143	0.0121
36		New Seven tools	10	2	7	6	3425.3	5992.5	0.5716	0.0186
37		Modern seven tools	2	3	9	5	603.7	1198.5	0.5037	0.0033
38		Taguchi Methods for Process optimization	8	3	3	3	2877.2	4794.0	0.6002	0.0156
39		Prevention vs. Remedial philosophy	9	3	3	2	2516.6	5393.3	0.4666	0.0136
40	Lean Manufacturing	Emphasis on "Pull"	7	7	8	9	2339.2	4194.8	0.5577	0.0127
41		JIT/Kanban Philosophy	8	2	9	1	2326.0	4794.0	0.4852	0.0126
42		Waste Elimination	4	4	2	10	1166.8	2397.0	0.4868	0.0063
43		Value-Added Based Decisions	3	8	8	8	970.7	1797.8	0.5399	0.0053
44	Continuous Improvement	Employee Suggestions Program	10	8	0	9	2139.0	5992.5	0.3569	0.0116
45		Process Control Through k-Sigma Measure	9	8	10	8	3017.9	5393.3	0.5596	0.0164
46		Lot Control	6	5	0	0	1251.0	3595.5	0.3479	0.0068
47		Taguchi Methods	1	5	2	7	380.5	599.3	0.6349	0.0021
48		Work Teams	5	1	7	5	1422.4	2996.3	0.4747	0.0077
49	Quality Measurement	Extent of Documentation	7	0	2	3	1593.2	4194.8	0.3798	0.0086
50		Non-conforming	3	4	7	4	850.2	1797.8	0.4729	0.0046
51		Cost of Quality	10	0	6	2	2455.8	5992.5	0.4098	0.0133
52		Index of quality	9	5	1	3	2039.2	5393.3	0.3781	0.0110
53		Quality of Design	7	8	8	8	3455.4	4194.8	0.8237	0.0187
54		Reliability of Products	5	7	7	4	1318.0	2996.3	0.4399	0.0071
55		Gauge Maintenance and Repeatability	6	6	2	6	1922.0	3595.5	0.5345	0.0104
56		Degree of Conformance	5	2	8	6	1273.5	2996.3	0.4250	0.0069
57		Trends in Operational Performance, Supplier Quality	10	10	9	1	4258.3	5992.5	0.7106	0.0231
		Sum =	308.0	293.0	272.0	260.0	93411.8	184569.0	0.5070	0.5061

Table 4. Department-Consciousness Matrix for Company B

		State of Quality Consciousness					Weighted Quality Consciousness Level	Normalized Weighted Quality Consciousness Level
		Crisis Manage-ment	Awareness	Emergence	Maturity	Sustenance		
Department/Functional Unit	Weight	2.0	4.0	6.0	8.0	10.0		
Production	10	0	0	1	8	1	800.0	10.00
Quality Assurance	10	0	0	8	2	0	640.0	8.00
Production Planning and Control	6	0	5	5	0	0	300.0	3.75
Employee Empowerment and Organizational Learning	7	0	5	3	2	0	420.0	5.25
Finance	5	0	2	6	2	0	300.0	3.75
Marketing	7	1	2	6	1	0	378.0	4.73
Accounting	4	0	5	5	0	0	200.0	2.50
Human Resources	8	0	2	4	4	0	512.0	6.40
Engineering and R&D	10	1	2	6	1	0	540.0	6.75

Table 5a: Quality-Competitiveness Matrix for Company B

Row \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Production	Quality Assurance	PPC	Employee Empowerment & Learning	Finance	Marketing
2				10	8	3.75	5.25	3.75	4.725
3	Integration of Quality Into Operations Strategy	Quality Assurance As Part of Org. Planning	2	3	1	8	6	1	4
4		Design for Manufacturability	8	1	4	1	2	5	8
5		Motivational Programs	9	2	3	3	3	5	8
6		Quality As Part of Mission Statement	4	0	2	3	0	4	3
7		Quality As Distinctive Competency	7	7	8	0	7	3	2
8		ROQ Accounting	1	7	4	6	4	2	8
9		Quality Review Frequency and Level	1	0	0	7	7	3	6
10	Quality Leadership Organizational Learning	Top Management Commitment	9	3	7	0	6	6	6
11		Quality Training	5	1	0	1	6	3	8
12		Quality Circles	9	2	5	4	3	3	7
13		Development of Supportive Structures	6	0	8	0	3	2	0
14		Communication Efficacy	1	5	1	0	0	2	6
15		Change Management	1	2	5	1	7	7	8
16	Customer Satisfaction	Quality Function Deployment	1	2	5	5	2	3	6
17		Complaint Disposal Time	6	5	2	7	8	3	3
18		Guarantee & Warrantee	3	5	7	3	2	3	8
19		Product Liability Extinction System	7	1	3	5	1	5	3
20		Field Investigation	2	6	8	3	4	5	1
21		Complaint Management System	1	7	1	3	8	6	2
22		Customer Involvement in Policy Formulation	3	6	1	5	5	4	3
23		Frequency of Customer Surveys	5	6	7	3	1	4	5
24	Employee Empowerment and Organizational Learning	Work Teams	6	0	2	8	5	8	4
25		Quality Training	7	0	6	4	6	3	0
26		Quality Circles	1	5	5	3	8	3	5
27		Rewards and Incentive System	1	5	7	1	3	0	3

Table 5b. Quality-Competitiveness Matrix for Company B

Row \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Production	Quality Assurance	PPC	Employee mpowermer & Learning	Finance	Marketing
2				10	8	3.75	5.25	3.75	4.725
28	Quality Cost System	Data at Source and Integrity	8	0	7	6	8	6	8
29		Quality Cost Reduction Programs	5	4	6	2	3	4	0
30		External Failure cost	5	2	3	2	6	7	6
31		Internal Failure Cost	2	3	3	4	5	8	2
32		Prevention Cost	9	2	3	5	5	7	2
33		Appraisal Cost	10	5	7	3	3	1	5
34		Quality-Optimality at 1005 conformance	10	7	7	2	5	6	0
35	Problem Solving	Old seven tools	9	8	2	1	0	7	3
36		New Seven tools	10	8	2	6	2	1	7
37		Modern seven tools	2	1	8	1	5	3	2
38		Taguchi Methods for Process optimization	8	0	0	5	5	7	5
39		Prevention vs. Remedial philosophy	9	1	8	7	6	6	3
40	Lean Manufacturing	Emphasis on "Pull'	7	1	1	5	0	0	6
41		JIT/Kanban Philosophy	8	3	4	4	0	5	8
42		Waste Elimination	4	1	2	0	6	6	7
43		Value-Added Based Decisions	3	4	4	1	1	1	3
44	Continuous Improvement	Employee Suggestions Program	10	3	2	5	4	7	2
45		Process Control Through k-Sigma Measure	9	4	7	1	7	1	2
46		Lot Control	6	5	7	4	5	1	8
47		Taguchi Methods	1	3	7	1	5	1	1
48		Work Teams	5	5	1	8	0	0	8
49	Quality Measurement	Extent of Documentation	7	1	1	8	3	2	5
50		Non-conforming	3	4	6	7	4	4	8
51		Cost of Quality	10	1	3	7	1	1	4
52		Index of quality	9	3	0	2	5	0	0
53		Quality of Design	7	4	4	2	1	1	2
54		Reliability of Products	5	8	6	2	7	7	4
55		Gauge Maintenance and Repeatability	6	2	2	3	1	4	4
56		Degree of Conformance	5	2	8	1	8	3	2
57		Trends in Operational Performance, Supplier Quality	10	7	5	8	8	1	3
		Sum =	308.0	183.0	228.0	197.0	226.0	201.0	235.0

Table 5c: Quality-Competitiveness Matrix for Company B

Row \ Col.	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Accounting	Human Resources	Engineering and R&D	Weighted Quality Competi-tiveness Strength	Weighted Maximum Quality Compet. Strength	Quality Competi-tiveness Efficiency of Subfcator	Relative Contribution of Subfactor to Competi-tiveness
2				2.5	6.4	6.75				
3	Integration of Quality Into Operations Strategy	Quality Assurance As Part of Org. Planning	2	6	3	1	326.2	1022.5	0.3190	0.0021
4		Design for Manufacturability	8	6	3	0	1176.0	4090.0	0.2875	0.0075
5		Motivational Programs	9	0	8	1	1669.5	4601.3	0.3628	0.0106
6		Quality As Part of Mission Statement	4	3	2	5	441.9	2045.0	0.2161	0.0028
7		Quality As Distinctive Competency	7	5	7	3	1883.0	3578.8	0.5262	0.0120
8		ROQ Accounting	1	5	3	2	236.0	511.3	0.4616	0.0015
9		Quality Review Frequency and Level	1	0	6	6	181.5	511.3	0.3550	0.0012
10	Quality Leadership Organizational Learning	Top Management Commitment	9	0	3	7	2113.2	4601.3	0.4593	0.0134
11		Quality Training	5	8	1	8	873.5	2556.3	0.3417	0.0055
12		Quality Circles	9	4	3	0	1478.5	4601.3	0.3213	0.0094
13		Development of Supportive Structures	6	7	2	0	705.3	3067.5	0.2299	0.0045
14		Communication Efficacy	1	0	6	3	152.5	511.3	0.2983	0.0010
15		Change Management	1	5	4	2	216.2	511.3	0.4228	0.0014
16	Customer Satisfaction	Quality Function Deployment	1	2	5	4	192.9	511.3	0.3772	0.0012
17		Complaint Disposal Time	6	4	2	2	1175.9	3067.5	0.3833	0.0075
18		Guarantee & Warrantee	3	4	5	0	656.4	1533.8	0.4280	0.0042
19		Product Liability Extinction System	7	2	4	5	1086.9	3578.8	0.3037	0.0069
20		Field Investigation	2	3	2	1	413.6	1022.5	0.4044	0.0026
21		Complaint Management System	1	5	1	5	215.9	511.3	0.4222	0.0014
22		Customer Involvement in Policy Formulation	3	6	5	4	648.5	1533.8	0.4228	0.0041
23		Frequency of Customer Surveys	5	0	1	2	955.1	2556.3	0.3736	0.0061
24	Employee Empowerment and Organizational Learning	Work Teams	6	3	2	6	1091.7	3067.5	0.3559	0.0069
25		Quality Training	7	4	6	6	1362.6	3578.8	0.3807	0.0087
26		Quality Circles	1	0	2	7	238.2	511.3	0.4659	0.0015
27		Rewards and Incentive System	1	1	5	1	181	511	0.3539	0.0011

Table 5d: Quality-Competitiveness Matrix for Company B

Col. / Row	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Quality Competitiveness Weights	Accounting	Human Resources	Engineering and R&D	Weighted Quality Competi- tiveness Strength	Weighted Maximum Quality Compet. Strength	Quality Competi- tiveness Efficiency of Subfcator	Relative Contribution of Subfactor to Competi- tiveness
2				2.5	6.4	6.75				
28	Quality Cost System	Data at Source and Integrity	8	4	5	8	2214.4	4090.0	0.5414	0.0141
29		Quality Cost Reduction Programs	5	0	6	7	1059.5	2556.3	0.4145	0.0067
30		External Failure cost	5	4	7	4	1097.0	2556.3	0.4291	0.0070
31		Internal Failure Cost	2	5	1	5	374.7	1022.5	0.3665	0.0024
32		Prevention Cost	9	3	1	0	1162.4	4601.3	0.2526	0.0074
33		Appraisal Cost	10	5	1	8	2332.8	5112.5	0.4563	0.0148
34		Quality-Optimality at 1005 conformance	10	4	4	7	2651.0	5112.5	0.5185	0.0168
36	Problem Solving	Old seven tools	9	0	3	1	1495.1	4601.3	0.3249	0.0095
36		New Seven tools	10	2	6	2	2227.3	5112.5	0.4356	0.0141
37		Modern seven tools	2	4	6	5	413.7	1022.5	0.4046	0.0026
38		Taguchi Methods for Process optimization	8	3	3	4	1188.6	4090.0	0.2906	0.0075
39		Prevention vs. Remedial philosophy	9	5	0	1	1689.1	4601.3	0.3671	0.0107
40	Lean Manufacturing	Emphasis on "Pull'	7	1	1	2	612.5	3578.8	0.1711	0.0039
41		JIT/Kanban Philosophy	8	3	4	6	1657.2	4090.0	0.4052	0.0105
42		Waste Elimination	4	5	4	7	793.7	2045.0	0.3881	0.0050
43		Value-Added Based Decisions	3	5	2	3	433.4	1533.8	0.2826	0.0028
44	Continuous Improvement	Employee Suggestions Program	10	8	6	4	2068.5	5112.5	0.4046	0.0131
45		Process Control Through k-Sigma Measure	9	2	4	0	1622.7	4601.3	0.3527	0.0103
46		Lot Control	6	1	1	5	1388.7	3067.5	0.4527	0.0088
47		Taguchi Methods	1	0	8	6	216.2	511.3	0.4228	0.0014
48		Work Teams	5	5	5	7	1087.8	2556.3	0.4255	0.0069
49	Quality Measurement	Extent of Documentation	7	7	3	2	1015.5	3578.8	0.2838	0.0064
50		Non-conforming	3	3	2	3	685.8	1533.8	0.4471	0.0044
51		Cost of Quality	10	2	4	7	1660.0	5112.5	0.3247	0.0105
52		Index of quality	9	6	2	3	1006.2	4601.3	0.2187	0.0064
53		Quality of Design	7	1	4	5	1118.6	3578.8	0.3126	0.0071
54		Reliability of Products	5	3	8	7	1616.8	2556.3	0.6325	0.0103
55		Gauge Maintenance and Repeatability	6	0	6	5	951.3	3067.5	0.3101	0.0060
56		Degree of Conformance	5	4	5	1	996.0	2556.3	0.3896	0.0063
57		Trends in Operational Performance, Supplier Quality	10	3	3	0	2266.3	5112.5	0.4433	0.0144
		Sum =	308.0	181.0	206.0	206.0	58774.2	157465.0	0.3771	0.3733

Table 6a: Variance in Quality Competitveness Between Company A and B

Col. / Row	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Company A		Company B		Variance (A-B)	
	Quality Factor	Instrument of Accomplishment (Subfactor)	Competi-tiveness Efficiency	Relative contribution to competi-tiveness	Competi-tiveness Efficiency	Relative contribution to competi-tiveness	Competi-tiveness Efficiency	Relative contribution to competi-tiveness
3	Integration of Quality Into Operations Strategy	Quality Assurance As Part of Org. Planning	0.4244	0.0028	0.3190	0.0021	0.1053	0.0007
4		Design for Manufacturability	0.4780	0.0124	0.2875	0.0075	0.1905	0.0049
5		Motivational Programs	0.4368	0.0128	0.3628	0.0106	0.0739	0.0022
6		Quality As Part of Mission Statement	0.6867	0.0089	0.2161	0.0028	0.4706	0.0061
7		Quality As Distinctive Competency	0.5840	0.0133	0.5262	0.0120	0.0579	0.0013
8		ROQ Accounting	0.3285	0.0011	0.4616	0.0015	-0.1331	-0.0004
9		Quality Review Frequency and Level	0.4541	0.0015	0.3550	0.0012	0.0991	0.0003
10	Quality Leadership Organizational Learning	Top Management Commitment	0.4486	0.0131	0.4593	0.0134	-0.0106	-0.0003
11		Quality Training	0.5562	0.0090	0.3417	0.0055	0.2145	0.0035
12		Quality Circles	0.4852	0.0142	0.3213	0.0094	0.1639	0.0048
13		Development of Supportive Structures	0.4768	0.0093	0.2299	0.0045	0.2468	0.0048
14		Communication Efficacy	0.6214	0.0020	0.2983	0.0010	0.3231	0.0010
15		Change Management	0.5331	0.0017	0.4228	0.0014	0.1103	0.0004
16	Customer Satisfaction	Quality Function Deployment	0.3538	0.0011	0.3772	0.0012	-0.0234	-0.0001
17		Complaint Disposal Time	0.6024	0.0117	0.3833	0.0075	0.2191	0.0043
18		Guarantee & Warrantee	0.6129	0.0060	0.4280	0.0042	0.1850	0.0018
19		Product Liability Extinction System	0.5808	0.0132	0.3037	0.0069	0.2771	0.0063
20		Field Investigation	0.6998	0.0045	0.4044	0.0026	0.2953	0.0019
21		Complaint Management System	0.6224	0.0020	0.4222	0.0014	0.2002	0.0007
22		Customer Involvement in Policy Formulation	0.3919	0.0038	0.4228	0.0041	-0.0309	-0.0003
23		Frequency of Customer Surveys	0.4914	0.0080	0.3736	0.0061	0.1177	0.0019
24	Employee Empowerment and Organizational Learning	Work Teams	0.6247	0.0122	0.3559	0.0069	0.2688	0.0052
25		Quality Training	0.6462	0.0147	0.3807	0.0087	0.2655	0.0060
26		Quality Circles	0.6333	0.0021	0.4659	0.0015	0.1675	0.0005
27		Rewards and Incentive System	0.2727	0.0009	0.3539	0.0011	-0.0812	-0.0003

Table 6b: Variance in Quality Competitveness Between Company A and B

Row \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Quality Factor	Instrument of Accomplishment (Subfactor)	Company A		Company B		Variance (A-B)	
2			Competitiveness Efficiency	Relative contribution to competitiveness	Competitiveness Efficiency	Relative contribution to competitiveness	Competitiveness Efficiency	Relative contribution to competitiveness
28	Quality Cost System	Data at Source and Integrity	0.5941	0.0154	0.5414	0.0141	0.0527	0.0014
29		Quality Cost Reduction Programs	0.4441	0.0072	0.4145	0.0067	0.0296	0.0005
30		External Failure cost	0.4310	0.0070	0.4291	0.0070	0.0018	0.0000
31		Internal Failure Cost	0.4322	0.0028	0.3665	0.0024	0.0658	0.0004
32		Prevention Cost	0.3403	0.0099	0.2526	0.0074	0.0877	0.0026
33		Appraisal Cost	0.6469	0.0210	0.4563	0.0148	0.1906	0.0062
34		Quality-Optimality at 1005 conformance	0.3741	0.0121	0.5185	0.0168	-0.1444	-0.0047
35	Problem Solving	Old seven tools	0.4143	0.0121	0.3249	0.0095	0.0894	0.0026
36		New Seven tools	0.5716	0.0186	0.4356	0.0141	0.1359	0.0044
37		Modern seven tools	0.5037	0.0033	0.4046	0.0026	0.0991	0.0006
38		Taguchi Methods for Process optimization	0.6002	0.0156	0.2906	0.0075	0.3096	0.0080
39		Prevention vs. Remedial philosophy	0.4666	0.0136	0.3671	0.0107	0.0995	0.0029
40	Lean Manufacturing	Emphasis on "Pull"	0.5577	0.0127	0.1711	0.0039	0.3865	0.0088
41		JIT/Kanban Philosophy	0.4852	0.0126	0.4052	0.0105	0.0800	0.0021
42		Waste Elimination	0.4868	0.0063	0.3881	0.0050	0.0987	0.0013
43		Value-Added Based Decisions	0.5399	0.0053	0.2826	0.0028	0.0028	0.0025
44	Continuous Improvement	Employee Suggestions Program	0.3569	0.0116	0.4046	0.0131	-0.0477	-0.0015
45		Process Control Through k-Sigma Measure	0.5596	0.0164	0.3527	0.0103	0.2069	0.0060
46		Lot Control	0.3479	0.0068	0.4527	0.0088	-0.1048	-0.0020
47		Taguchi Methods	0.6349	0.0021	0.4228	0.0014	0.2120	0.0007
48		Work Teams	0.4747	0.0077	0.4255	0.0069	0.0492	0.0008
49	Quality Measurement	Extent of Documentation	0.3798	0.0086	0.2838	0.0064	0.0960	0.0022
50		Non-conforming	0.4729	0.0046	0.4471	0.0044	0.0258	0.0003
51		Cost of Quality	0.4098	0.0133	0.3247	0.0105	0.0851	0.0028
52		Index of quality	0.3781	0.0110	0.2187	0.0064	0.1594	0.0047
53		Quality of Design	0.8237	0.0187	0.3126	0.0071	0.5112	0.0116
54		Reliability of Products	0.4399	0.0071	0.6325	0.0103	-0.1926	-0.0031
55		Gauge Maintenance and Repeatability	0.5345	0.0104	0.3101	0.0060	0.2244	0.0044
56		Degree of Conformance	0.4250	0.0069	0.3896	0.0063	0.0354	0.0006
57		Trends in Operational Performance, Supplier Quality	0.7106	0.0231	0.4433	0.0144	0.2673	0.0087
			0.5070	0.5061	0.3771	0.3733	0.1298	0.1329

Table 7: Comparative Analysis of Design for Manufacturability subfactor for Companies A and B

	Production	Quality Assurance	PPC	Employee Empowerment & Learning	Finance	Marketing	Accounting	Human Resources	Engineering and R&D	Weighted Quality Competi-tiveness Strength	Weighted Maximum Quality Compet. Strength	Quality Competi-tiveness Efficiency of Subfcator	Relative Contribution of Subfactor to Competi-tiveness
Synthetically Generated Weights	10.000	9.500	5.300	5.250	4.300	5.775	2.300	7.600	10.000				
Company A													
8	4	4	6	3	3	10	1	9	2	2291.6	4794.0	0.4780	0.0124
Company B													
	10.000	8.000	3.750	5.250	3.750	4.725	2.500	6.400	6.75				
8	1	4	1	2	5	8	6	3	0	1176.0	4090.0	0.2875	0.0075

Table 8: Comparative Analysis of Department-Consciousness Matrix for Companies A and B

		State of Quality Consciousness						
		Crisis Manage-ment	Awareness	Emergence	Maturity	Sustenance	Total Contribution by each	Relative Contribution by each
Department/Functional Unit	Weight	2.0	4.0	6.0	8.0	10.0		
Company A								
Production	10	0	0	1	8	1	800.0	10.00
Production Planning and Control	6	0	0	5	5	0	420.0	5.25
Human Resources	8	0	0	4	4	2	608.0	7.60
Company B								
Production	10	0	0	1	8	1	800.0	10.00
Production Planning and Control	6	0	5	5	0	0	300.0	3.75
Human Resources	8	0	2	4	4	0	512.0	6.40