

# Algorithms and R Codes for the Analysis of Reliability and Unidimensionality of Measurement Scales: Application to Total Quality Management Practices



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*Measurement scales used by many studies in social sciences must satisfy some psychometric conditions to make them valid and reliable. Some conditions are verified by using different statistical techniques within an iterative process, which generally requires a considerable amount of time for the user. We present a computational algorithm for the reliability and the study of unidimensionality associated to measurement scales. The suggested algorithm is implemented using the popular statistical software R. Codes are written in the form of R functions and therefore can be easily used. Assuming real data extracted from the industrial sector, the proposed R codes are used to study the reliability and the unidimensionality of measurement scales. This can serve as a practical guide to show how to use the R functions.*

**Keywords:** Questionnaires, Cronbach's Alpha, Principal Component Analysis, Confirmatory Factor Analysis

## 1. Introduction

Many studies in social sciences and social research are based upon questionnaires, which are considered as a useful measurement instrument and can be used to collect factual information in order to classify people or companies and their circumstances. Questionnaires can be applied to areas such as management and business administration, medicine, psychology, education, political science, and other many social sciences disciplines. For example, questionnaires can be used as an assessment tool, that assists researchers in analyzing the behavior of strategic variables, such as total quality management (TQM), and how they are related to organizational performance (Malhotra, 2004; Bardasi et al. 2011). Many studies have investigated the relationships between TQM practices and performance using questionnaires (Saraph et al.1989; Dow et al. 1999; Samson and Terziovski, 1999; Kaynak, 2003; Kaynak and Hartley, 2008). Relevant applications can be also found in environmental / management systems (see Wu et al., 2008), integrated management systems (Savino and Mazza, 2013), etc.

Traditional structure for questionnaires is composed of different measurement scales, which may contain various items with a Likert scale. Different statistical techniques can be used to analyze the reliability and the unidimensionality of measurement scales. This process ensures that scales are appropriate in the sense to

make them valid and reliable. A brief review about the use of a Likert scale in quality issues and the corresponding statistical techniques can be seen in Section 2. This section also includes a brief revision about TQM practices and Quality Management Systems.

An iterative process is required when analyzing the reliability and the unidimensionality of measurement scales. This process involves repeating the whole analysis whenever a certain technique suggests eliminating some specific items or scales from the study. In general, the user is responsible for removing the mentioned scales and items of the original data matrix, and this implies that the user generally requires a considerable amount of time for the analysis of reliability and unidimensionality of measurement scales.

A computational algorithm that describes the iterative process related to the analysis of reliability and unidimensionality is presented in the Section 3. Wu (2005) obtained R codes for the pseudo empirical likelihood method. Following this idea, we also present, in Section 4, aR function that implements the commented algorithm, i.e., the proposed function performs the iterative process without the user having to remove items from the original data matrix. In Section 5, a real data extracted from the industrial sector is used to study the reliability and the unidimensionality of measurement scales. This example can serve as a practical guide to show how to use the proposed R function. The proposed R function can be easily used by novel users in R, since codes are written in the form of R functions and some basic notions for novel users are also given. This paper concludes in Section 6, where the most important conclusions are summarized and a brief discussion is given.

## **2. Literature Review**

The main aim of this paper is to describe an algorithm and the corresponding R codes for the analysis of reliability and unidimensionality of measurement scales. For this purpose, the use of questionnaires, Likert scales and specific statistical tools are required. The measurement scales have important applications in TQM practices and Quality Management Systems. This section is devoted to give a revision about the literature related to these topics.

### **2.1 Likert Scales**

The measurement scales are generally based upon Likert scales, i.e., Likert scales are a common ratings format for surveys in many areas. Respondents rank the various items from low to high or worst to best using five or seven levels (Allen and Seaman, 2007).

Likert scales were developed as the familiar five-point bipolar response that most people are familiar with today (Likert, 1932). These scales range from a group of categories—least to most—asking people to indicate how much they agree or disagree, approve or disapprove. The ends of the scale often are increased to create a seven-point scale by adding “very” to the respective top and bottom of the five-point scales. The seven-point scale has been shown to reach the upper limits of the scale’s reliability (Nunnally, 1978).

Likert scales can be considered as an indispensable tool used in many social studies (e.g. Saraph et al, 1989; Kaynak and Hartley, 2008; Wu et al., 2008; Herzallah et al., 2014). For instance, Likert scales are consistently used to measure quality. According to Allen and Seaman (2007), for example, surveys might be used

to gauge customer perception of product quality or quality performance in service delivery. Moreover, Likert scales in questionnaires can be also used in the environmental / management systems (see Wu et al., 2008), integrated management systems (Savino and Mazza, 2013), and other many applications in the industrial sector (see, for example, Savino et al., 2012).

## 2.2 Statistical Tools Related to Measurement Scales

According to Hair et al. (2006) and Hulland, (1999), different statistical techniques should be used to ensure that scales are appropriate in the sense to make them valid and reliable. In particular, such statistical tools can be used to analyze the reliability and the unidimensionality of measurement scales.

Reliability indicates the consistency of a measure and the probability of obtaining similar results in case the measure was duplicated at different time periods (Oppenheim, 1992). In other words, reliability is the degree to which measures are free from error and therefore yield consistent results. The reliability of scales should be analyzed from two different viewpoints: through the analysis of internal consistency; and through the analysis of individual reliability. In particular, this is the case of measurement instruments with multiple-element dimensions (Bryman and Cramer, 2001).

The internal consistency method is considered as the most commonly used for reliability estimation (Nunnally, 1967). The internal consistency reliability of a scale can be estimated using a reliability coefficient such as the Cronbach's alpha (Cronbach, 1951; Nunnally, 1967; Selltitz, et al. 1976; Kaynak, 2003; Kaynak and Hartley, 2008; Kim et al., 2012) or the Gutmann's lambda (Guttman, 1945). In particular, the Cronbach's alpha is the most frequently reported measure of internal consistency reliability in the social research (Kaynak, 2003; Sekaran, 2003; Kaynak and Hartley, 2008; Kim et al., 2012; Herzallah et al., 2014).

The individual reliability can be analyzed using a Confirmatory Factor Analysis (CFA). CFA was proposed by Jöreskog (1969). CFA is a statistical technique commonly used in social research to verify the factor structure of a measurement instrument, i.e., it can be used to test the hypothesis that there is a relationship between the observed variables and their underlying structure (Suhr, 2006)]. Hence, it aims to confirm a pre-specified relationship between indicators and latent variables. In CFA, the first step is to develop a hypothesis about the factors that describe the measures. Then, constraints on the model based on the suggested hypotheses are imposed, which forces the model to be consistent with the proposed theory. In the case the constraints are inconsistent with the sample data, results derived from statistical tests of model fit will indicate a poor fit, which implies that the model must be rejected. This can be due to various reasons, such the fact some items within a factor are more related to items from alternative factor, or some items are measured by multiple factors. Additional information about CFA can be found, for example, in Thompson (2004).

In this study, we considered CFA as a validation method because TQM constructs were already empirically tested in theoretical models of previous studies (Kaynak, 2003; Kaynak and Hartley, 2008; Kim et al., 2012; Herzallah et al., 2014). Hulland (1999) gave some conditions for the individual reliability analyzed by the CFA. In particular, Hulland (1999) recommends significant factor loadings and an individual

reliability above 50% (see, also, Section 3). Alternative indices and conditions are described by Marsh et al. (2005).

A scale is required to be unidimensional, which is achieved if all items of the scale measure a single and common latent variable. Unidimensionality indicates that all the items of a scale are highly correlated with each other. According to Germianet al. (1994) and Rogg et al. (2001), a very common procedure to analyze the unidimensionality is the Principal Component Analysis (PCA), which implies that many social sciences studies use PCA for exploratory analysis and data reduction. In addition, PCA is considered as the most commonly used approach and it is widely used by researchers in quality management disciplines (Ngai and Cheng, 1997; Antony, et al. 2002; Sharma and Gadenne, 2002; Sebastianelli and Tamimi, 2003).

Note that exiting industrial research results use statistical tools such as CFA and PCA (e.g. Saraph et al, 1989; Kaynak, H. and Hartley, 2008; Herzallah et al., 2014). This implies that the propose algorithm in this paper can be applied in industrial research.

### **2.3 Total Quality Management Practices and Application in the Palestine Industrial Firms**

This paper discusses the application of measurement scales to TQM practices. In particular, we consider a real data set obtained from a survey about TQM practices in Palestine industrial firms. TQM is a management philosophy that seeks to integrate all organizational functions to focus on meeting customer needs and organizational objectives. It is clear that organizations need to adopt a TQM process and critical success factors if they are to achieve business excellence and sustainable best performance (Zairi, 2005). As the literature review suggests, the implementation of TQM requires the integration of quality principles into day-to-day activities and organizational culture. Positive performance results, or excellence in performance, arise as result of full integration and implementation of Critical Factors Implementation (CFI) of quality.

TQM approach depends on a number of practices and basis that lead to growth and enhance competitive capacity. The organization must identify these practices, time them, and know how to use them. Eight practices have been identified as critical for the successful TQM approach in the Palestinian industrial firms, which is the application discussed in this paper. Note that the suggested practices have been previously identified in published studies, such as discussed as follows:

- **First TQM practice: Management leadership.** The acceptance of quality responsibility by managers including comprehensive quality planning, allocation the resources, quality schedule, evaluation quality and participation in quality improvement efforts (Saraph et al., 1989).
- **Second TQM practice: Customer focus.** The degree to which the organizations continuously understanding satisfy the needs and expectations of the customer (Ahire and Ravichandran, 2001; Kim et al., 2012).
- **Third TQM practice: Training.** The degree to which an organization provides all employees with statistical training, trade training, quality-related training, and quality techniques (Saraph et al., 1989).
- **Fourth TQM practice: Employee relations.** The extent to which employees are involved in quality circles and efforts, contribute in quality

management activities, participate in quality decisions, have responsibilities to quality, are recognized for superior quality performance, handle quality issues, and continuous improvement to quality awareness for all employees (Saraph et al., 1989).

- **Fifth TQM practice: Quality data and reporting.** The extent to which an organization collects and uses quality data, measures quality at suitable time, gets feedback of quality data to employees and managers for problem solving, and evaluates managers and employees based on quality performance (Saraph et al., 1989).
- **Sixth TQM practice: Supplier management.** The extent to which an organization depends on fewer suppliers, offers long-term relationships to suppliers, selects suppliers based on quality rather than price in purchasing policy and based on their ability to meet the organization's requirement, and supports suppliers in product development (Saraph et al., 1989).
- **Seventh TQM practice: Product/service design.** The extent to which all departments in an organization are involved in design reviews and in the efforts to achieve clarity of specifications; and to which an organization emphasizes productivity; and highlights quality to avoid frequent redesigns (Saraph et al., 1989).
- **Eighth TQM practice: Process management.** The extent to which an organization achieves clarity of process and steps; uses preventative maintenance and employee self-inspection; statistical techniques and automated testing are used in order to reduce variance in processes (Saraph et al., 1989).

There are many challenges facing the Palestinian industrial firms in local and international market competitiveness. One of these major challenges is the ability of Palestinian industrial firms for the effective introduce of quality management approach such as total quality management, and can increase the efficiency of people and improve their ability to respond to international competition.

Many Palestinian organizations have started the quality movement and implemented quality programs including quality control, Six Sigma and ISO 9000 series.

Despite the problems faced the Palestinian Industrial firms, many of them have ISO certificate and international Certificates (65 factories and 50 service companies), and about of 71 factories have The PSI Quality Mark and 39 have Palestinian Supervision Mark (Palestinian certificates)(Palestinian Ministry of National Economy, 2014; Palestinian Standards Institution,2014).

## 2.4 Quality Management Systems

As discussed in Section 2.1, Likert scales have important applications in Quality Management Systems (see, for example, Wu et al., 2008; Savino et al., 2012; Savino and Mazza, 2013).

Systems for improving, managing quality and Implementing TQM in manufacturing firms have increased during the last two decades, with high market competition and globalization (Lenka and Suar, 2008;Juneja, 2011; Bon, 2013). The implementation of TQM systems is integrating them into daily business process. In addition, some practices of the firm's management system (such as management

leadership, employee relations, and customer focus) play an important role in the implementation of TQM to improve the performance of firms (Lewis, 2006)].

Ahmed et al. (2005) concluded that the success of any quality management system depends significantly on the strong commitment of management leadership and how customers are distinguished (and how the firms distinguish the customers).

Results derived from Fotopoulos and Psomas (2009) showed that both aspects of TQM – the “soft” and the “hard” side – play a significant role in gaining benefits from the quality management system, both inside and outside the business environment.

Prajogo and Sohal (2003) found that the effects of the TQM system on product and process quality and innovation are important.

Quality management systems help in increasing product quality, providing firms methods to achieve higher quality processes. As a direct result of this, customer satisfaction will be increased (Pfeifer et al., 2004).

There are many benefits of implementing the TQM system. Many studies (e.g. Atkin, 1983; Bulled, 1987) claimed that profit is increased through reduced cost, satisfied customers, reduced waste reduction and decreased time spent on modification of designs and procedures.

An environmental management system is: “part of an organization’s management system used to develop and implement its environmental policy and to manage its environmental aspects” (Dansk Standard, 2004). Integration of environmental management system in quality management system can be a beneficial method for a firm to improve its performance (Savino and Mazza, 2014). Zhou and Sarkis (2004) investigated the effect of quality management system on relationships between environmental sustainability practices and performances.

### **3. A Computational Algorithm**

The analysis of reliability and unidimensionality is based upon statistical techniques such as the PCA or the CFA. The calculation of coefficients such as the Cronbach’s alpha is also required. These statistical tools can suggest eliminating certain items and scales according to some fixed conditions. Some of the most common conditions of such techniques when they are applied to the analysis of reliability and unidimensionality are now discussed.

Nunnally (1978) and Hair et al. (2006) suggested that a value for the reliability coefficient above 0.70 is an acceptable value. However, DeVellis (1991) and Sekaran (2003) consider acceptable a value above 0.60. In addition, it is common practice to calculate the reliability coefficient for the case of each item within a scale is removed one by one. This method can improve the reliability coefficient for the corresponding scale.

Hulland (1999) gave some conditions for the individual reliability analyzed by the CFA. Assuming a  $1 - \alpha$  confidence level, Hulland (1999) first recommends significant factor loadings, which is achieved if the  $z$ -values are larger than  $Z$ , where  $Z$  is the  $1 - \alpha / 2$  quantile of the standard normal distribution. For example,  $Z = 1.96$  when  $1 - \alpha = 0.95$ . The second condition is that the individual reliability, which is explained by the R-square, should be above 50%.

PCA can be applied for the analysis of unidimensionality. Unidimensionality will be obtained if the number of components suggested by the PCA is one. Cattell’s

scree diagram is one of the simplest tests for the problem of determining the number of components. Horn (1965) developed an alternative method for the number of components, which is known as the parallel analysis (see, also Franklin et al. 1995). The parallel analysis determines the numbers of components in a matrix of data by comparing the scree of components of the observed data with that of a random matrix of data. Finally, the classical Kaiser’s rule based on eigenvalues (Zwick and Velicer, 1986) can be also applied. The Kaiser’s rule is the default technique used in most statistical software. Different procedures can be followed when unidimensionality is not achieved, i.e., when a scale is measured by more than one component. For example, a scale without unidimensionality could be divided into as many variables as components determined by the PCA. However, this decision is subject to existing literature justifies the items making up each of the new components. This implies that each situation requires a deep analysis by the user.

We now present an algorithm for computing the various statistical tools used for the analysis of reliability and unidimensionality of measurement scales. This algorithm is based on the specification of some basic arguments, which are given in Table 1.

**Table 1** Arguments Required By the Computational Algorithm (ALG) and the R Function (R.FUNC). (= K) Indicates that the R Function Uses the Default Value K.

Argument (= k)	Description	Used by
BOUND.REL (= 0.7)	Bound for the reliability coefficient	ALG ; R.FUNC
BOUND.R2 (= 0.5)	Bound for the R-square coefficient	ALG ; R.FUNC
DATA	Matrix with the observed values	R.FUNC
ITEMS.NUM	Vector with the number of items per scale	R.FUNC
ITEMS.NAMES	Vector with the names assigned to items	R.FUNC
SCALES.NAMES	Vector with the names assigned to scales	R.FUNC
CFA.MODEL	Name of the file with the encoding of the path diagram for the Confirmatory Factor model	R.FUNC
CL (=0.95)	Confidence Level	ALG ; R.FUNC
SCREE.PLOT(= FALSE)	If true, the parallel scree plots are exported to files	R.FUNC

**Step 1:** Calculate  $r_i$ , with  $i = 1, \dots, I$ , which is defined as an estimate of the reliability for the  $i$ th scale, where  $I$  is the total number of scales. Go to Step 2 if  $r_i < BOUND.REL$  and go to Step 4 otherwise.

**Step 2:** For scales with a reliability coefficient less than  $BOUND.REL$ , calculate  $r_{ij}$ , with  $i = 1, \dots, I$  and  $j = 1, \dots, J_i$ , which is defined as the reliability coefficient for the  $i$ th scale when the  $j$ th item is removed, and where  $J_i$  denotes the number of items for the  $i$ th scale.

**Step 3:** Drop from the scale  $i$  the item  $j$  if  $r_{ij} > r_i$  and  $r_{ij} > r_{ik}$  for all  $j \neq k$  and  $(j, k) = 1, \dots, J_i$ .

**Step 4:** Remove the scales with a reliability coefficient less than  $BOUND.REL$ .

**Step 5:** Do a Principal Component Analysis to analyze the unidimensionality of scales. Go to Step 6 if all scales are measured by a single latent variable. Stop if unidimensionality is not achieved, since the user would have to analyze how to solve the lack of unidimensionality.

**Step 6:** Do a Confirmatory Factor Analysis and drop the items that do not satisfy a specified condition. This condition can be: (i) a value of R-square larger than *BOUND.R2*; (ii) a *z*-value larger than *Z*; or (iii) a value of R-square larger than *BOUND.R2* and a *z*-value larger than *Z*. The iterative process is finished if this specified condition is satisfied. Go to Step 1 otherwise.

## 4. R Functions for the Analysis of Reliability and Unidimensionality

### 4.1 Existing R Functions

Given a scale, the internal consistency reliability can be analyzed with the software R using the function *alpha*, which is available in the R package *psych* (Revelle, 2012). The function *alpha* only requires an argument with the matrix of data of the corresponding scale, although optional arguments can be also given. The function *alpha* provides a list with different values. For example, estimates of reliability given by the function *alpha* are the Cronbach's coefficient alpha based upon the covariances, the Cronbach's coefficient alpha based upon the correlations and the Guttman's coefficient Lambda. The function *alpha* also calculates the previous estimates of reliability when each item from the scale under study is removed one by one. It can be easily seen that the user has to repeat this analysis for the various scales in the study. Note that it would be desirable in terms of time that the user provides the whole matrix of data, and the program directly obtains the reliability coefficients for the various scales. In addition, if the estimate of reliability improves when a specific item is dropped, the user also has to eliminate such item from the matrix of data. Also, it would be desirable that the software used for this analysis could do this work for each of the various scales in the study. Finally, the user needs to remove from the original matrix of data the scales with a reliability coefficient less than the specified bound for the reliability (*BOUND.REL*), which is not an effective issue for the user in terms of time saving.

Some popular procedures to analyze the unidimensionality of scales are the parallel analysis (Horn, 1965) and the Kaiser's rule (Zwick and Velicer, 1986). Parallel analysis can be realized with R using the function *fa.parallel*, which is also included in the R package *psych*. The function *fa.parallel* can be easily used, since a single argument with the data of a given scale is required. Among other values, this function returns Parallel Analysis Scree Plots and a suggestion about the number of components to retain according to the Parallel Analysis. The function *prcomp* can be used to apply the classical Kaiser's rule. *prcomp* returns a list with the standard deviations of the principal components, i.e., the square roots of the eigenvalues.

Finally, the CFA can be realized with the function *sem*, which is included in the R package *sem* (Fox, 2006). The function *sem* requires a Confirmatory Factor model, which is proposed by the user via the function *specify Model*. Among other many optional arguments, the function *sem* also requires the covariance matrix and the number of observations on which the previous covariance matrix is based. Note that the function *sem* assumes that missing values are not presented. A classical method

to deal with this problem is to impute the missing values with the median. The function *impute*, included in the R package *Hmisc*, can be used to deal with the problem of missing data.

#### 4.2 The Proposed R Function

The analysis of reliability and unidimensionality is a common issue in many studies in social sciences. This analysis is based upon an iterative process on which the user has to remove items and scales according to the conclusions derived from statistical tools such as PCA and CFA, and from coefficients such as the Cronbach's alpha. This process is generally slow regardless of the selected software, since the user has to repeat the analysis for the various scales in the study, and eliminate items and scales from the original matrix of data according to the conclusions derived from the statistical procedures. We now present the function *RELIABILITY*, which realizes the analysis of reliability and unidimensionality described in the algorithm introduced in Section 3.

The function *RELIABILITY* uses the aforementioned functions *alpha*, *fa.parallel*, *prcomp*, *sem* and *impute*, hence the proposed R function requires to activate the packages *psych*, *sem* and *Hmisc*. The function *library* can be used for loading packages. The function *RELIABILITY* can be used with the following instruction

```
>RELIABILITY (DATA, ITEMS.NUM, ITEMS.NAMES, SCALES.NAMES,
CFA.MODEL, BOUND.REL, BOUND.R2, CL, SCREE.PLOT)
```

Where the different arguments (*DATA*, *ITEMS.NUM*, etc) are described in Table 1. Once the arguments are introduced, the user is asked to choose a reliability estimation method, a method for determining the numbers of components and the conditions for the CFA. The options for the estimates of the reliability are the Cronbach's alpha, the standardized Cronbach's alpha and the Guttman's Lambda (Guttman, 1945; Cronbach, 1951). Possible methods for determining the number of components are the Parallel analysis and the Kaiser's rule, whereas the conditions for the CFA can be chose between the R-square and z-value. It is quite common to consider both conditions at the same time, and for this reason this option is also available.

Assuming real data from a survey about Total Quality Management (TQM) in Palestinian industrial firms, in the next section the proposed function is used for the analysis of reliability and unidimensionality of measurement scales. This real study can serve as a practical guide to using the proposed function *RELIABILITY*, which can be easily used by novel users in R. In addition, this example is used to explain the results obtained after using the function *RELIABILITY*. Note that additional details and future versions of the function *RELIABILITY* can be found at the web page <http://metodoscuantitativos.ugr.es/pages/web/jfmunoz/investigacion>

### 5. Application to the Study of Total Quality Management Practices

The proposed R function is now used with real data derived from a survey about TQM practices in Palestinian industrial firms. The questionnaire was developed after an extensive review of the literature related to quality management practices. We used items for TQM practices from Saraph et al. (1989)] measurement instrument. Saraph et al. (1989) constitutes one of the TQM seminal papers. Its scales have been

used in other referenced studies such as Kaynak (2003) and Kaynak and Hartley (2008).

The instrument (questionnaire) had 41 items measuring the TQM practices. A seven Likert scale was used, where 1 was strongly disagree and 7 was strongly agree. The study population selected to carry out the investigation is made up of firms in the industrial sector. We used the database from the Palestinian Ministry of National Economy, which includes about 13,000 factories in Palestine (most of them are small).

A total of 350 structured questionnaires with closed questions were sent to firms in July 2012, including a cover letter, assuring confidentiality, and offering the resulting general firm profile for participating in the survey in order to obtain a better response rate. We requested data from the respondents in order to measure the intensity of TQM practices. Respondents completed the questionnaires mostly via face-to-face interviews, but they also participated in the survey by mail, e-mail, and fax. Questionnaires were answered by general managers and quality managers, since they are directly involved in the process and have knowledge of quality improvement implementations activities.

Note that various industrial sectors were considered in this study, such as described in Table 2. This table gives the response rates for the various industrial sectors. We observe that the construction sector is the one with the higher response rate (80%), whereas the handicraft and traditional industries was the sector with the lower response rate (45%).

**Table 2** *Response Rates (%) for the Various Industrial Sectors.*

<b>Industrial Sector</b>	<b>No. of Questionnaires</b>	<b>No. of valid Questionnaires</b>	<b>Response Rate (%)</b>
Mining and quarrying	30	19	63.3
Leather and shoe Industry	25	15	60.0
Metal Industries	30	19	63.3
Chemical Industry and Veterinary Industries	30	20	66.7
Handicraft and Traditional Industries	20	9	45.0
Textile Industries	40	21	52.5
Food Industry and beverages	70	41	58.6
Plastic Industry	30	15	50.0
Paper Industry	25	12	48.0
Furniture Industry	25	14	56.0
Construction	25	20	80.0
Total	350	205	58.6

A total of 228 questionnaires were completed and returned, from which 23 were incomplete and they were excluded because of a large number of missing values. Consequently, we obtained a total of 205 valid and usable questionnaires, which give a general response rate of 58.6% (see Table 2). The response rate is considered a good representation of the population, as the response rate of 50 to 65 % for business

surveys is considered acceptable (Willimack et al., 2002). To test the nonresponse bias for early and late respondents, sample t-test procedures were performed for observed variables. T-tests showed no significant differences were found between the early and late respondents.

Many studies are based on a particular industrial sector. For example, Savino et al. (2013) analyze the electromechanical sector. The purpose of this paper is to illustrate the proposed algorithm by using the total number of questionnaires. For this reason, the analysis for the various sectors is beyond the scope of this paper, hence this issue could be an interesting study for a future research.

According to Saraph et al. (1989), we analyzed eight TQM practices: Management leadership (named as A11), customer focus (A12), Training (A13), Employee relations (A14), Quality data and reporting (A15), Supplier quality management (A16), Product/service design (A17) and Process management (A18).

The first step to use the function *RELIABILITY* is to prepare the matrix of data, the model for the CFA and remaining arguments described in Table 1. R can import data from different types of files. For simplicity, we consider that the matrix of data is saved into an ASCII file, which is named as *DATA.txt*. In this situation, the matrix of data can be imported to the object *DATA.TQM* with the instruction

```
> DATA.TQM <- read.Table("DATA.txt")
```

Note that it is necessary to change the directory to the folder where the file *DATA.txt* is located, and this option is available in the menu. Another option is to indicate the whole path of the file to import. For example, we can use

```
> DATA.TQM <- read.Table("C:\\DATA.txt")
```

The next arguments for the function *RELIABILITY* are the vectors with the names that we wish for the items and the scales. In our example, this information is introduced as:

```
> SCALES.NAMES <- c("A11", "A12", "A13", "A14", "A15", "A16", "A17", "A18")
> ITEMS.NAMES <- c("A111", "A112", "A113", "A114", "A115", "A116",
  "A121", "A122", "A123", "A124", "A125", "A126",
  "A131", "A132", "A133", "A134", "A135",
  "A141", "A142", "A143", "A144",
  "A151", "A152", "A153", "A154",
  "A161", "A162", "A163", "A164", "A165", "A166",
  "A171", "A172", "A173", "A174",
  "A181", "A182", "A183", "A184", "A185", "A186")
```

Similarly, the vector with the numbers of items for each scale is saved as

```
> ITEMS.NUM <- c(6, 6, 5, 4, 4, 6, 4, 6)
```

The R package *sem* uses a RAM diagramming system for the implementation of the model for the CFA (see, also, Fox, 2006). This RAM specification consists of a simple encoding of the path diagram for the model. The path diagram in the RAM system for the example studied here can be seen in Figure 1. Note that the variances for the scales are fixed at 1.

The R package *sem* can easily decoded a model represented in the RAM path diagramming system. Appendix 1 gives the corresponding codes required for the path diagram illustrated in Figure 1 (see, also, Fox, 2006). Such codes can be saved into an ASCII file. For example, Note Pad can be used. Assume that our codes are saved in a file called *CFA\_model\_TQM.txt*.

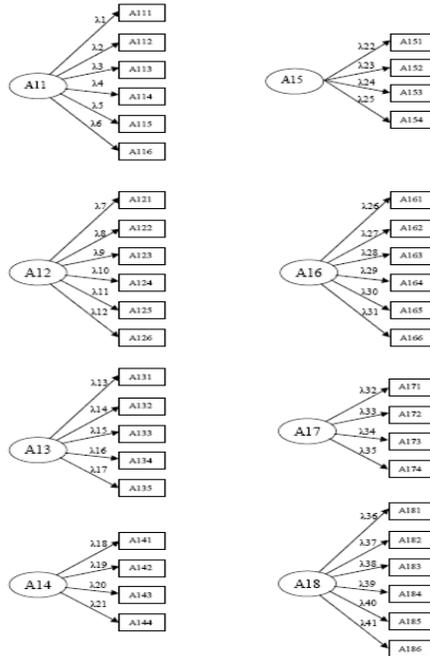


Figure 1 Path Diagram in the RAM System

Note that the names for the items and scales used in the previous codes must be the same than the names used in the objects *SCALES.NAMES* and *ITEMS.NAMES* previously defined. Then, the name of the file *CFA\_model\_TQM.txt* is saved in the object *NAME.CFA.MODEL*, which is the last argument required by the function *RELIABILITY*.

```
> NAME.CFA.MODEL <- "CFA_model_TQM.txt"
```

After installing and loading the packages *psych*, *sem* and *Hmisc*:

```
> library(psych)
```

```
> library(sem)
```

```
> library(Hmisc)
```

We can use the proposed function with the arguments previously defined:

```
> RELIABILITY (DATA.TQM, ITEMS.NUM, ITEMS.NAMES, SCALES.NAMES,
NAME.CFA.MODEL, BOUND.REL=0.8, SCREE.PLOT=TRUE)
```

Recall that Nunnally (1978) and Hair et al. (2006) suggest that a value for the reliability coefficient above 0.7 is an acceptable value. Following this recommendation, we considered a value more conservative, i.e., we considered a bound for the reliability coefficient equal to 0.8. This is due to the fact that the value 0.8 obviously requires a larger number of iterations within the proposed iterative process, and this situation allows us to illustrate the proposed method in a better way. This issue is also discussed below when we describe the iterative process step by step.

In the previous function *RELIABILITY*, we also indicate, with the instruction *SCREE.PLOT=TRUE*, that Parallel Analysis Scree plots will be exported to files.

Note that the previous files *DATA.txt* and *CFA\_model\_TQM.txt*, and a brief guide on how to use the proposed function *RELIABILITY* are also available at the web page <http://metodoscuantitativos.ugr.es/pages/web/jfmunoz/investigacion>

The output of the function *RELIABILITY* can be seen in Appendix 1. First, we observe that 41 variances are added to the model, which corresponds to the variances of the 41 items in the model. This information is added because such variances were not introduced in the codes of the file *CFA\_model\_TQM.txt*, and the R packages can incorporate this information when it is lacking. Then, three different menus are shown and they allow the user to choose between various options. We can observe that we selected the “Cranach’s Alpha” as the reliability estimation method, the “Kaiser’s rule” as the method for determining the number of components in the PCA, and “both: R-square and z-value” as the criterium for the CFA. Then, we observe that the analysis of reliability and unidimensionality is carried out in two iterations, i.e., two iterations in the iterative process are required in this example to satisfy the specified psychometric conditions.

The iterative process is described as follows. In the first iteration, we can observe the matrices with the removed items and scales. The reasons to remove such items or scales are also given. For example, the scale A12 is removed because of the bound *BOUND.REL*, i.e., the reliability coefficient for the scale A12 is less than the specified bound *BOUND.REL*. For this reason, items from A121 to A126 included in the scale A12 are also removed. Item A134 is removed because this item does not satisfy the criterium for the CFA, etc. Then, we also observe additional “information for scales in iteration 1”. This information is described in Table 3. We now describe the iterative process step by step.

**Iteration 1 - Step 1:** The iterative process begins with the calculation of the values of  $r_i$ , i.e., the reliability coefficients for the various scales (Step 1). From appendix 2 we observe that we selected the Cranach’s alpha as the reliability coefficient, hence that the values  $r_i$  denote the Cranach’s alpha coefficients in this illustrative example. Column REL in the matrix “information for scales in iteration 1” (see Appendix 2) contains the Cronbach’s alpha coefficients for the various scales (see also Table 3). We observe that the various scales satisfy that  $r_i$  is larger or equal than the specified bound *BOUND.REL* = 0.8, except for the second scale (scale A12), where  $r_2 = 0.77$ .

**Iteration 1 - Step 2:** This step is required since the reliability coefficient for the scale A12 is less than 0.8. The proposed R function calculates the various values of  $r_{ij}$ , i.e., the reliability coefficient for the  $i$ th scale when the  $j$ th item is removed. It can be seen that Steps 2 and 3 would not be required if we had used a bound equal to 0.7 for the reliability coefficient. We considered the bound 0.8 for the purpose of illustrating Steps 2 and 3.

to Step 3. However, we observe that  $r_{2j} = 0.78$  is also smaller than the proposed

**Iteration 1 - Steps 3 and 4:** For each scale, the maximum of the values  $r_{ij}$  are given by the matrix “information for scales in iteration 1” (see the column REL.DROP). Let  $j$  be the item of the scale A12 that achieves the maximum value of  $r_{2j}$ , i.e.,  $r_{2j} = 0.78$ . We observe that this reliability coefficient is better than the original value

$r_2 = 0.77$ . This implies that  $r_{2j} > r_2$  and  $r_{2j} > r_{2k}$ , for all  $j \neq k$ , and the item  $j$  is removed according bound  $BOUND.REL = 0.8$ , and for this reason, and following Step 4, the scale A12 is removed. Since the whole scale A12 is removed, the various items (from A121 to A126) included in this scale are also removed, as described in Appendix 1.

**Iteration 1 - Step 5:** A Principal Component Analysis is realized to analyze the unidimensionality of scales. There is no information about the lack of unidimensionality; hence we go to the next step.

**Iteration 1 - Step 6:** The propose R function realizes a Confirmatory Factor Analysis (CFA) with the criterium previously selected. Recall that we selected the third option, i.e, values of R-square larger than  $BOUND.R2$  and z-values larger than  $Z$ . We observe that various items (A134, A142, A161, A162, A165, A166, A173, A174, A183, A185) do not satisfy the required conditions for the CFA, and for this reason they are removed and we have to go to Step 1 in a second iteration.

**Iteration 2 - Steps 1 and 4:** First, we observe that any item and any scale have been removed in this second iteration. From “information for scales in iteration 2” we observe that the various valid scales have a reliability coefficient (calculated by Step 1 in iteration 2) larger than 0.8. For this reason, Step 2 and 3 are not required. In addition, no scale is removed as a result of reliability coefficients smaller than 0.8.

**Iteration 2 - Step 5:** Scales are measured by a single latent variable and we go to Step 6.

**Iteration 2 - Step 6:** Conditions required by the CFA are also satisfied, since no scale has been removed in this iteration. This completes the iterative process.

**Table 3** Description of the Additional “Information for Scales” for Each Iteration within the Iterative Process.

Column	Description
<i>REL</i>	The reliability coefficient for the various scales (the user can choose among the Cronbach’s alpha, the standardized Cronbach’s alpha and the Guttman’s Lambda)
<i>IT.NUM</i>	The number of items
<i>REL.DROP</i>	The maximum reliability coefficient when items are removed one by one
<i>IT.NUM.DROP</i>	The number of items after applying the step 3 of the algorithm in Section 3
<i>IT.NUM.CFA</i>	The number of items after applying the CFA

In summary, various items and scales have been removed in the first iteration. The scale A12 is removed because it has a reliability coefficient smaller than  $BOUND.REL$ , and for this reason items from A121 to A126 are also removed. Then, items A134, A142, A161, A162, A165, A166, A173, A174, A183, A185 are removed because they do not satisfy the required conditions for the CFA. Scales A16 and A17 only contained 1 or 2 items after removing the previous items, and for this reason scales A16 and A17 are also removed. Note that scales with more than 2 items are required by the statistical software R.

Finally, results derived from the CFA are also shown. In addition, the function *RELIABILITY* exports, for each iteration, files with the matrix of data, the codes with

the path diagram in the RAM system, the names of items and scales, and the number of items that we keep at the ending of the corresponding iteration. As we commented, Parallel Analysis Scree plots, such as the one illustrated in Figure 2, are also exported.

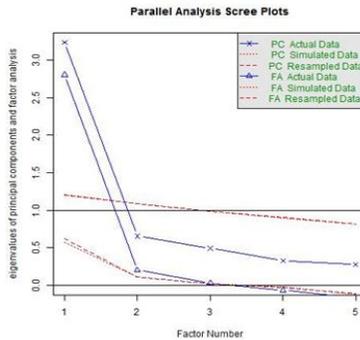


Figure 2 Example of a Parallel Analysis Scree Plot

## 6. Conclusions and Discussion

Many studies in social sciences and social research are based upon questionnaires. For instance, questionnaires can be used to assist researchers in analyzing the behavior of strategic variables, such as total quality management (TQM), environmental / management systems, integrated management systems, etc. The traditional structure of questionnaires is based on measurement scales, which may contain various items with a Likert scale. It is a common practice to make the scales valid and reliable. This process can be obtained by analyzing the reliability and the unidimensionality of measurement scales and using different statistical techniques such as CFA or PCA.

This paper discusses the analysis of reliability and unidimensionality of measurement scales. An algorithm that explains this iterative process is described. Existing software for this analysis can say to the user the scales and items that should be removed according to certain psychometric conditions. However, the user generally has to do this work for any of the various scales in the study, which implies that this process can be slow, especially for sets of data with a large number of scales. In addition, the user generally has to do the work of eliminating from the original matrix of data the items suggested by the different statistical procedures used in the analysis of reliability and unidimensionality.

An R function called *RELIABILITY* is proposed in this paper. This function can be easily used, since some basic arguments are only required. This function can realize the analysis of reliability and unidimensionality for the various scales, and it is not necessary that the user has to repeat the analysis for each of the various scales. In addition, the function *RELIABILITY* eliminates from the matrix of data the items and scales suggested by the different statistical tools, and the new sets of data are exported to files. This can be useful because the user can easily have a reliable set of data to be used in future works. For practical benefit, these arguments suggests that the function *RELIABILITY* can save time and make the user’s work easier to manage, especially for sets of data with a large number of scales.

A real example was considered to show step by step how to use the R function. In particular, we consider a real data set obtained from a survey about TQM practices in Palestine industrial firms. This example can serve as a practical guide, especially for novel users in R. Finally, note that possible suggestions and recommendations can be addressed in future versions of the proposed function *RELIABILITY*, and which will be available at the web page

<http://metodoscuantitativos.ugr.es/pages/web/jfmunoz/investigacion>

The purpose of this paper was to illustrate the proposed algorithm by using the total number of the questionnaires in the Palestine industrial firms. Note that the analysis for the various industrial sectors could be an interesting study for a future research. In addition, this study contributes to total quality management practices and research. The instruments for measuring TQM practices are reliable and valid, and they can be used by other researchers to test the impacts of TQM practices on performance.

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## **Appendix 1 Codes Related to the Path Diagram Illustrated in Figure 1**

### **## Scale A11**

A11 -> A111, lambda01, NA  
 A11 -> A112, lambda02, NA  
 A11 -> A113, lambda03, NA  
 A11 -> A114, lambda04, NA  
 A11 -> A115, lambda05, NA  
 A11 -> A116, lambda06, NA

### **## Scale A12**

A12 -> A121, lambda07, NA  
 A12 -> A122, lambda08, NA  
 A12 -> A123, lambda09, NA

A12 -> A124, lambda10, NA  
A12 -> A125, lambda11, NA  
A12 -> A126, lambda12, NA

**## Scale A13**

A13 -> A131, lambda13, NA  
A13 -> A132, lambda14, NA  
A13 -> A133, lambda15, NA  
A13 -> A134, lambda16, NA  
A13 -> A135, lambda17, NA

**## Scale A14**

A14 -> A141, lambda18, NA  
A14 -> A142, lambda19, NA  
A14 -> A143, lambda20, NA  
A14 -> A144, lambda21, NA

**## Scale A15**

A15 -> A151, lambda22, NA  
A15 -> A152, lambda23, NA  
A15 -> A153, lambda24, NA  
A15 -> A154, lambda25, NA

**## Scale A16**

A16 -> A161, lambda26, NA  
A16 -> A162, lambda27, NA  
A16 -> A163, lambda28, NA  
A16 -> A164, lambda29, NA  
A16 -> A165, lambda30, NA  
A16 -> A166, lambda31, NA

**## Scale A17**

A17 -> A171, lambda32, NA  
A17 -> A172, lambda33, NA  
A17 -> A173, lambda34, NA  
A17 -> A174, lambda35, NA

**## Scale A18**

A18 -> A181, lambda36, NA  
A18 -> A182, lambda37, NA  
A18 -> A183, lambda38, NA  
A18 -> A184, lambda39, NA  
A18 -> A185, lambda40, NA  
A18 -> A186, lambda41, NA

**## Scale Variances Fixed at 1**

A11 <-> A11, NA, 1  
A12 <-> A12, NA, 1

A13 <-> A13, NA, 1  
 A14 <-> A14, NA, 1  
 A15 <-> A15, NA, 1  
 A16 <-> A16, NA, 1  
 A17 <-> A17, NA, 1  
 A18 <-> A18, NA, 1

## Appendix 2 Output of the Function Reliability

Read 49 records

NOTE: adding 41 variances to the model

Select a reliability estimation method:

1. Cronbach's Alpha.
2. Standardized Cronbach's Alpha.
3. Guttman's Lambda

### Selection: 1

Select a method for determining the numbers of components:

1. Parallel Analysis.
2. Kaiser's rule.

### Selection: 2

Select a criterium for the Confirmatory Factor Analysis:

1. R-square for Endogenous Variables.
2. 2: z-value.r
3. 3: Both: R-square and z-value.

### Selection: 3

```
##### ITERATION 1:
# REMOVED ITEMS:      [,1]
A121 "BOUND.REL"
A122 "BOUND.REL"
A123 "BOUND.REL"
A124 "BOUND.REL"
A125 "BOUND.REL"
A126 "BOUND.REL"
A134 "BOUND.CFA"
A142 "BOUND.CFA"
A161 "BOUND.CFA"
A162 "BOUND.CFA"
A165 "BOUND.CFA"
A166 "BOUND.CFA"
A173 "BOUND.CFA"
A174 "BOUND.CFA"
A183 "BOUND.CFA"
A185 "BOUND.CFA"
# REMOVED SCALES:    [,1]
A12 "BOUND.REL"
```

A16 "BOUND.CFA"  
 A17 "BOUND.CFA"

# INFORMATION FOR SCALES IN ITERATION 1:  
 REL.IT.NUM.REL.DROP.IT.NUM.DROP.IT.NUM.CFA

A11	0.89	6	0.89	6	6
A12	0.77	6	0.78	5	NA
A13	0.90	5	0.90	5	4
A14	0.83	4	0.83	4	3
A15	0.89	4	0.89	4	4
A16	0.80	6	0.80	6	2
A17	0.83	4	0.83	4	2
A18	0.85	6	0.85	6	4

# TOTAL NUMBERS OF ITEMS: 21  
 # RESULTS DERIVED FROM THE CONFIRMATORY FACTOR ANALYSIS IN  
 ITERATION 1:

Model Chisquare= 2506.492 Df = 560 Pr (>Chisq) = 2.547959e-243  
 AIC = 2646.492  
 BIC = -474.394

Normalized Residuals

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-1.703	4.300	5.726	5.021	6.606	9.640

R-square for Endogenous Variables

A111	A112	A113	A114	A115	A116	A131	A132	A133	A134	A135
A141	A142	A143	A144	A151						
0.5550	0.5113	0.7008	0.5738	0.6159	0.5511	0.7085	0.7672	0.6541	0.4923	0.5642
0.5581	0.3180	0.7099	0.6846	0.7613						
A152	A153	A154	A161	A162	A163	A164	A165	A166	A171	A172
A173	A174	A181	A182	A183						
0.7924	0.5252	0.5792	0.3933	0.1074	0.6683	0.7520	0.2730	0.4708	0.6201	0.6669
0.4644	0.4909	0.6289	0.5410	0.4149						
A184	A185	A186								
0.5591	0.3058	0.5783								

**Parameter Estimates**

Estimate Std Error z value Pr(>|z|)

lambda01	0.9658712	0.08055834	11.989711	4.023084e-33	A111 <--- A11
lambda02	0.9437580	0.08331282	11.327885	9.548284e-30	A112 <--- A11
lambda03	0.9874032	0.06940987	14.225687	6.347761e-46	A113 <--- A11
lambda04	0.8255323	0.06725840	12.274041	1.248623e-34	A114 <--- A11
lambda05	1.1112052	0.08603107	12.916324	3.641242e-38	A115 <--- A11
lambda06	1.0144782	0.08503468	11.930170	8.240535e-33	A116 <--- A11
lambda13	1.2300388	0.08527820	14.423837	3.663922e-47	A131 <--- A13
lambda14	1.3354447	0.08699807	15.350280	3.526609e-53	A132 <--- A13

lambda15 1.1797416 0.08689510 13.576618 5.511272e-42 A133 <--- A13  
 lambda16 1.1003392 0.09913505 11.099396 1.262942e-28 A134 <--- A13  
 lambda17 1.2395495 0.10166864 12.192053 3.426785e-34 A135 <--- A13  
 lambda18 1.1779610 0.10042374 11.729906 8.955785e-32 A141 <--- A14  
 lambda19 0.9052510 0.11038212 8.201066 2.382653e-16 A142 <--- A14  
 lambda20 1.1374723 0.08263660 13.764751 4.153112e-43 A143 <--- A14  
 lambda21 1.1362708 0.08460864 13.429726 4.049044e-41 A144 <--- A14  
 lambda22 1.3480204 0.08909580 15.130011 1.026790e-51 A151 <--- A15  
 lambda23 1.2757721 0.08175759 15.604327 6.802355e-55 A152 <--- A15  
 lambda24 1.0246955 0.08856519 11.569959 5.851092e-31 A153 <--- A15  
 lambda25 1.1346913 0.09160457 12.386842 3.079342e-35 A154 <--- A15  
 lambda26 0.8368425 0.08892145 9.411031 4.912942e-21 A161 <--- A16  
 lambda27 0.4973685 0.11022754 4.512198 6.415916e-06 A162 <--- A16  
 lambda28 1.0527350 0.07861453 13.391100 6.816399e-41 A163 <--- A16  
 lambda29 1.2935101 0.08876757 14.571876 4.240806e-48 A164 <--- A16  
 lambda30 0.6820069 0.09032269 7.550782 4.326516e-14 A165 <--- A16  
 lambda31 1.1903148 0.11270645 10.561195 4.508848e-26 A166 <--- A16  
 lambda32 0.9958353 0.08052136 12.367344 3.925906e-35 A171 <--- A17  
 lambda33 1.1161900 0.08602475 12.975219 1.691125e-38 A172 <--- A17  
 lambda34 0.8372875 0.08169762 10.248616 1.200499e-24 A173 <--- A17  
 lambda35 0.8340148 0.07851634 10.622181 2.350059e-26 A174 <--- A17  
 lambda36 1.2794447 0.09955676 12.851410 8.445647e-38 A181 <--- A18  
 lambda37 1.0503621 0.09081547 11.565894 6.134914e-31 A182 <--- A18  
 lambda38 0.9128305 0.09404399 9.706420 2.831067e-22 A183 <--- A18  
 lambda39 1.0549865 0.08917294 11.830792 2.705769e-32 A184 <--- A18  
 lambda40 1.0029869 0.12467457 8.044839 8.635871e-16 A185 <--- A18  
 lambda41 1.2337047 0.10186259 12.111460 9.184480e-34 A186 <--- A18  
 V[A111] 0.7479647 0.08652899 8.644093 5.423426e-18 A111 <--> A111  
 V[A112] 0.8514554 0.09585879 8.882393 6.543734e-19 A112 <--> A112  
 V[A113] 0.4163298 0.05665376 7.348669 2.001896e-13 A113 <--> A113  
 V[A114] 0.5062999 0.05937834 8.526677 1.506119e-17 A114 <--> A114  
 V[A115] 0.7701024 0.09368753 8.219903 2.036671e-16 A115 <--> A115  
 V[A116] 0.8383621 0.09672543 8.667443 4.419344e-18 A116 <--> A116  
 V[A131] 0.6224778 0.08307575 7.492894 6.737138e-14 A131 <--> A131  
 V[A132] 0.5410677 0.08221830 6.580867 4.677118e-11 A132 <--> A132  
 V[A133] 0.7358975 0.09095013 8.091219 5.907030e-16 A133 <--> A133  
 V[A134] 1.2485001 0.13735499 9.089587 9.941613e-20 A134 <--> A134  
 V[A135] 1.1869880 0.13577636 8.742229 2.285562e-18 A135 <--> A135  
 V[A141] 1.0986798 0.13798631 7.962237 1.689558e-15 A141 <--> A141  
 V[A142] 1.7578428 0.18815916 9.342318 9.424739e-21 A142 <--> A142  
 V[A143] 0.5287233 0.09086696 5.818652 5.932402e-09 A143 <--> A143  
 V[A144] 0.5949264 0.09505973 6.258448 3.888284e-10 A144 <--> A144  
 V[A151] 0.5698765 0.09057908 6.291480 3.144528e-10 A151 <--> A151  
 V[A152] 0.4264464 0.07562794 5.638742 1.712967e-08 A152 <--> A152  
 V[A153] 0.9491401 0.10689249 8.879390 6.722802e-19 A153 <--> A153  
 V[A154] 0.9355721 0.10920914 8.566793 1.064071e-17 A154 <--> A154  
 V[A161] 1.0802873 0.11810441 9.146884 5.859938e-20 A161 <--> A161  
 V[A162] 2.0554667 0.20705937 9.926943 3.178494e-23 A162 <--> A162

V[A163] 0.5501525 0.07979953 6.894182 5.417551e-12 A163 <--> A163  
V[A164] 0.5518444 0.10085267 5.471787 4.455191e-08 A164 <--> A164  
V[A165] 1.2383628 0.12960729 9.554731 1.239049e-21 A165 <--> A165  
V[A166] 1.5925854 0.18147250 8.775905 1.695353e-18 A166 <--> A166  
V[A171] 0.6074608 0.08878800 6.841700 7.825895e-12 A171 <--> A171  
V[A172] 0.6222676 0.10127377 6.144410 8.026136e-10 A172 <--> A172  
V[A173] 0.8083747 0.09587947 8.431155 3.422696e-17 A173 <--> A173  
V[A174] 0.7213045 0.08759043 8.234969 1.796043e-16 A174 <--> A174  
V[A181] 0.9658335 0.12951017 7.457588 8.812086e-14 A181 <--> A181  
V[A182] 0.9358515 0.11315811 8.270300 1.336222e-16 A182 <--> A182  
V[A183] 1.1749606 0.13041800 9.009191 2.075829e-19 A183 <--> A183  
V[A184] 0.8775751 0.10795968 8.128730 4.338108e-16 A184 <--> A184  
V[A185] 2.2842053 0.24232617 9.426160 4.253775e-21 A185 <--> A185  
V[A186] 1.1098160 0.13933098 7.965321 1.647951e-15 A186 <--> A186  
Iterations = 25

## ##### ITERATION 2:

# REMOVED ITEMS: No item has been removed in this iteration.

# REMOVED SCALES: No scale has been removed in this iteration.

## # INFORMATION FOR SCALES IN ITERATION 2:

REL IT.NUM REL.DROP IT.NUM.DROP IT.NUM.CFA

A11	0.89	6	0.89	6	6
A13	0.89	4	0.89	4	4
A14	0.84	3	0.84	3	3
A15	0.89	4	0.89	4	4
A18	0.84	4	0.84	4	4

## # TOTAL NUMBERS OF ITEMS: 21

# RESULTS DERIVED FROM THE CONFIRMATORY FACTOR ANALYSIS IN ITERATION 2:

Model Chi square= 1058.919Df = 189 Pr(&gt;Chisq) = 5.914583e-121

AIC = 1142.919

BIC = 52.87033

## Normalized Residuals

Min. 1st Qu. Median Mean 3rd Qu. Max.

-0.7418 4.9310 6.1060 5.1250 6.9160 9.6400

## R-square for Endogenous Variables

A111 A112 A113 A114 A115 A116 A131 A132 A133 A135 A141

A143 A144 A151 A152 A153

0.5550 0.5113 0.7008 0.5738 0.6159 0.5511 0.7048 0.8501 0.6078 0.5138 0.5188

0.7673 0.6646 0.7613 0.7924 0.5252

A154 A181 A182 A184 A186

0.5792 0.6747 0.5438 0.5480 0.5183

**Parameter Estimates**

Estimate Std Error z value Pr(&gt;|z|)

lambda01 0.9658703 0.08055827 11.989710 4.023126e-33 A111 <--- A11  
 lambda02 0.9437559 0.08331285 11.327856 9.551406e-30 A112 <--- A11  
 lambda03 0.9874034 0.06940985 14.225694 6.347120e-46 A113 <--- A11  
 lambda04 0.8255335 0.06725836 12.274065 1.248258e-34 A114 <--- A11  
 lambda05 1.1112031 0.08603104 12.916304 3.642208e-38 A115 <--- A11  
 lambda06 1.0144758 0.08503471 11.930138 8.243699e-33 A116 <--- A11  
 lambda13 1.2267836 0.08565048 14.323137 1.568786e-46 A131 <--- A13  
 lambda14 1.4057578 0.08490906 16.556041 1.448152e-61 A132 <--- A13  
 lambda15 1.1372116 0.08841640 12.861998 7.364798e-38 A133 <--- A13  
 lambda17 1.1828978 0.10341181 11.438711 2.678356e-30 A135 <--- A13  
 lambda18 1.1357547 0.10223675 11.109065 1.133396e-28 A141 <--- A14  
 lambda20 1.1825944 0.08398098 14.081693 4.921610e-45 A143 <--- A14  
 lambda21 1.1195794 0.08694283 12.877191 6.049729e-38 A144 <--- A14  
 lambda22 1.3480196 0.08909579 15.130002 1.026918e-51 A151 <--- A15  
 lambda23 1.2757693 0.08175755 15.604300 6.805253e-55 A152 <--- A15  
 lambda24 1.0246943 0.08856506 11.569962 5.850858e-31 A153 <--- A15  
 lambda25 1.1346882 0.09160459 12.386806 3.080725e-35 A154 <--- A15  
 lambda36 1.3251418 0.10090619 13.132414 2.147019e-39 A181 <--- A18  
 lambda37 1.0529910 0.09254440 11.378225 5.368121e-30 A182 <--- A18  
 lambda39 1.0444560 0.09132295 11.436950 2.733266e-30 A184 <--- A18  
 lambda41 1.1678976 0.10593587 11.024572 2.909004e-28 A186 <--- A18  
 V[A111] 0.7479632 0.08652884 8.644091 5.423523e-18 A111 <--> A111  
 V[A112] 0.8514579 0.09585899 8.882400 6.543297e-19 A112 <--> A112  
 V[A113] 0.4163289 0.05665373 7.348659 2.002058e-13 A113 <--> A113  
 V[A114] 0.5062980 0.05937820 8.526664 1.506286e-17 A114 <--> A114  
 V[A115] 0.7701037 0.09368759 8.219911 2.036542e-16 A115 <--> A115  
 V[A116] 0.8383652 0.09672568 8.667453 4.418953e-18 A116 <--> A116  
 V[A131] 0.6304943 0.08513619 7.405714 1.304467e-13 A131 <--> A131  
 V[A132] 0.3483387 0.07996690 4.356036 1.324387e-05 A132 <--> A132  
 V[A133] 0.8344463 0.09853640 8.468406 2.487735e-17 A133 <--> A133  
 V[A135] 1.3242390 0.14669464 9.027180 1.761519e-19 A135 <--> A135  
 V[A141] 1.1963415 0.14625715 8.179713 2.845205e-16 A141 <--> A141  
 V[A143] 0.4240437 0.10204688 4.155382 3.247449e-05 A143 <--> A143  
 V[A144] 0.6325780 0.10426968 6.066749 1.305249e-09 A144 <--> A144  
 V[A151] 0.5698763 0.09057923 6.291468 3.144779e-10 A151 <--> A151  
 V[A152] 0.4264481 0.07562804 5.638757 1.712822e-08 A152 <--> A152  
 V[A153] 0.9491364 0.10689217 8.879382 6.723284e-19 A153 <--> A153  
 V[A154] 0.9355754 0.10920944 8.566800 1.064007e-17 A154 <--> A154  
 V[A181] 0.8468235 0.13842405 6.117604 9.499290e-10 A181 <--> A181  
 V[A182] 0.9303320 0.11912525 7.809697 5.732576e-15 A182 <--> A182  
 V[A184] 0.8996912 0.11582679 7.767557 8.001423e-15 A184 <--> A184  
 V[A186] 1.2678703 0.15760663 8.044524 8.658152e-16 A186 <--> A186

Iterations = 21

**About Authors**

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**Ahmad Herzallah** is a Lecturer of Business Administration at Al-Quds University-Palestine and now a PhD Candidate in the University of Granada. He finished his MBA in 2000. His current research interests include Total Quality Management and Quality Exploration and Quality Exploitation, and their relationships with Competitive Strategies, Organizational Performance, Organizational Learning and Knowledge Management.

**Leopoldo J. Gutiérrez-Gutiérrez** is Associate Professor of Operations Management at the University of Granada. He finished his PhD in 2008, which analyses quality Management initiatives and their influence through dynamic capabilities. From 2003 to 2005, he held a research grant in the Department of Business Administration (University of Granada) to develop the line of research based on quality management. He was also awarded a government collaboration grant from 2001 to 2002. His research has been published in journal such as International Journal of Operations and Production Management, International Journal of Production Research, International Journal of Production Economics or Industrial Management and Data Systems.