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Quality Management Practices and Performance Measurement in the Manufacturing Industry: An Instrument Validation

(Amalan Pengurusan Kualiti dan Pengukuran Prestasi dalam Industri Pembuatan: Suatu Pengesahan Alat)

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ABSTRACT

The aim of this article was to validate an instrument of quality management practices (QMPs) and performance measurement for the manufacturing industry in Malaysia. QMPs and performance were measured using the following six value indicators: Management commitment, training, process management, quality tools, continuous improvement and organisational performance. A total of 480 questionnaires were distributed and 210 questionnaires were valid for analysis. A confirmatory factor analysis (CFA) approach was employed using analysis of moment structures (AMOS) software. The results for the hypothesised CFA model showed the following fit statistics: Comparative fit index (CFI) = 0.924, Tucker Lewis index (TLI) = 0.913 and root mean square error of approximation (RMSEA) = 0.061. The values of CFI and TLI ≥ 0.9 and at the same time the value of RMSEA ≤ 0.08 showed that CFA model fits the data very well. Hence, the results of the study can be used by managers in manufacturing companies to consider and adapt their QMPs and performance assessments toward increasing competitiveness.

Keywords: Confirmatory factor analysis; manufacturing industry; organisational performance; quality management practices

ABSTRAK

Tujuan makalah ini adalah untuk mengesahkan alat amalan pengurusan kualiti (QMPs) dan pengukuran prestasi bagi industri pembuatan di Malaysia. QMPs dan prestasi diukur menggunakan enam petunjuk nilai berikut: Komitmen pengurusan, latihan, pengurusan proses, alat berkualiti, penambahbaikan berterusan dan prestasi organisasi. Sebanyak 480 kertas soal selidik telah diedarkan dan 210 kertas soal selidik adalah sah untuk dianalisis. Pendekatan analisis faktor pengesahan (CFA) telah diguna pakai menggunakan perisian analisis struktur masa (AMOS). Keputusan hipotesis bagi model CFA menunjukkan statistik padanan seperti berikut: Indeks padanan komparatif (CFI) = 0.924, indeks Tucker Lewis (TLI) = 0.913 dan penganggaran min ralat punca kuasa dua (RMSEA) = 0.061. Nilai CFI dan TLI ≥ 0.9 serta nilai RMSEA ≤ 0.08 menunjukkan bahawa model CFA padan dengan data. Oleh itu, keputusan kajian ini boleh digunakan oleh pengurus di syarikat pembuatan untuk mempertimbang dan menggunakan QMPs dan penilaian prestasi mereka ke arah peningkatan daya saing.

Kata kunci: Amalan pengurusan kualiti; analisis faktor pengesahan; industri pembuatan; prestasi organisasi

INTRODUCTION

In mass production, a high accuracy in the manufacturing line, better quality and less variance are invaluable. Higher quality implies lower costs and increased productivity, which in turn give the organisation a greater market share and better competitive fitness (Evans & Lindsay 2002). The content of quality management practices has been steadily expanding since the quality revolution began in Japan in 1950s. Currently, QMPs consists of not only traditional quality management methods such as quality measurement and control, but sets of quality programs and philosophies in TQM and ISO 9000 quality systems (Su et al. 2008). Wilkinson (1992) divided quality management factors into two distinct groups called soft and hard factors. 'Hard' quality management factors are more technique and tool-oriented; these include statistical process control, quality function deployment and other production and quality improvement techniques. On the other hand, 'soft' quality management factors involved with the establishment of customer awareness and management of human resources. In Malaysia, many small and medium enterprises (SMEs) have an awareness of the necessity to implement quality management. However, very few research findings have been reported on implemented hard factors of QMPs which were quality tools and continuous improvement. Most previous studies were related to soft factors of QMPs and the impact to business performance (Arumugam et al. 2008; Idris 2011; Sohail & Hoong 2003). In addition, as stated in the Malaysian Third Industrial Master Plan (IMP3), these SMEs contributed the growth of manufacturing, services and agriculture sectors, as well as ICT services, in terms of output, value-added, employment and exports. Recent evidence showed that SMEs contribute 32% to gross domestic product, 56.4% to employment opportunities and 19% to export (SMIDEC 2008).

Several similar studies addressing empirically validated scales for quality management practices have been conducted (Ahire et al. 1996; Saraph et al. 1989; Yusof & Aspinwall 2000; Zhang et al. 2000). Much attention in the literature has been devoted to developing measurement constructs for quality management practices and performance (Agus 2005; Flynn et al. 1995; Kaynak 2003; Lakhal et al. 2006; Samson & Terziovski 1999; Tari et al. 2007). These instruments differ in terms of their constructs and measurement items and each has its own strengths and weaknesses. The literatures have demonstrated a significant research gap in term of the quality management practices and organisational performances particularly in manufacturing industry between large enterprises and SMEs. Therefore, the proposed framework has been developed based on the importance for SMEs to implement quality management practices in Malaysia. The main reason for this reluctance by SMEs seems to be lacks of understandings of QMPs by top managers. Despite the fact that the SMEs were known as a business entity that facing challenges in expanding and succeed in business because their constrain in aspects of lack of knowledge, technical skills, business resources and low quality products (Davig et al. 2003; Islam and Karim 2011; Mustapha et al. 2011). This study explores the following research questions: What are the perceptions that constitute a valid construct of quality management practices and performance for manufacturing industry? and does a factor's reliability influence the variability of its indicators?

Quality management practices generally refer to an organised and integrated set of operational processes that delivery quality, which is defined as all of the features and characteristics of a product or service that affect its ability to satisfy a given need. These include organisational responsibilities, resources, procedures and structures (Yeung et al. 2005). Based on literature review on quality management and performance (Saraph et al. 1989; Grandzol & Gershon 1998; Yusof & Aspinwall 2000; Kaynak 2003; Lakhal et al. 2006; Tari et al. 2007), commonly encountered constructs, such as management commitment, training, process management, quality tools, continuous improvement and organisational performance, were also used in this research. The constructs of product design, supplier management and customer focus were not included in this study because the researcher's focus was on the manufacturing process on the production floor. This article has put forward a succinct basis for the selection of the six factors or constructs as presented in Table 1.

Chrusciel and Field (2003) defined top management commitment as an active and visible support or commitment from the management of an organisation, often taking the

TABLE 1. Comparison of quality management and performance constructs across different studies

No	Saraph et al. 1989	Grandzol & Gershon 1998	Yusof & Aspinwall 2000	Kaynak 2003	Lakhal et al. 2006	Tari et al. 2007	Proposed constructs
1	The role of top management leadership	Leadership	Management leadership	Management leadership	Top management commitment	Leadership	Management commitment
2	Training Employee relation	Learning	Education and training	Training Employee relations	Employee training	Learning Human resource management	Training
3	Process management	Process management	System and process	Process Management		Process management	Process management
4	Quality data and reporting		Improvement tools and techniques	Quality data and reporting	Statistical quality techniques	Quality tools and techniques	Quality tools
5	Product/service design		Measurement and feedback	Product/service Design			-
6	Supplier quality management	Cooperation	Supplier quality assurance	Supplier quality management	Supplier quality management	Supplier management	-
7	The role of quality department	Customer relationship			Customer focus	Customer focus	-
8		Continuous improvement	Continuous improvement system		Continuous Support	Continuous improvement	Continuous improvement
9		Organisational performance		Firm Performance	Organisational performance	Quality outcome	Organisational performance

form of a champion for the organisation. Top management commitment has been identified as one of the major determinants of the success of quality management implementation (Ahire et al. 1996). The top management acts to drive quality management implementation, creating values, goals and systems to satisfy customer satisfactions and improve upon an organisation performance's. Grandzol and Gershon (1998), Kaynak (2003), Lakhal et al. (2006), Saraph et al. (1989), Tari et al. (2007) and Yusof and Aspinwall (2000) include research management commitment or leadership as a key dimension of quality management in their studies.

Training refers to a planned effort by a company to facilitate employee' acquisition of job-related competencies, including knowledge, skills or behaviours that are critical for successful job performance (Noe 2008). Employee in the organisation should be continually and adequately trained to perform work procedures at a level of quality that relies upon teamwork skills and problem-solving techniques. Only when employees are trained in quality concepts and tools can they productively understand quality-related issues. Employees should be regarded as valuable long-term resources worthy of receiving education and training throughout their careers (Zhang et al. 2000).

A process may be defined simplistically as a transformation of input or resources into output or goods and services (Armistead et al. 1995). Process management requires knowledgeable individuals who are able to operate in increasingly complex, process-oriented environments. The analysis of Palmberg (2009) showed two distinctly different movements. The first of these involve process management for the improvement of a single process, utilising a structured systematic approach to analyse and continually improve the process. The second involves process management as a part of the systems management of the entire organisation and draws upon a more holistic manner of engaging with all aspects of business and developing a valuable perspective in determining organisational effectiveness. Process management in this study refers to the actions of planning, implementing, controlling and continuously improving the quality of the product produced.

Quality management is achieved not only by honing the above-mentioned skills, but is supported by quality management tools and techniques. The literature refers to recent studies regarding the implementation of quality tools in such studies as those by Ahmed and Hassan (2003), Fotopoulos and Psomas (2009), Hagemeyer et al. (2006), Handfield et al. (1999) and Tari and Sabater (2004). A single tool is a device with a clear function that is usually applied on its own, whereas a technique has a wider application and is understood to comprise a set of tools (McQuater et al. 1995). Ahmed and Hassan (2003) divided quality tools and techniques into the following three groups: statistical process control (SPC) tools, management tools and advanced techniques. A wide range of SPC tools, such as Pareto charts, cause-effect diagrams and control charts, were used to monitor quality (Ahire et al. 1996). In order to use these quality tools effectively, production workers should have an adequate knowledge regarding their usage.

Bhuiyan and Baghel (2005) define continuous improvement as a culture of sustained improvement targeting the elimination of waste in all systems and process of an organisations. It involves everyone working together to make improvements without necessary making huge capital investments. The continuous improvement cycle consists of establishing customer requirements, meeting the requirements, measuring success and continuing to check customers' requirements to find area in which improvements can be made. Customers may be internal or external, depending on whether they are located within or outside the organisation. Internal customers are working towards external customer satisfaction (Chang 2005). Several authors suggest that continuous improvement can play a major role in the success of organisational performance (Grandzol & Gershon 1998; Lakhal et al. 2006; Tari et al. 2007; Yusof & Aspinwall 2000).

A large number of studies have examined the relationships between quality management practices and their impact of such practices on performance. Grandzol and Gershon 1998, Kaynak 2003 and Lakhal et al. 2006 conducted empirical studies in order to test the relationship between quality management practices and organisational performance. The empirical evidence suggested that quality management practices lead to increased quality and productivity. On the other hand, a high quality product may produce a more satisfied customer, increased sales and enlarged market share. Quality performance enhances profitability through reductions in cost and increases in the market share.

These quality management practices, performance factors and final sets of associated items are shown in Table 2. There are 33 items or indicators and six factors of constructs in the quality management practices and performance measurement framework.

MATERIALS AND METHODS

The instrument used in this study was a structured survey questionnaire that was designed to assess the companies in terms of the described constructs. This study explores the QMPs in the manufacturing industry in Selangor, Malaysia. The state of Selangor was chosen because of rapidly developing manufacturing sectors in Malaysia (Agus 2005; Osman et al. 2009). The sample companies were drawn through stratified sampling from a list obtained from the Federal Malaysian Manufactures (FMM-Malaysian Industries Directory 2010) and Malaysia Small and Medium Enterprise (SME Business Directory 2007). In this sampling technique, it partitioned the population into sub-sectors including electrical and electronics, machinery and equipment, metal and transport equipment and then a proportionate number of companies were selected. A mailed survey was used to collect the data for this

TABLE 2. Factors and indicators identified in these studies

Factors	Indicators
1. Management commitment	Financial, reward, recognition, strategy, communication
2. Training	Problem-solving skill, training hour, training budget, statistical, analysis software
3. Process management	Activity tracking, process data, project management, quality team, quality initiative, work procedure
4. Quality tools	Process flow diagram, check sheet, cause and effect diagram, run chart, pareto chart, histogram, control chart
5. Continuous improvement	Waste/scrap reduction, process improvement, quality awareness, quality improvement, quality culture
6. Organisational performance	Profitability, productivity, product quality, cost efficiency, customer satisfaction

study. Mailed surveys were used because they represent a relatively simple way to collect quantitative data. The survey packet consisted of a large mailing envelope that included the instrument, a cover letter and a postage-paid return envelope. A sample size of 480 companies was determined using a formula provided by Rea and Parker (1997). A total of 480 questionnaires were mailed to selected companies, however only 210 questionnaires were returned.

The measures selected for quality management practices and performance was based on Kaynak (2003) and Tari et al. (2007). The questionnaire contained information on both the soft and hard aspects of quality management practices, assessing overall quality improvement in the manufacturing industry. The Likert scale was used throughout the study to measure all the items. This scale was able to address the conceptual nature of the subject area, the large number of items and difficulties eliciting specific information from the respondents. The data in this study were analysed using statistical package SPSS version 20 and AMOS version 16.

CONFIRMATORY FACTOR ANALYSIS (CFA)

Confirmatory factor analysis (CFA) can be used to assess unidimensionality. A CFA was conducted for each of the six constructs to determine whether the 33 indicators measured the construct to which they were assigned adequately. In other words, this test indicate how well the construct explained by its constituent variables (Hair et al. 2010). In fact, whenever the researcher bases his/her study on sound theoretical justification, a method confirmatory mode is very much delighted. Basically, there are many reasons supporting the use of CFA, among them the capacity to empirically test a measurement model, thereby constructing and validating a measurement scale (Ab. Hamid et al. 2012). Schreiber et al. (2006) also mentioned that when a CFA was conducted, a researcher used a hypothesised model to estimate a population covariance matrix. Technically, the researcher hopes to minimise the differences between the estimated and observed matrices.

MODEL SPECIFICATION – THE HYPOTHESISED CFA MODEL

The model to be tested postulates a priori that appropriate models for quality management and performance measurement in the manufacturing industry in Malaysia is a six-factor structure composed of the following latent variables: Management commitment, training, process management, quality tools, continuous improvement and organisational performance. These constructs were represented schematically in Figure 1. The use of this latent variable model, in which the factor loading of each indicator on its corresponding construct can be assessed, allow researchers to evaluate the indicators' relative significance for the successful implementation of

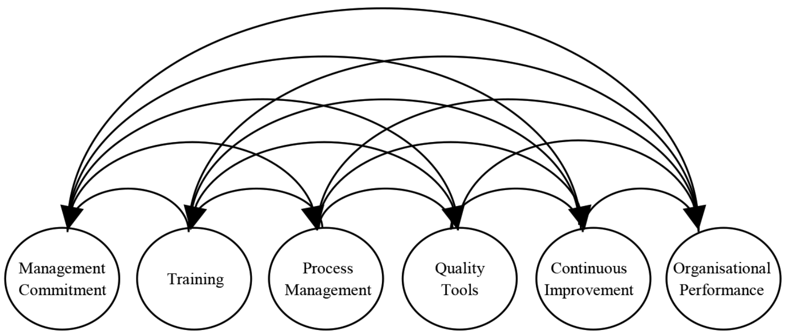

FIGURE 1. Hypothesised CFA model of quality management practices and performance measurement in manufacturing industry

that particular construct. The constructs of management commitment, training, continuous improvement and organisational performance were measured by five indicators, while the construct of process management and quality tools were measured by six and seven indicators, respectively. Each of the observed variables is regressed onto its respective factor (Byrne 2010). In addition, the reliability of each variable is influenced by random measurement errors.

RESULTS AND DISCUSSION

In this section, the assessment of the model's adequacy will be discussed before proceeding to the explanation of the CFA results of the model as a whole and substantiating these findings with the test of discriminant validity, as suggested by Fornell and Lacker (1981).

ASSESSMENT OF MODEL ADEQUACY

The fit indices of the hypothesised model, as shown in Table 3, showed the following: (df=284), p-value < 0.01, Normed chi-square = 1.787, CFI = 0.924, TLI = 0.913 and RMSEA = 0.061. The p-value statistic tests for the consistency of the hypothesised model with the empirical data, determining whether nonzero values in the residual matrix could have occurred simply due to chance. However, these fit statistics are sample size- dependent. As the number of subjects included in the sample size increases, the tendency of the chi-square test to become significant becomes apparent (Byrne 2010; Hair et al. 2010). Therefore, another way to interpret this result was by dividing the chi-square value with the degree of freedom that produced the normed chi-square statistics. A value lower than five may be regarded as an acceptable fit. Next, the CFI and TLI indices test for incremental fit, indicating an improvement in the fit of a hypothesised model over a baseline model. Those cut-scores for these fit statistics that were greater than or equal to 0.90 indicate a well-fitting model. RMSEA is a related residual in the model that represents how well a model fits a population. In other words, it estimates the lack of fit of the hypothesised model to the population covariance matrix. Acceptable model fits are indicated by RMSEA values of 0.08 or less.

All of these fit statistics conformed to the recommended threshold values of norms chi-square < 5, CFI > 0.90, TLI = 0.90 and RMSEA < 0.08, except for the significant p-value. However, the p-value is based on a chi-square test, which is influenced by the sample size. Given that the sample size in this study (210 respondents) was considerably large, the researcher may opt for other fit statistics to assess the fitness of the model, as relying to on only one type of fit statistic was not advised (Byrne 2010; Hair et al. 2010). Regarding the size of sample and complexity of the model, we may impose rather less strict criteria for their evaluation for fitness (Hair et al. 2010). Hence, the CFA results supported the adequacy of the hypothesised model. A summary of the fit statistics is shown in Table 3.

TABLE 3. Goodness-of-fit statistics

Fits statistics	Hypothesised model
CMIN	507.489
df	284
CMIN/df	1.787
p-value	0.000
CFI	0.924
TLI	0.913
RMSEA	0.061

Before the results of this analysis were interpreted, the researcher should consider the reasonableness of the parameter estimates. First, no offending estimates, such as negative error variances or illogical correlation coefficients, were found. Factor loading should be 0.50 or higher and ideally 0.70 or higher (Hair et al. 2010). The observed variables or items that has factor loading of less than 0.50 should be dropped from the model. Here, four items were deleted from the constructs, including statistical from the training constructs and process flow diagram, check sheet and run chart from the quality tools constructs. Next, we examined the standardised residuals matrix to ensure that it was within the acceptable value of |4|. Residuals can be either positive or negative, depending on whether the estimate covariance is under or over the corresponding observed covariance. Another three items with standardised residuals greater than |4| were excluded, including process data from the process management construct, conformance from the continuous improvement construct and product efficiency from the organisational construct. A total of seven items were deleted from the model and the remaining 26 items represents the six different constructs. The remaining factor loadings were of practical importance and statistically significant. After all of these have been examined, the researcher may then proceed to the discussion of the construct validation analysis.

CONSTRUCT VALIDATION

Construct validity is the extent to which the items on a scale measure the intended abstract or theoretical construct (Churchill 1979; Kaynak 2003). In other words, this term refers to the degree to which a direct measurement represents an unobserved latent construct. In general, construct validity consists of convergent validity and discriminant validity. Convergent validity refers to the extent to which varying approaches to the measurement of the construct yield the same result (Ahire et al. 1996). In the case of a self-administered questionnaire survey, each item was treated as a different approach toward measuring the same construct. To assess the convergent validity, we examined factor loadings, the extracted variance and reliability. If factor loadings fall below 0.70, they could still be considered significant, but more of the variance in the measure become error variance than explained variance (Hair et al. 2010). From the CFA results in Table 4, there were five items with factor loadings between 0.50 and 0.70, while the remaining factor loadings were above 0.70. This succinctly indicated that the convergent validity for the CFA model was supported. When examining convergent validity, the researcher should examine two additional measures: average variance extracted (AVE) and composite reliability (CR). The AVE estimates all exceeded 0.50 and the composite reliability estimates all exceeded 0.70. Therefore, adequate evidence of convergent validity was provided. To strengthen the construct validity and reliability, we performed a higher level validity test by establishing the discriminant validity test for the CFA model.

DISCRIMINANT VALIDITY OF CONSTRUCT

Discriminant validity is the degree to which measures of different latent variables were sufficiently unique to be distinguished from other constructs. Simply stated, the absence of cross-loading would support discriminant validity. In fact, the presence of the cross-loading can be investigated in the analysis output or by resorting to empirical calculation. According to Fornell and Larcker (1981), the average variance extracted (AVE) should be more than the correlation squared of two constructs to support discriminant validity. AVE is a measure of the error-free variance of a set of items that represent the amount of variance captured by a latent variable in relation to the amount of variance that is due to its measurement error (Fornell & Larcker 1981). The correlation squared was also referred to as the shared variance among the two latent constructs. Table 4 shows the results of the calculated average variance extracted (AVE) and Table 5 presents the matrix of the correlation squared and the AVE (off-diagonal) for comparison.

Referring to Table 5, the management commitment had an average variance extracted (AVE) estimated at 0.658 and the correlation squared for training, process management, quality tools, continuous improvement and organisational performance were 0.040, 0.115, 0.010, 0.065 and 0.089, respectively. Thus, the AVE estimates for the management commitment constructs were larger than the interconstructed correlation squared. For training, the AVE was estimated to be 0.575 and the correlation squared for management commitment, process management, quality tools, continuous improvement and organisational performance were 0.098, 0.047, 0.182 and 0.144, respectively. Thus, the AVE estimates for training constructs again were larger than the inter-constructed correlation

TABLE 4. AVE and CR for latent constructs

Constructs	Core values	Factor Loadings	SMC = r^2	Error	AVE	CR
Management commitment	Financial	0.801	0.642	0.358	0.658	0.906
	Reward	0.829	0.687	0.313		
	Recognition	0.800	0.640	0.360		
	Strategy	0.836	0.699	0.301		
	Communication	0.789	0.623	0.377		
Training	Problem-solving skills	0.759	0.576	0.424	0.575	0.842
	Training hour	0.713	0.508	0.492		
	Training budget	0.644	0.415	0.585		
	Analysis software	0.894	0.799	0.201		
Process management	Activity tracking	0.815	0.664	0.336	0.645	0.898
	Project management	0.850	0.723	0.278		
	Quality team	0.546	0.300	0.702		
	Quality initiative	0.938	0.880	0.120		
	Work procedure	0.813	0.661	0.339		
Quality tools	Cause and effect diagram	0.557	0.311	0.690	0.515	0.803
	Pareto chart	0.833	0.692	0.306		
	Histogram	0.858	0.734	0.264		
	Control chart	0.567	0.323	0.679		
Continuous improvement	Waste/scrap reduction	0.841	0.707	0.293	0.562	0.834
	Process improvement	0.553	0.306	0.694		
	Quality improvement	0.793	0.629	0.371		
	Quality culture	0.778	0.605	0.395		
Organisational performance	Profitability	0.882	0.778	0.222	0.581	0.846
	Productivity	0.665	0.442	0.558		
	Cost efficiency	0.692	0.479	0.521		
	Customer satisfaction	0.791	0.626	0.374		

Note: AVE is average variance extracted; CR is composite reliability

TABLE 5. AVE and correlation squared

Constructs	1	2	3	4	5	6
Management commitment (1)	0.658					
Training (2)	0.040	0.575				
Process management (3)	0.115	0.098	0.645			
Quality tools (4)	0.010	0.047	0.054	0.515		
Continuous improvement (5)	0.065	0.182	0.130	0.116	0.562	
Organisational performance (6)	0.089	0.144	0.256	0.042	0.130	0.581

Note: Correlation is significant at the 0.01 level (2-tailed); the value in bold is the AVE

squared. The results for other constructs such as process management, quality tools, continuous improvement and organisational performance, also had AVE estimates that were larger than the corresponding correlation squared. Therefore, the six-construct CFA model demonstrated discriminant validity.

CONCLUSION

In this paper, an instrument intended purely for confirmatory and validating processes was described. The results of the six-factor model showed that the measurement models for quality management and performance construct had a good fit and thus that the model is valid and reliable for use in the Malaysian manufacturing industry. All of the research questions put forward were answered through the analysis. As the responses here were shown to be influenced by the six-factor as hypothesised, manufacturing companies should possess the following factors to increase their competitiveness: 'management commitment', 'training', 'process management', 'quality tools', 'continuous improvement' and 'organisational performance'. This research finding aligns with previous findings from Kaynak (2003), Su et al. (2008), Tari et al. (2007) and Zhang et al. (2000) on the validation of an instrument's use with the CFA method. In conclusion, the demonstrated fit statistics indicate an acceptable fit for a CFA model. The instrument used in this study can be used by manufacturing companies to assess their performance through the six factors, as the instrument is construct-valid and reliable.

Therefore, it was important to appreciate the differences that exist between SMEs and large scale companies. In other words, it is essential to understand SMEs issues and characteristics before making any attempt to assist them in implementing quality improvement activities such as applying correct quality tools and continuous improvement. It can be concluded that efficient production system plays an important role in explaining the competitiveness of the large enterprises and SMEs, not to deny the use of appropriate technology. Thus, a quality management practices and performance framework is needed to help the SMEs in their effort to become more effective, productive and improve their competitiveness level in national, regional and international markets. The framework can be considered as the answer for the missing link in the existing literature. The next step in this study will be to propose a structural model of the relationship between quality management practices and performance using structural equation modelling (SEM).

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